Computing in Pre-primary Education with Coloured Paths

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Abstract. In this paper we discuss several characteristics of environments for developing computational thinking in pre-primary education. Then we present our contribution and approach to develop computational thinking in pre-school age (5 to 6 years) which is a part of upcoming conception of informatics from pre-school to upper secondary school in Slovakia. We present a "programming tool" called *Coloured Paths*, a methodology for teachers with graduated activities for children to be done a) with the software in front of an interactive whiteboard b) without the software in a workbook using some other printed materials. We write about iterative process of designing, developing, evaluating and analysing the software and related materials realized before and during the Covid19 pandemic.

Keywords: Computation in pre-primary education · Instructions, sequence, plan · Orientation in a map

1 Background

Various studies [2–5] confirm that pre-school children can build computing concepts and operations using developmentally appropriate tools. We thought about what computing tools or environments are used in the pre-primary or primary education, what are the differences between them and what do they have in common. In [6] three aspects of tools are considered: the way of control, type of an agent and the level of interaction. We consider few more aspects: basic instructions and what do we control with them, the environment in which the agent lives and the possibility of changing an agent.

Basic instructions and what do we control with them. In most tools we control the movement of an agent in the meaning of changing its position usually in a square grid. We can change the position of an agent either in relative or absolute way [8]. In relative way the agent moves forward in its actual direction, it can rotate left or right, mostly by 90 degrees. The basic instructions are forward, turn left and turn right. This way of controlling can be found in Bee-Bot, KIBO or Code a Pillar. In absolute way the agent usually moves up, down, left or right (like in ScratchJr, Kodable). In non-grid environments which are more like a general ordinary graph (map) the agent is controlled by giving an adjacent vertex it should move to or an edge it should take. Thus, the program is

either a sequence of vertices or a sequence of edges, like in one world of Thomas The Clown [9]. Rarely we can meet environments like Circus [1] where we do not control the movement of an agent, but we choose some actions an agent would do – like clapping, jumping, ...

What environment does the agent move in? In most tools an agent moves in a form of a square grid (Emil the Robot, LightBot, Kodable). The grid has not to be visualised, it can be just imaginary, like in KIBO, Code the Pillar, Bee-Bot or ScratchJr. In some tools an agent moves in a map of streets and intersections (Thomas the Clown).

Possibility of changing an agent. There are tools with just one immutable agent, like LightBot. In some environments we can choose from two or several immutable agents (Run Marco), in other environments we can change the visual representation of an agent (ScratchJr, Circus).

At present, robotic toys or virtual environments in which the agent moves in a square grid are mainly used in kindergartens. We were quite interested in moving an agent in a form of a simplified map. We have seldom encountered such an environment, and therefore we have decided that for our further research on how to develop computer thinking in pre-primary education, we will design and use an environment of this nature. In such an environment, we will also be able to examine how children orient themselves in a simple map, whether they can navigate an agent by instructions other than forward, up, down, ... think about different routes in a map and their properties.

2 Coloured Paths – software, methodology and workbook

Coloured Paths project is aimed to develop computational thinking in pre-school age. It forms a part of the nascent Slovak concept of informatics from pre-school age to graduation [10]. *Coloured Paths* environment is inspired by previous successful projects Thomas The Clown and Trips of Thomas the Clown [9]. In the *Coloured Path* children will encounter controlling an agent using instructions, symbolic recording of executed instructions, reading such a record and planning. In addition, methodological materials for teachers with a proposal of activities to work with the environment and worksheets for children are being developed.

2.1 Coloured Paths environment

The central character of *Coloured Paths* is a robot called Emil, who drives a car along the colourful paths of the farm [Fig. 1]. Emil goes to visit animals and sometimes he can carry cubs in his car. The robot is controlled by clicking the coloured paths symbols on the left panel. Instructions given to Emil are recorded to a line at the top of the screen - we call it a record or a record panel.

Coloured Paths consist of five levels, which differ:

- in maps - layout of paths, intersections, animals (topology of a graph),
- in the way of controlling the robot - direct control and planning,
- and in the possibility of transporting cubs.

Fig. 1. Coloured Paths - 4th level (map with a cycle, transporting cubs, direct control)

2.2 Interactive whiteboard activities

Coloured Paths is meant to be used by a small group of children in front of an interactive whiteboard. Teacher should be a moderator of children' activity, give assignements, challenges, ask questions, moderate the discussion.

