DEVELOPMENT OF ALGORITHMIC THINKING SKILLS IN EARLY AND PRESCHOOL EDUCATION

L. Vujičić, L. Jančec, J. Mezak

University of Rijeka, Faculty of Teacher Education (CROATIA)

Abstract

In search for an answer to the question of what skills and knowledge will be needed by future generations from an early age, we have come to a conclusion that special attention should be paid to developing the ability to think creatively, i.e. to solving problems in everyday situations in the institutional context – the kindergarten. In doing so, we are especially committed to collaborative participatory learning of children and adults who develop a responsibility for a quality, stimulating socio-pedagogical environment, in which the abilities of each individual will be updated in a personalized system of learning, teaching, play and research. In this context, we also consider the development of algorithmic thinking skills in children of an early age. Algorithm and algorithmic thinking skills are not primarily affiliated to education but instead considered as a set of actions involving understanding of objectives of further activities and undertaking a series of steps to solve practical problems [18], highlighting its contribution to the field of education. For example, algorithm comprehension makes it possible to transfer the method of solving a problem to similar tasks since algorithmic thinking is a way of reaching a solution by defining the steps clearly [23]. Algorithmic thinking provides a basis for understanding and learning how to achieve goals or for understanding a situation of performing a task in creating and following simple sequences, going forward and backwards in combination. There can be more than one adequate and correct method (algorithm) in solving a problem. Thus, a satisfying procurement of algorithmic thinking skills makes it possible for future generations to take the most suitable steps to achieve the desired level or the preferred goal. The aim of our research is to determine and identify algorithmic thinking skills in daily practice, with a specific and straightforward analysis of kindergarten teachers' propositions (N=40) from seven different kindergartens given by focus groups and a close reading of participants activities´ proposals afterwards. Using the methodology of qualitative research and content analysis on the collected 200 examples of proposed and described activities from educational practice, we have identified the elements that contribute to the development of algorithmic thinking skills in the institutional context of early childhood education and care. The analyzed elements as well as a holistic approach to this kind of thinking will be detected as responsible for fostering and innovating a set of algorithmic thinking skills in preschool institutions, with a highlighted bottom up approach, based on the best kindergarten practices in Croatia.

Keywords: algorithmic thinking, institutional context, qualitative research, early childhood education and care

1 INTRODUCTION

Play is a meaningful activity for children in early preschool education and represents one of their basic rights. According to Hännikäinen, Singer and Oers [5], learning occurs during play in multiple ways and children could gain a lot from supportive environments, teachers or other adults allowing them space, time, and interaction to develop their play activities. In addition, one of the most important aspects of a child's learning is the child's activity. One feature of active learning is the constant creation of a conducive environment that encourages learning. A stimulating environment is a surrounding in which positive social interactions and mutual trust prevail. In such an environment, children develop social skills and competencies, which significantly affects their development. Such conditions in kindergarten are created by adults, who strive to recognize the specific interests and skills of each child, and provide them with the appropriate incentive and initiative for collaborative learning. Educators support collaborative learning of children through special support strategies, e.g. arranging space and environment, establishing an atmosphere of positive social interaction, encouraging children's activities and considering their interests and initiatives and thinking about them ([11], [9], [8], [19], [20]). Collaborative learning of children of early and preschool age is a process in which the child learns through the shared experience of solving problems together with others [12]. Besides, play is a non-

specialized, undifferentiated, very complex, ambiguous, multifunctional activity [3], which the child enjoys because it is fun, the child mingles with friends, and can take place both indoors and outdoors. Play changes and develops alongside the child, who reveals his interests to us. If the child is curious, it explores and learns through the game and practices different skills. In the game, the child brings its own interpretations of different situations, events and experiences and develops social relationships. In order to play, a child needs time to develop the play, space, other children or adults, and toys that can be real objects or symbols that the child uses during play [7]. The game engages the child´s motor, sensory, affective, social, cognitive, conative abilities, and children spontaneously choose exactly those kinds of play and games that encourage their development [3]. Therefore, the relationship between play and development is classified as reciprocal; development is reflected in the play while the play encourages development [7]. In addition, Rajić and Petrović Sočo [15] claim that “a child grows with play, and play grows with it. They are a unique and effective way of natural learning”. In preschool educational institutions, the curriculum is built and starts from understanding the importance of children's play for the development, well-being and progress of the child. Play has always been a part of growing up and all major functions of play are part of the child´s accidental experience, the outcomes of which are not conscious products. Play is a part of one´s own enjoyment in life in this world, alongside physical and emotional needs. Developmental neuroscience pays a lot of attention to the interaction between the child and its immediate surrounding, thereby indicating at the ways neural connections change in the brain, which is caused by a stimulating environment [21].

