ALGORITHMIC THINKING AND CREATIVITY: A DECK OF CARDS FOR EARLY CHILDHOOD EDUCATION

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Abstract

The challenges presented to educational systems and researchers about algorithmic thinking are wide and exciting. Several initiatives are working on contributions. In the framework of a European Project focused on algorithmic thinking skills through play-based learning, we undertook the development of a resource for introducing algorithmic thinking to teachers and children in Early Childhood Education. The paper presents the resource, a deck of cards, highlighting its connections to creativity and algorithmic thinking. The paper briefly introduces the research design in place to pilot together with preliminary data from the tests with future teachers and a group of 5 years-old children. The deck of cards has been well received by both future teachers and children. The simple drawings are considered attractive and allow for diverse decisions about what to represent. Conditions, in particular, were well received by children. Further analysis of existing data will provide more information regarding the potential and limitations of the deck of cards.

Keywords: Algorithmic thinking, early childhood education, play, creativity, deck.

1 INTRODUCTION

Computational thinking and algorithmic thinking have been promoted in several educational systems as preparation for the challenges of the future. Algorithmic thinking, in particular, has long traditions in different scientific areas and can be connected to all curricular areas of Early Childhood Education in Portugal [1]. Algorithmic thinking is defined as the ability to think in terms of clear, simple, and small sequences and repetitive rules to solve a problem or understand a situation [2]–[4]. It can be connected to deep procedural knowledge, which involves understanding procedures, associated with comprehension, flexibility, and critical judgment [5].

With a focus on problem solving together with thinking and creativity skills, teachers and curriculum developers are being challenged to foster algorithmic thinking skills starting from the preschool period [6]. In articulation with the principles of the national guidelines, an approach based on unplugged activities for introducing algorithmic thinking through play and games has been suggested for Early Childhood Education in Portugal [1], [7].

The initiatives to introduce programs, activities and curricular topics related to algorithmic thinking require strong content knowledge as well as creative and flexible didactical knowledge [1], [8]. Therefore, the strong emphasis on introducing algorithmic thinking in Early Childhood Education requires the development of proposals for teacher education that are based on research and tested for relevance [8]. The project “Algorithmic Thinking Skills through Play-Based Learning for Future’s Code Literates” (Algolittle), funded by the Erasmus+ Programme (2020-1-TR01-KA203-092333), is being developed by a consortium of institutions and organisations from Turkey, Italy, Portugal, Slovenia, and Croatia and has created a curriculum for initial teacher education.

Based on work developed in Algolittle, a deck of cards has been developed to work with future teachers and children in Early Childhood Education on algorithmic thinking and creativity. The resource is being validated through a process of design-based research [9]. The deck was created as part of one of seven modules of the online training course that operationalizes the Curriculum – Integration of Algorithmic Thinking Skills into Preschool Education [10]. The module is focused on Creative Skills and Algorithmic Thinking.

2 CREATIVITY AND ALGORITHMIC THINKING

In this paper, we present the conceptual framework that supported the development of the deck. The research on algorithmic thinking in Early Childhood Education was articulated with research on creativity. From that relationship, the decision to create a deck of cards followed, particularly connected to studies about decks as manipulatives for supporting creativity [11]. The option for a deck of cards was also based on the familiarity of that resource in Early Childhood Education.

2.1 Creativity

In the academic field, but also in educational systems and the daily life of teachers and students, there is a wide and deep interest about creativity. In the last decades, it has come to be accepted as being an important outcome of schooling [12], [13]. The many definitions and conceptions about creativity are encapsulated in different models that also guide how best it can be cultivated. For this paper, we based the work on the five-dimensional definition from Lucas et al. [12]. (Figure 1).

Figure 1. Five Creative Dispositions Model by Lucas et al. [12].

We also took on the authors' list of assumptions, based on research, about creativity: "Complex and multi-faceted, occurring in all domains of life (Treffinger et al., 2002); learnable (Csikszentmihalyi, 1996); core to what it is to be successful today (Sternberg, 1996); capable of being analysed at an individual level in terms of dispositions (Guilford, 1950); and strongly influenced by context and by social factors (Lave and Wenger, 1991)" [12, p. 6]. For the working group involved in the creation of the deck, as part of the training module, these were translated into the following ideas:

1 Human capacity: creativity is considered a skill or a habit of mind. It is part of the capacities that humans develop throughout their life (not a talent or a trait). This means everyone has the capacity to be creative. It also means creativity is learnable and improvable, and therefore it can be taught.