We have designed activities for five meetings with the software. At the first meeting children control the robot to visit individual animals. They should start to realize the connection between a) the instructions given to the robot, b) the path symbols recorded in the record panel, and c) the paths the robot followed. During the second meeting children explore transporting animals. They learn to distinguish two parts of the robot's route - without and with the cub - and to read more detailed information about robot's trip from the record. They explore where the robot can get and where he can't get if a certain path is damaged.

At the third meeting children will encounter a map with a cycle. The aim of the meeting is to realize that there are different ways of how to get from one animal to another one, to distinguish between them, find out, which trip has smaller/bigger number of paths, explore where the robot can get if a certain path is damaged.

At the fourth meeting children transport animals on a map with a cycle and a bridge (see Fig. 1). After each finished trip or even continuously we talk about the route taken - the number of paths, the colour of the paths, whether the robot walked on the bridge or under the bridge. Later, we ask children to choose the route for the robot so that it meets the specified requirement, for example, the given number of paths, it must go with the cub on the red, etc.

At the fifth meeting we move on from direct control to planning the robot's trip. Children create plans for visiting individual animals, first without any restrictions, later with some request to the route.

2.3 Activities in workbook

The tasks in the worksheets follow up on the content and complexity of the meetings with the software. They can be structured into three categories. One type of activities are tasks in which children are given a map and an incomplete record and search for missing "symbols" according to the map, e.g.:

- determine the missing start, destination (Fig. 2 on the left) or path symbol,
- find the sequence (or sequences) of paths for the given start and destination,
- find the return trip,
- find out if the record describes the correct path,
- find an error in the record and, if necessary, suggest how to fix it.

Another type of activities is aimed at observing a given record of some robot's trip without a map. Children find out various information from the record, such as the number of paths taken, the number of paths of a specific colour, or, conversely, the path that the robot followed a given number of times. In the records with transporting the cub, they look for similar information separately for the part of the trip without/with the cub, they determine where the robot started his trip, where the robot picked up the cub and where he unloaded it.

Last type is aimed at reading a map. Children solve problems like:

- find animals from which a path of a given colour leads,
- find out, if it is possible to get from a given start to a given destination without using a path of a specified colour (Fig. 2 on the right),
- to whom the robot will get from a given start following exactly three paths.

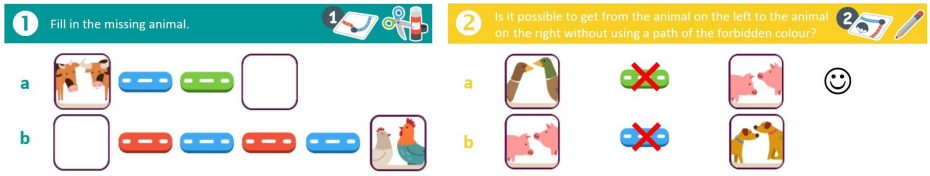

Fig. 2. Sample from a workbook – completing records according to a map

3 Method

In our study we applied the design based research approach [11]. We built on experience of our colleagues from [12], on the studies of Emil the Robot [13] and on our own experience from development of Circus software [1]. First prototype of the *Coloured Paths* software was ready two years before, before the summer. We decided to make some early experiments during the summer holidays. After the first intervention with kindergarten children the software was changed a little

bit according to our findings and more levels were added. In parallel we have designed activities to be done with the software and related unplugged activities. New version of software as well as prototypes of software and unplugged activities were planned to introduce to children gradually in five sessions. Due to the pandemic just two of them were realised. We continued to work on materials for teachers and printed workbook for children. In 2021 we decided to do some online sessions with children.

All present sessions were conducted in the same kindergarten and were realized by the same research group consisting of three researchers and a kindergarten teacher. The same research team participated on the online sessions.

4 Interventions

4.1 Interventions before Covid19 pandemic

We had three sessions with pre-school children before Covid19 pandemic. Inspired by [14] we chose the model of distributing children into several groups, all staying in the same class. One group worked with the software at the interactive whiteboard, the other one solved tasks from prepared worksheet (if there were any) at the table. Other groups were doing activities prepared by the kindergarten teacher. The groups rotated after 10-15 minutes.

First session was aimed at 1) the software itself, its functionality and user-interface, especially controlling the robot 2) how children do orient in a simple map. We had no worksheets prepared to this session yet. The session was attended by two groups of four children who started primary school after holidays.

Children had no problems with controlling the robot. Some children tried to click at the paths in a map at first, or tried to move the robot by a finger, but finally all children discovered the symbols of paths in the left panel and used them to control the robot. Both groups managed visiting animals as well as transporting the cubs. Children's orientation on the map was good.