The Croatian National Curriculum for Early and Preschool Education [2] is based on the Convention on the Rights of the Child from 1989 and includes a number of strategic and program national documents. Among mentioned documents, “Program Orientation for Work with Preschool Children” [14] from a professional point of view, is very useful because even today the classification of types of activities according to this document is still used. This document together with the National Curriculum for Early and Preschool Education represents a framework for working with children from age of six months to primary school. The National Curriculum for Early and Preschool Education in the Republic of Croatia respects the specifics of each kindergarten, and refers to the aspirations and actions of all those who act and participate in it every day; their interactions with space and other people, their communication and relationships, ways of organizing time and activities and so on [2]. Therefore, the development of educational practice and curriculum in kindergarten cannot be achieved partially and mechanically, this process is rather carried out gradually and systematically, as a result of joint thinking and work of all those who participate in it. In addition, this umbrella document encourages and strengthens the development of core competencies that are integrated in early and preschool education and care through activities that promote holistic development. In addition, it relies on eight basic competences for lifelong learning, which the Croatian education policy has accepted from the European Union, namely: communication in the mother tongue, communication in foreign languages, mathematical competence and basic competences in science, digital competence, learn how learning, social and civic competence, initiative and entrepreneurship, and cultural awareness and expression.

It is the propensity for algorithmic thinking that is recognized in these areas of development with the increased intention of unequivocally encouraging the application of learning and teaching methods that enable the active role of the child in the development of knowledge, skills and attitudes with the support of educators interacting with other children. Among the basic guidelines of this document is a crucial feature of early and preschool education, which is that "play is the foundation of children's development [and it is necessary] to avoid" schooling "in early and preschool education." [2].

Through play, children are often put in a situation where they need to follow the "rules" of the game or solve a particular problem in order to fulfil the objectives of the game. Problem - solving involves researching and understanding the problem, which develops skills of decision making and drawing conclusions in children [13]. Problem-solving skills and managing new information, as well as logical thinking, are the competences required by every individual and should be developed from the early ages. There is an increasing importance of computer science education for young children. Instead of teaching about technology and the use of technology, children can begin their computer science education by acquiring computational thinking skills based on cognitive processes involved in solving problems with computers and other technologies [16]. As part of computational thinking, algorithmic thinking can be used as a first step. “Algorithmic thinking is a competence to formulate a solution of a problem in the form of an algorithm and then to implement the algorithm as a computer program” [17]. Algorithmic thinking represents the ability to understand the problem as a series of simple and small tasks that lead to a solution. Through an algorithm a problem is broken down to a set of simple tasks that can lead to solving a problem as a whole [10]. Algorithmic thinking skills include a range of analytical

skills that are applicable to many areas of life, such as problem solving, recursive thinking, the application of abstraction, and the use of heuristic reasoning, all in order to track down solutions [22]. Algorithmic thinking skills that can be started in preschool include decomposing problems into smaller parts, determining the process of reaching a solution by sequential steps, trying to find the most effective solution, developing logical thinking, and various other socio-educational skills [18].

Kindergarten curriculum implies the totality of educational interactions within the physical and social environment of the kindergarten, which includes children and adults, and is an educational concept that is jointly developed, i.e. 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. Children learn through play and, in addition to research and other activities that are useful to them, enter a variety of interactions with other children and adults who support them. The self-organization, research and discovery potential of children's activities are strengthened, and those forms of the educator's support are provided that engage children's thinking capacities and that encourage them to reflect on their own experiences. Such an understanding of learning finds its theoretical basis in the theory of constructivism and socioconstructivism and the importance of encouraging the development of children's metacognitive abilities" [2]. One of the basic tasks of the National Curriculum for Early and Preschool Education is to ensure the preconditions for unhindered and "natural" mobility / continuity in education, especially during the transition from kindergarten to school.