2 Originality: creativity is about generating ideas that are new, different, or fresh, in the context where they are produced. Ideas here refers to thoughts, solutions, movements, sounds, approaches, etc.

3 Meaningfulness: creativity is about generating relevant ideas, i.e., ideas that work or possess some degree of usefulness or value, that are appropriate to the task at hand or some redefinition of that task.

4 Intersubjectivity: creativity is a process that depends on culture and language that are shared among members of a society; it happens in interaction with others – ideas, experiences, emotions, people, knowledge; it is dependent on the evaluation of others, as well: the originality and functionality/value of ideas requires that the community acknowledges or validates the ideas.

5 Contextuality: creativity is dependent on context(s) since something is new or relevant according to a specific context. Also, being creative is domain-specific: the creative skills of a scientist are

different from those of an artist as they are based on different knowledge and practices, and serve different purposes.

6 Indispensability: creativity is vital for social and economic innovation and development, as well as for individual and community well-being.

The idea of context is very important in education, particularly in Early Childhood Education. As an inherent part of learning, supporting children to develop creative skills requires complex pedagogy. In the module, we highlighted some aspects of these pedagogy: a) s socioemotional climate that fosters risk-taking, idea-sharing, and self-expression; b) space and materials to experiment, build and create (loose parts, artistic, different sizes, tools, etc.) as well as time and space to play and explore; c) adults modelling and supporting solving problems in novel ways (think-aloud); d) preference for open questioning and open tasks and also opportunities for rethinking rules, games, etc.; and e) focus on "what it can be" instead of only on "what it is". The deck was created considering these pedagogical principles as guidelines.

2.2 Connections between creativity and algorithmic thinking

As an important part of the development of the module and preparation of the deck, connections between creativity and algorithmic thinking were discussed. The first one, important for laying the foundations of a training for future teachers, is that creativity and algorithmic thinking are both human capacities that can be learned and improved, and therefore they can be taught which means everyone can learn them and use them. Algorithmic thinking and creativity also share being important skills for the daily life and well-being of children, and for the future of society.

Focusing on the algorithms, it's important to acknowledge them as human creations – they are thought of and produced through processes of creativity, aiming at a purpose. Algorithms can also be recreated, improved, repurposed – even existing algorithms are an arena for creativity. On the other hand, algorithms are themselves used for creating things, such as applications, games, social media platforms, rockets, and art works.

Algorithmic thinking and creativity share other features since they both imply a problem-solving attitude, curiosity through exploration and experimentation, persistence, and developing ideas through manipulation, trials, and improvement. As in other creative processes, creating algorithms requires knowledge and some understanding of the resources involved (language, processes, rules, tools, …). This set of connections inspired us to develop the deck of cards in terms of using algorithms for creative outcomes, like drawings, and for inspiring creativity about algorithms and its components (in the case, cards).

3 A DECK OF CARDS FOR CREATIVE DRAWING BASED ON ALGORITHMIC THINKING

The material was created as a resource to introduce algorithmic thinking, with a focus on the following concepts: algorithm, sequence, loop/cycle/repetition, and condition/decision/selection. It was also intended to allow the exploration of the process of creation: of something (drawing) through or according to an algorithm; of cards and conditions; and of rules for a game. The deck presents four basic cards (Figure 2): twig, leaf, fruit, and caterpillar.

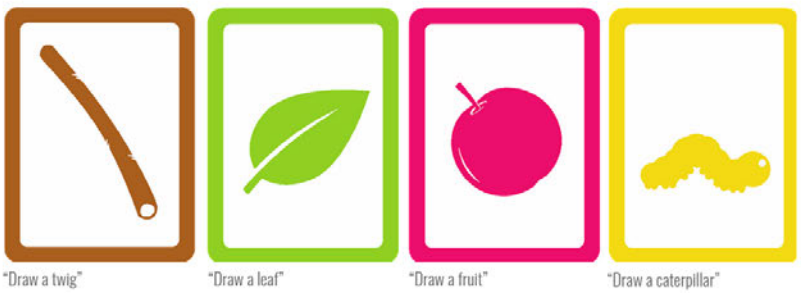

Figure 2. Basic cards and simple instructions from the deck of cards.