After first session some small changes were made in the software. The control panel was redesigned so that the path symbols were more accessible to smaller children. The maps were simplified - we decreased the number of intersection and edges so that the trips and their records would be shorter. Next two sessions took place in the following school year with about 20 mainly pre-school children.

At the second session, we verified the activities designed for the first meeting. We noticed, that when answering the questions about a finished route, children mostly look at the map and imagine the route again instead of looking at the record panel. In worksheets children had to solve tasks with an incomplete record. They were quite successful in completing a missing target animal or a missing symbol of a path, or in inventing the whole route with given start and finish. The most difficult turned out to be a task, where children were given a wrong record of a route and had to find a wrong element.

At the third session, we verified activities related to the second level. Children have quickly understood how transporting of animals worked. The record panel has already been used by more children than in the previous meeting.

The present sessions help us to find bugs, deficiencies in user interface (like long lasting animations, or too much fun elements) and in the proposals of software and paper activities. As for paper activities, we stated that we should:

- make the paper activities more diverse, not just of one type,
- give each child or a pair its own paper map, not one map to a group,
- reconsider the complexity of the tasks, include more challenging tasks later,
- change the organization model – paper activities should not be realised in parallel with the software ones, because they need a full-time moderator.

4.2 Interventions during Covid Pandemic

During Covid Pandemic we mainly focused the verification on understanding the assignments of the tasks that should be done with the software and assignments of the tasks in the workbook. We did the online verification with two pre-schoolers, girls. We had five online meetings with each of them, separately. At each meeting, they first worked with the *Coloured Paths* application doing activities as proposed in the methodology. Immediately afterwards they solved the tasks from the corresponding paper worksheet.

Both girls managed the activities with the software very well, visiting the animals or transporting the cubs did not cause any problems. When answering questions about a route taken, one girl used the record panel from the first moment, the second one answered according to remembered solution of the task firstly, but later she also analyzed the record.

Both pre-schoolers were good at looking for different routes from one animal to another one, discussing which one is shorter or longer. They discovered the possibility of walking around the cycle as after a roundabout or going back and forth along some paths when looking for a long route. They also managed looking for an alternate route, or determine where the robot can (can't) get if one or two paths were damaged, both on a map without and with a cycle.

Assignments asking to take a route with some specific request were also understood and solved well by the girls, both in direct and planning mode. The transition from direct mode to planning mode was seamless. Both girls even managed to plan a route for visiting two animals which we consider to be the most challenging at this level.

As for unplugged activities both girls handled the tasks *to find out some information from the given record* well. They were also successful in tasks with yes or no answer, e.g. whether it is possible to move from one animal to another without using a path of a particular colour or whether the sequence of paths between the two animals is correct.

The difficulty of the tasks for *completing a record* varied. It was easy for the girls to complete the record if the target animal or the last path was missing. Even the task with missing first path was solved quite easily. Completing a record with missing starting animal was a little more complicated. One girl used a strategy of looking for an animal from which a path of the given first path's colour leads. The second one interpreted the record on a map in reverse. The

most complicated was completing a record where a path symbol somewhere in the middle of the route or two path symbols at the end were missing.

After our experience in the kindergarten we included the task for *finding an error in a record* as the last one. Even so both pre-schoolers had troubles with solving it especially if the wrong element was just before the target animal. We have realized that it is like looking for an error in the foreign code, which is really difficult and we decided to exclude this kind of tasks from the worksheets.

This verification enabled us to find out which tasks are suitable and which tasks are too difficult for pre-school age. Based on this, we modified the worksheets, changed the wording of some assignments, changed the order of tasks or eliminated some tasks completely.

To prevent monotony and develop fine motor skills children alternated between various activities while solving the tasks like gluing, circling, drawing, filling in the tables, walking with a stick figure on the map. We saw that both girls liked this.

5 Conclusion

We have presented a two-years design-based research study with *Colourful paths* software. The results of our iterative process are the *Colourful path* application, materials for teachers and worksheets for children. At present we are planning training courses for kindergarten teachers.

Children worked with the software intuitively, they discovered the control of the robot and were able to visit and transport animals by giving instructions to the robot. They were also able to speak about the route taken, find out different information about it from the record. At the end they were able to design a route (plan) for the robot even with some given request to the route. We found out that children in the pre-school age able to orient in a simple map: they can find and describe way or also more ways from one place to another and think about their length in the meaning of number of edges, they can consider the availability of places if any of the paths is destroyed.

We realize that two children is a small sample to state some generalizations. Nevertheless, we are glad that this verification took place at all and we are convinced that this verification has helped us to improve both the worksheets and the methodology.

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