The education of students of Early and Preschool Education at the Faculty of Teacher Education in Rijeka is based on the National Curriculum previously described, however, in subjects that include educating students about integrated activities that develop children's abilities, the inclusion of algorithmic thinking was not implemented. In order to upgrade the competencies of our students, we joined Erasmus+ project "Algorithmic Thinking Skills through Play-Based Learning for Future's Code Literates" (Algolittle). The project is planned to last two years and started on September 1, 2020. The project consortium consists of Izmir Democracy University (Turkey) - coordinator, The Faculty of Teacher Education, University of Rijeka (Croatia), Polytechnic Institute of Viseu (Portugal), The Faculty of Education of the University of Maribor (Slovenia), The School of Robotics (Italy) and Educloud enterprise (Turkey). The main goal of the project is "to prepare a course program and teaching materials to teach preschool teaching undergraduates how to reflect on the algorithmic thinking skills in all areas of preschool education as an innovative approach to teaching" [1]. In order to achieve a greater connection with practice, the first activity of all partners was to hold workshops with preschool teachers, experts in practice to gain insight into their understanding of the concept of algorithmic thinking and how algorithmic thinking skills can be integrated into everyday practice in kindergarten [6].

2 METHODOLOGY

The aim of this research was to determine how preschool teachers, practitioners, see the possibility of integrating algorithmic thinking skills in everyday activities in kindergarten, in particular in which activities they can be integrated.

For the purposes of this paper, a qualitative methodology was used to conduct a documentation study of the collected documents. By analyzing the content of the Activity description form in which the respondents had to specify up to five activities in which to apply algorithmic thinking skills, new insights were gained. Due to the limitations of this qualitative research, we will not be able to be generalize them to the wider population, but they can serve as a basis for some other research.

The documentation study processed 40 responses of participants from seven Croatian kindergartens from two counties (Istria and Primorje-Gorski Kotar county) who, after the workshops and focus groups, filled out the Activity description form.

After the workshops and focus groups in the online environment, the applicants were asked to fill in the Activity description form that they submitted to the selected platform. A documentation study of the collected forms was performed by data analysis with two stages of coding, after which the data were rearranged and sorted.

The classification of activities according to the "Program Orientation for Work with Preschool Children" [14] was used for the first coding:

- life-practical and work - activities related to biological needs, child care, undressing, dressing, self-service, household chores, plant and animal care, making objects and toys, etc.
- various games - functional, symbolic, games of building and construction, games with rules, etc.
- social and socio-entertaining - socializing, parties, festivities, walks, so-called performances, etc.
- artistic-observation, listening, interpretation of artistic creation for children, picture books, art, literary, musical, stage, film and other works
- diverse expressions and creations of the child-singing, playing, drawing, painting, modelling, building and constructing, speech, stage expression, dancing, etc.
- research-cognitive - research manipulation of objects, observation, acquaintance, walks, visits, meetings with people of different professions, creators, research activities in the narrow sense - discovery and simple experimentation, verbal and practical solving of various problems, intentional learning and practicing procedures, behaviour, rules, etc.
- specific activities with movement - physical exercise, swimming, sledding, skating, roller-skating, cycling, skiing, etc.

Textual forms were used to investigate the similarities and differences between the listed activities. The most important aspect of the analysis was the reduction of data by the method of comparison and contrast of data, and by the method of grouping all the above activities that showed similarity. If more than one participant provided the same examples of activities, they were not repeated. The classifications are mostly of an artificial nature, they were made regarding the dominant type of activity, and above all it should be noted that most activities can be classified in several groups of activities. An integrated approach to children's activities is proposed because children's learning and development are integrated and as such observed in the offered proposals, taking into account the fact that all developmental areas evolve parallely and are interconnected. After the first analysis, the activities were grouped into six groups and the second coding stage was approached. As a basic unit of analysis in coding, words and phrases are defined that represent the integration of algorithmic thinking into activities: "algorithm, sequence, process steps, repetition, conditional branching, finding the best solution, logical thinking, thinking by the rules, analysis".