The simplest instruction states that players draw an object connected to the one pictured in the card. The objects shown are simple enough to allow for, or even invite, different interpretations or representations of the concepts depicted.

The deck also includes control cards, distinguishable by their gray frames. They express repetitions and conditions. Repetitions provide a sequence to be repeated a certain number of times (Figure 3). The idea of repetition is represented by an arrow, the number of times with numbers and, in the middle of the arrow, the sequence to be repeated.

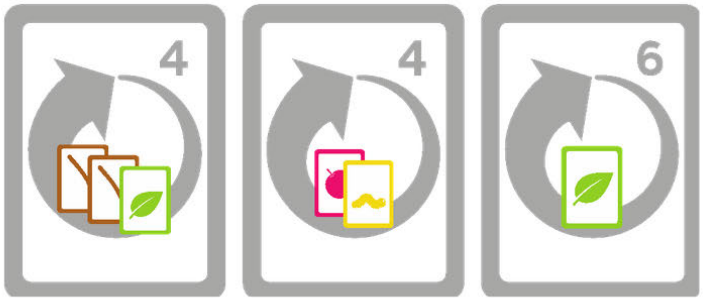

Figure 3. Examples of repetition cards.

The conditions set what to do depending on something that needs to be checked in the existing drawing (Figure 4).

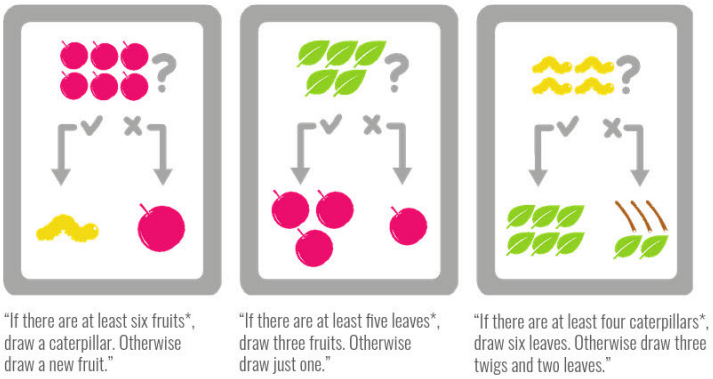

Figure 4. Examples of condition cards.

The deck [15] is provided as a PDF, ready to be printed and cut. The basic deck includes several copies of the four basic cards as well as conditions and repetitions, and blank cards. Players are invited to customize the deck they will play with either by adding or subtracting cards. The suggested use is that cards are shuffled, and that each player takes a card and uses his/her creativity to decide how and where to draw the element on the sheet of paper.

In sequences, all cards are played according to the order they show up in the shuffled deck. Each card represents either a simple instruction (drawing an object), a repetition, or a condition. The person who turns the card, draws accordingly. This forms a sequence of cards that will have inspired the drawing/s. The sequence is the algorithm and the drawing one of its possible creative outcomes.

When playing with the deck, decisions about rules will present themselves and were intentionally left open. For example, rules that are not made explicit can be set by players in each game, either tactilely or as a convention – e.g., new objects may or may not need to be connected to each other; sizes, shapes and even colours may vary, etc.

The deck also includes empty cards that children or teachers can craft to serve their creativity. Both the moment when the cards are created and whether they should be reused is up to the participants: e.g., a few empty cards might be shuffled together with the rest of the deck, so that a person who will get one is entitled to define what shall be done – and then that card might be reshuffled back into the deck so that someone else will eventually get it too. Ultimately, players might design new worlds by creating new sets of objects to be sequenced and their respective repetitions and conditions.

4 PILOTING PROCESS

The deck of cards will be evaluated following a design research process as development studies [9]. This type of design research is defined as the analysis, design, and evaluation of educational interventions for generating research-based solutions for complex problems in educational practice, as well as advancing the knowledge about the characteristics of these interventions and the processes of designing and developing them [9]. The following phases have been developed:

a) Preliminary research: needs and context analysis, review of literature, development of a conceptual or theoretical framework for the study – this has been based on the work from the Algolittle project, including the knowledge paper, the curriculum, and the modules for the online training course.

b) Development or prototyping phase: iterative design phase consisting of iterations, each being a micro-cycle of research with formative evaluation, as the most important research activity aimed at improving and refining the intervention – this is still in development. We report on some of the iterations in this paper.

c) Assessment phase: (semi-) summative evaluation to conclude whether the solution or intervention meets the pre-determined specifications. This phase often results in recommendations for improvement of the intervention – this is still in development.