3 RESULTS

The participants identified and listed various activities in which they see the possibility of integrating algorithmic thinking skills that are grouped according to the Program Orientation for Work with Preschool Children.

In life-practical and work activities, educators recognized the development of a sequence, thinking by the rules, recognizing the algorithm.

- Performing actions in a certain order - sequence (preparation for daily rest, washing hands, going outside, disposing of cutlery after lunch, plant care)
- Thinking by the rules (development of habits and independence in meeting the physiological needs of the child, development of habits of cultural behaviour, development of digital competencies)
- Recognition of the algorithm (preparation of tea, preparation of lemonade, making cheese, building a bird feeder, preparation of tables for art activities, making a modelling dough)

In various games, following algorithmic thinking skills were recognized: steps in the procedure, repetition, conditional branching, finding the best solution, logical thinking, thinking by the rules. Participants pointed out various symbolic games, functional games, board games, construction games, rule games, social fun games, and role-playing games.

In artistic activities, the skills of sequencing the steps of procedure, pattern recognition and presenting a story as an algorithm were recognized:

- Art projects
- Storytelling

In activities in which children express themselves and create in different ways, the skills of sequencing, repetition, conditional branching, finding the best solution, logical thinking and thinking by the rules were recognized:

- sequencing: rhythmic movements with and without music, modelling
- loops: making a booklet, painting and modelling
- logical thinking, thinking by the rules: building and constructing
- finding the best solution: expressing emotions, creating and developing stories

Research and cognitive activities included the skills of finding the best solution, logical thinking and thinking by the rules:

- logical thinking: solving riddles, BeeBot, constructing by the scheme, premathematical games, research games
- thinking by the rules: premathematical games
- best solution recognition: treasure hunt

In the group of specific activities with movement, the skills of sequencing, repetition and thinking by the rules were recognized:

- sequencing: polygon, relay games, dancing and singing choreography
- repeating and loops: motoric exercises,
- thinking by the rules: games with predefined rules

According to the first classification of activities, preschool teachers suggested the largest number of activities from the research cognitive area in which they would apply algorithmic thinking skills. The smallest number of such activities, in which algorithmic thinking skills can be promoted, present the activities from the artistic field. In the first coding, it was found that it is not possible to fully follow the predetermined categories determined by the researchers according to the Program Orientation of Preschool Education, while for example the category "social and socio-entertainment activities" merged with "diverse games" through participants' answers. After the classification, six groups of activities emerged which were considered for the following procedure.

During the second coding, the results in the existing groups of activities were additionally classified according to words and phrases that represent the integration of algorithmic thinking into the activity.

Among the life-practical and work activities, educators most often recognized the design of a sequence, describing the actions that children usually do in kindergarten. For example, the sequence for the activity “Going outside”: 1. entering the dressing room, 2. taking off the slippers, 3. tidying up the slippers, 4. getting the shoes, 5. putting on the shoes, 6. getting dressed and buttoning the jackets (if it is cold), 7. putting on a hat (if it is cold). Activities involving thinking by the rules were also listed - Teaching polite phrases using simple comics. If I see someone eating, I wish him: "Good appetite." If I give something to someone, I say: "Here you are", to which I get the answer: "Thank you" and I answer: "You're welcome", etc. When recognizing the algorithm in the activities, educators also gave several examples such as recipes for making dough for modelling in pictures (the pictures show the amounts of flour, salt, water in cups arranged in the order of adding ingredients to the bowl).

Among various games, in addition to the well-known and final-shaped games, as Bingo (Fig.1), Connect 4, Twister, Tic Tac Toe, there are numerous games without rules set in advance, for example, manipulative table games with creating rules according to participants (number and age of participants).