In terms of prototyping, different ways of using the deck were prepared: first with future teachers, next with children. For both targets, the plan was to have small groups playing with the deck and observing interactions, creations and uses. A third one was possible, with adolescents, which brought more richness to the piloting. We next report on initial observations from those iterations.

The data is to be analysed looking for evaluating the deck in terms of quality criteria for interventions [15]: relevancy (also called content validity), consistency (also called construct validity), actual practicality (usable in the setting for which it has been designed) and effectiveness (using the product results in desired outcomes).

4.1 Piloting with future Early Childhood Education teachers

In a meeting scheduled for the purpose of discussing a resource for working with children, five students from a Master's Degree in Early Childhood Education and Primary Education (initial teacher education in Portugal) first analysed and discussed the deck. The visuals were considered simple enough but well designed and attractive for children. The colours were considered adequate as well as the size of each drawing. The four basic cards were perceived as easily readable by children. Repetition cards were also welcomed and thought of as simple, based on their experience with the game Uno. Condition cards were considered complex, and it was not simple to read them on their own.

Before the gameplay was explained, student teachers were asked to come up with ways of using the cards. Several card games were suggested. The deck was therefore considered to be flexible and suggestive of different games and play. However, it was not suggested to use it as prompts for drawing. This was later introduced by the moderator.

After the explanation of the instructions, future teachers were allowed some time for playing the game. One single sheet of paper was offered and some drawing materials as crayons and pens. After this experience, all cards were deemed as readable and accessible to children, in the context of the game. The waiting time between cards/drawing, as others play/draw, was signalled as something that might move children away from the game after some rounds. But the dynamic that was created when playing as a group was described as pleasant and engaging as players were interested in what cards were being turned and what each player decided to draw.

The elements were interpreted and represented in different ways, without the need for an explicit suggestion. Twigs were drawn in different sizes and shapes, although always brown. A full tree was drawn with one single twig card. Leaves were drawn in different sizes, shapes and colours and usually connected to twigs. Fruits were varied in type, since it was felt that the original card didn't indicate a specific fruit. Caterpillars were drawn in different sizes and colours, but kept their identity as caterpillars.

The cards that had been played were put on the table allowing to follow/acknowledge the sequence that had been drawn so far (Figure 5). This constitutes a visual representation of the algorithm based on which the drawing had been created.

Figure 5. Cards in a sequence after being played.

4.2 Piloting with adolescents

Later in the year, we took the opportunity to present the deck of cards to a group of 22 secondary school students, and their 15 teachers from five European countries: Portugal, Poland, Italy, Turkey, and Greece. The group was involved in a mobility Erasmus+ project and it was the first time they met.

After a brief introduction on the purpose and the basic rules, sheets of paper, drawing materials and decks were distributed. In groups of four, the students started using the deck as they wished. Each group was handed a version of the deck with 24 cards of each element and control cards as well as blank cards. The instruction that was provided was of drawing what was on the card. Again, the cards were well received and complimented in terms of design. All cards were understood and used.

In the beginning, the trend was that each player used part of the sheet of paper for its own drawings, some connecting the elements, others drawing them side by side (Figure 6).

Figure 6. Drawings created by using the deck of cards, stage 1.

With some discussion and reorientation, in a second stage, collective drawings were created – where the elements were connected, and all players contributed to the same set or composition (Figure 7). The opportunity of creating new cards was also suggested and taken by the players.

Figure 7. Drawing created by using the deck of cards, stage 2.

4.3 Piloting with Early Childhood Education children

For one month, four children from a group of Early Childhood Education were invited to use the deck. The four children were 5 years-old, two girls and two boys. They were chosen from a group composed by 25 children with 3 to 5 years old with whom students from the Master's Degree in Early Childhood Education and Primary Education were working with since September 2021. They are the eldest and used to playing together.

Initially, children were introduced to the simple cards only, with the four basic elements. They would play by turning cards and drawing the element depicted. The same individual use of space that was observed with the adolescents happened with the children (Figure 8). Each card inspired a drawing, and the elements were not connected and placed in each own's space in the sheet.

Figure 8. Children using the deck of cards.

Children enjoyed the cards, had no difficulty reading them and understanding the game play that was suggested. At first, they tried to copy the image from the card, but very quickly (second or third round) new interpretations of fruit and leaf started to appear. Fruits were the most diversified: pineapples, bananas, strawberries, grapes, and watermelons were drawn with great joy (Figure 9).

Figure 9. Example of diversification of drawings: fruits.

In the second week, a different gameplay was tested: distributing several cards to each child instead of turning one by one. This allowed children to start connecting elements in their own drawings, instead of drawing loose elements. The relationships were the ones the elements suggest – e.g., caterpillars eating leaves. As shown in Figure 10, elements were by now interpreted by the children in ways that differed from the original card.

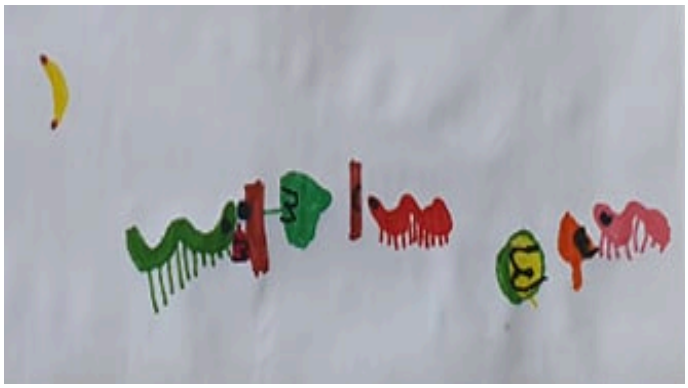

Figure 10. Example of elements connected in the drawing.

In the third week, conditions and repetitions were introduced in the deck after being explained to children based on existing drawing (so that conditions could be checked). The conditions were easily understood and became a favourite part of the game since they introduced a dynamic and shared moment when children checked if the conditions were true or false. Repetitions were not received the same way. Apparently, since each drawing was invested and required decisions – which fruit to draw, where to place it – having a set of cards that was to be repeated was not well received.

In the fourth week, new cards were introduced following children's interest in the conditions. This opened new possibilities for the children to think of conditions themselves since the conditions were more transgressive (Figure 11). They each created their own cards with conditions. These were also transgressive in terms of the elements depicted but were still inside the narrative: checking if there are five caterpillars and if so, draw hamburgers for them to eat, for example.

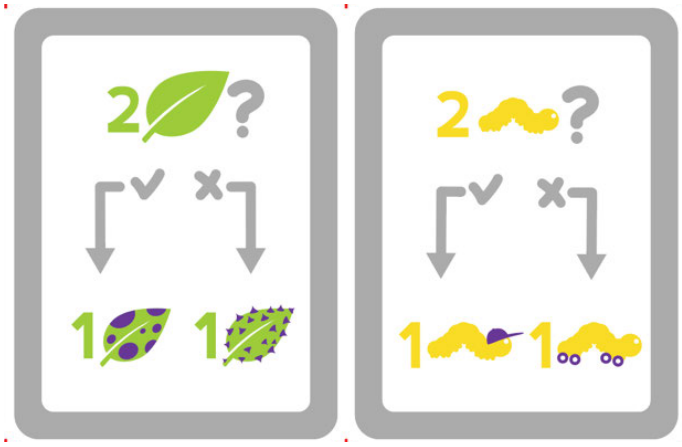

Figure 11. New condition cards.

In this last week, as a support for the understanding of repetitions, a new challenge was presented. A big tree was already drawn on the sheet of paper and children could choose only 10 cards to use so they could turn the tree in a good place for caterpillars to live in. All children chose repetition cards as they allowed to draw a larger number of leaves and fruits.

5 CONCLUSIONS

The data collection is still ongoing, and the results presented are based on the first analysis. The results suggest that the design is simple and attractive, and seen as appropriate for Early Childhood Education. Several ways of using the cards were listed, showing there is potential for the deck to be used openly, beyond the instructions presented. The steps prepared were helpful for an easy start to using the deck and allowed for a good understanding of the concepts involved.

The products created (drawings) were very different from each other in many ways, which reinforced the idea of an open-ended material. The possibility of creating new rules and cards was explored by the participants

and the creations were innovative. The suggestion to create stories both with the drawings and with the cards themselves was put forward and will be further investigated in future instances of the research.

The support needed for children to understand and use conditions and repetitions in their sequences is an open question, but the preliminary analysis suggests good solutions were devised.

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