Figure 1. Social game with rules: “Kindergarten Bingo”

Within art activities preschool teachers noticed that defining steps and pattern recognition can be used in art projects, while any story can be represented as an algorithm for easier understanding and interpretation. For example, the description of the project “My vision of nature”: Children are sitting in pairs leaning against each other. They have the same colours and the same drawing pad. The instruction is to create the same drawing by arranging each step without looking. Children take turns determining what and where to draw. For example, the first child says "Let's draw a yellow sun in the upper left corner of the paper." After drawing, the other child says, "Let's draw a bird with outstretched wings under the sun." Children draw while they are interested or until the paper is filled out. The drawings are then compared in a way to determine similarities and differences, and one can analyze why the differences occurred. In cases of representing stories as an algorithm children can draw, tell or express story as a set of events described in specific order.

In activities in which children express themselves and create in a variety of ways, algorithmic thinking skills are recognized in the largest number. To determine the sequence of actions, teachers listed rhythmic movements with and without music, for example a song "If You're Happy and You Know it". Another example of a creative activity that applies a series of steps is making a boat out of paper as shown in Fig.2.

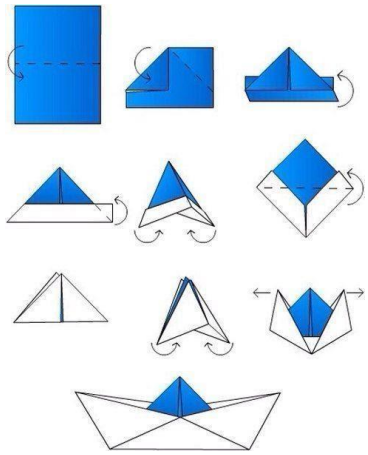

Figure 2. Steps in making a paper boat

To practice the process steps and repetition skills, the participants expressed different painting and modelling activities, as well as making a booklet. For example, in creating a leperello picture book the sequence of action is repeated: 1. fold the A4 paper in half, 2. draw the first scene of the story on the front of the paper with crayons, 3. draw the second scene of the story on the back side of the paper, 4. repeat step two, 5. repeat step three. After all four pages are filled in, a new piece of paper is taken and all five steps are repeated. The cycle continues until the end of the story. The picture book is made by taping together the folded papers. Furthermore, in thinking by the rules and logical thinking, preschool teachers identify origami and tangram (Fig.3). From geometric figures, new objects are arranged according to the child's interest. The child does not need to follow a series of actions to reach a solution, but by choosing geometric figures he manages to complete the task.

Figure 3. Tangram

In research and cognitive activities, the most frequent type of activities adequate for fostering algorithmic thinking skills were the skills of finding the best solution, logical thinking and thinking by the rules. Within best solution recognition, there is the example of the Treasure Hunt Game: Children are grouped into smaller groups of 5-6 children. Each group is given a map with checkpoints leading them to the place where the treasure is hidden. The map consists of pictures, text and plotted paths and certain knowledge and skills are needed to reach the goal. Checkpoints provide additional clarification of where the treasure is located and skipping or not finding checkpoints complicates the task and increases search time. Logical thinking is recognized in research games, such as shelter making game in nature: In the forest, children are asked how to make a shelter out of rain using all available resources. In this activity, they understand the role of gradual action in small steps on the way to the goal and, by logical thinking, build a shelter so that it does not collapse. In this activity, they themselves understand the role of gradual action in small steps on the way to the goal. Upon returning to the kindergarten, they remember the activities by drawing drawings in a row on the topic "How we built our shelter". Additional thinking by the rules includes pre-mathematical games such as the "Point, number, reel ". As shown on Fig. 4 the child needs to recognize the number, connect the concept of number and figure of number (quantity and quantity markings), make a sequence - add a reel of a certain colour, check on the drawn dots, add the next reel, check by counting until the number of reels matches the number of dots.

Figure 4. Pre-mathematical game "Point, number, ring"

Algorithmic thinking skills are also listed in the group of specific activities with movement. For example, the algorithm of the morning exercise, the repetition of activities in relay games or a series of activities in a predetermined order in the exercise of the polygon (Fig. 5).

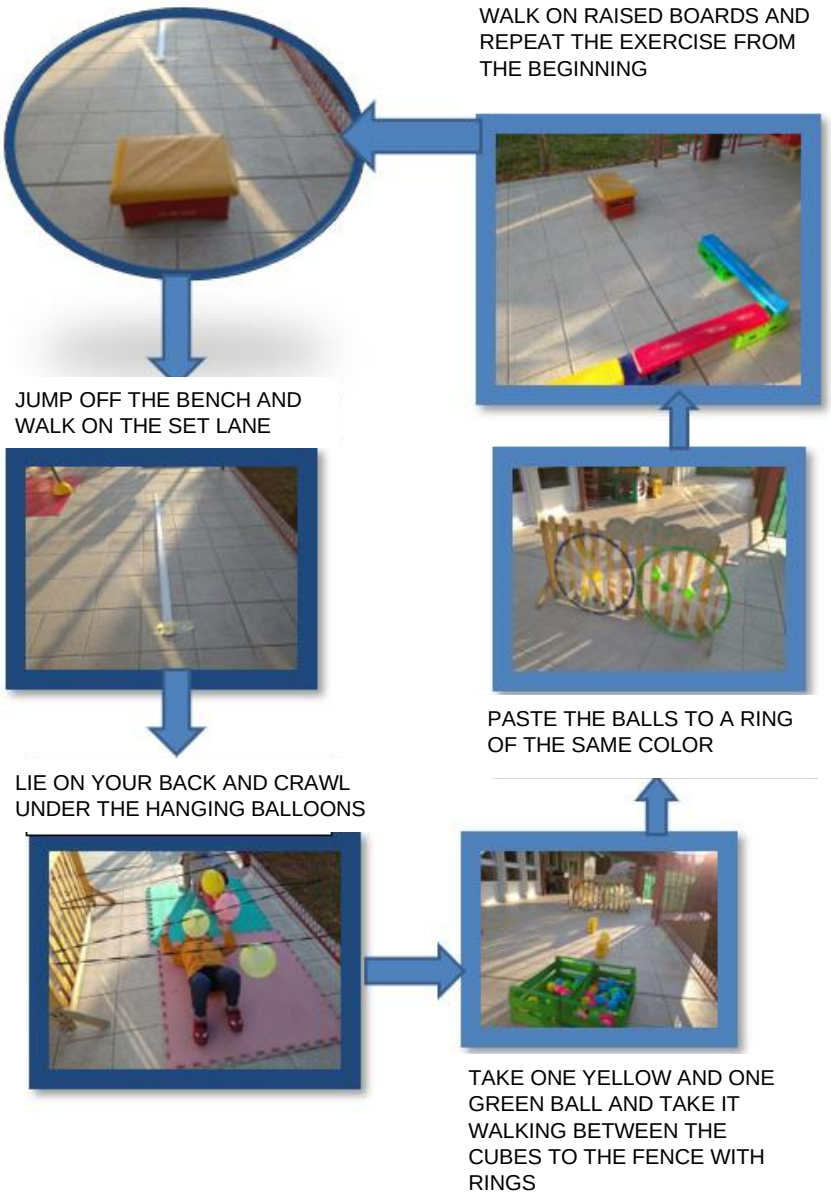

Figure 5. A polygon with a predetermined sequence of activities

4 CONCLUSION

The National Curriculum for Early and Preschool Education nurtures the principles of flexibility of the educational process in kindergarten, partnership with parents and the wider community, ensuring continuity in education and openness to continuous learning and readiness to improve practice. The latter, i.e. the openness to continuous learning, is based on the foundations of curriculum development of early and preschool education, where the basis of the child's learning is the kindergarten environment, and not separated learning content or subject areas. This 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 familiar and understandable ways and thus discover new areas.

The results of the workshop participants' reflection and the recognition of algorithmic thinking skills in everyday practice in early and preschool education institutions are a reflection of the diversity in the approach and implementation of the curriculum that educators shape together with children. In addition to learning about the benefits of algorithmic thinking, stand-out activities provide a good basis for encouraging the design of everyday activities in kindergartens in order to prepare children for the

challenges of the future by promoting this way of thinking. This paper contributes to the importance of the early and preschool period of childhood with the statements of preschool teachers who recognize to a large extent the possibilities of applying algorithmic thinking in children's activities. The results obtained through this research and proposed activities that promote the development of algorithmic thinking skills will be used for modelling a curriculum for the course "Algorithmic Thinking Skills in Early Childhood" as the main objective of the Algolittle project.

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