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A POSSIBLE WAY TO DEVELOP ALGORITHMIC THINKING

Gábor GEDA, Csaba BIRÓ

Abstract: The pace of development of computer technology and information technology over the last few decades has been unprecedented in the history of technology. Not to mention the impact this has on our daily lives. This requires our children to quickly become familiar with the mindset that is important to be able to use their IT tools effectively in their various activities in the future. This necessitates the development of the ability to follow rules and creativity at the same time. How could this contradiction, which is more present in younger age, be resolved? Perhaps it is not surprising that the key to success lies in playful exercises that children are eager to solve.

Keywords: algorithmic thinking, cellular machine, neighborhood relations, cellular automata in algorithmization

1. Introduction

Information technology is one of the fastest growing relatively young sciences. This simple fact explains a significant part of the problems related to its education. In the classical sense, education was based on an activity whereby representatives of the previous generations passed on their experience to younger people, preparing them for "life". Even today, this statement is more or less valid in many areas at different levels of education, with regards to the knowledge. (Geda, 2015).

However, in information technology, it is not easy to predict when the development will take a turn and in what direction, therefore it is not certain that it can be told exactly – or perhaps even approximately – what kind of factual knowledge we need to equip the rising generation with in the process of education. The most correct way is, probably, to get them to have the ability that will allow them to adapt to a rapidly changing world, the world of information technology.

1.1 What determines the necessary IT skills?

Due to the interdisciplinary nature of informatics, it is necessary for everyone to have a certain level of knowledge to be able to successfully pursue their chosen profession as well as to succeed as a private individual in several areas of life. This level is predominantly determined by the individual's career and scope of activities.

As mentioned previously, the science of information technology is changing rapidly, and its latest results are appearing faster and faster in our daily lives. Education, including IT education, of course, needs to adapt to this. This means that we should be able to predict the changes in a rapidly changing, complicated system with great precision in order to adjust our education to it. This is a very complex problem in a system of high inertia, such as society in general or an educational system.

The history of mankind, including the history of science and technology, is also a history of errors. Who would have thought that Charlie Chaplin himself, who is considered to be one of the greatest figures in the history of motion pictures, had thought of cinema as a passing whim? But we could also mention Einstein himself, who had never seen a way for mankind to ever use nuclear energy. Obviously, there are similar unfulfilled predictions in the field of information technology, too. This means that we are not in an easy position to predict what the curriculum in IT education should be, when we need to provide students of our age with the knowledge that they will really benefit from while practicing their profession, especially if these are the ones that may not even exist today.

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As weather forecasters do with the weather parameters of the past, when formulating forecasts, we need to adjust our curriculum from time to time to both technological advancements and societal demands. If this refinement is made at a sufficient frequency, then in theory, we can meet expectations quite well. The question is just to what extent the education system can tolerate this frequency of change? Of course, all curricula have timeless elements as well. One of the reasons why information technology is in a special position compared to many other subjects, is that the ratio of IT knowledge is much lower. Predicting the direction of IT development is also complicated by the fact that it can be influenced by many factors.

In addition to new scientific, technical and technical achievements, the role of various economic and political considerations can also be significant. Even with the development of other systems that can be described more easily by mathematical tools, we can predict the expected direction of development more precisely in the shorter term and less accurately in the longer term. The reason for this is that the applied mathematical model cannot take all circumstances into account and that in most cases we have to apply approximate methods to deal with them (Geda, 2009). What is quite likely in the long run is that the storage and transmission of information will primarily be based on the use of the properties of electric charges, as this is most effective in nature, such as in the case of living organisms as well. Being part of nature, we must follow its laws.

2. What brings IT tools to life…

Besides technical and technological knowledge, the factors that enable people to use IT tools efficiently in a wide variety of fields and at different levels also play an important role. Even the most advanced tools are of no use in absence of the proper skills and human creativity, as these qualities allow us to create programs that control our devices, enabling us to solve problems at different levels in various fields.

Of course, we cannot aim for everyone to delve into the mysteries of programming, but we cannot avoid learning about the algorithms that underlie the programs that ensure the proper functioning of IT tools, at a level and age appropriate for them (Geda, 2015).

Basically, algorithms provide a series of elementary steps that are consistently executed to solve a specific problem, even if the problem itself is not fully understood. Apparently, understanding the basic steps of the algorithm is essential, even if you do not see the problem entirely. However, this is the responsibility and task of the algorithm’s author. When we specify an algorithm, we essentially provide a general solution plan for problems of a given problem area. This means that algorithms and algorithmic thinking have a very important role in problem solving (Amorim, 2005).

With a bit of exaggeration, we can say that algorithms are as old as the thinking man and they have been bound to the most diverse fields of life and later to science. The above also means that the existence of algorithms does not depend on computers, while computers are much more dependent on algorithms, but at the same time their importance has increased significantly with the spread of computers. In fact, humans created computers in order to provide a tool that efficiently implements algorithms. Nevertheless, we must distinguish between the provision of the basic steps of the algorithms and the execution of these steps (Hromkovic, 2009). All the more so because the steps of an algorithm solving a problem are usually the result of serious brainwork, depending on the nature of the problem, and it usually requires mathematical description of the problem in question (Geda, 2011; Geda et al., 2011.), whereas the execution of the algorithms can be left to a "dumb" computer.

3. Objectives

In light of the above, we aimed to explore the potential of developing an activity-oriented tool that can be effectively used to develop students across a wide range of ages and with diverse target groups and conditions, in particular to lay the groundwork for the development of problem-solving thinking.

To achieve all this, we were looking for a brief, easily understandable and illustrative rule. In our view, the one originally formulated by Stanisław Ulam (Marx, 1984) exactly meets these conditions. According to this, a new, next-generation cell is created in an empty cell only if it has exactly one previous-generation neighbor. Although the wording is really short and simple, it is undoubtedly necessary to interpret and illustrate it depending on the target group.

4. First steps in algorithmisation

As in other areas, following certain patterns can be a useful practice in learning algorithmisation. We can give the student examples that will get them closer to following the instructions of algorithms that solve more and more complex problems, then understand their logic, and finally, based on previously known patterns, be able to specify the steps of algorithms for solving simple or complex problems independently.

4.1. Complex Basic Program

Nowadays, almost every school system in the developed world has faced a minor or major crisis in public education. The Complex Basic Program was aimed at the methodological transformation of the Hungarian public education, hoping that this would significantly reduce the rate of early school leaving, as a much higher proportion of students will have a positive learning experience due to the methodological changes. Within the framework of the program, pedagogues already practicing their profession will attend trainings in order to acquire the necessary knowledge from almost every schools in the country.

The project's Logic-Based Subprogram aims to improve students' thinking through an experiential approach adequate to different types of knowledge and the students' level of development. Visual representation opportunities play an important role in the learning process and we strive to create a learning environment fostering creativity (Arató, et al. 2018a; Arató et al. 2018b; Wiersumné, et al. 2018).

4.2. Cellular Machine

The effectiveness of playful learning lies in the fact that, regardless of age, a well-chosen game can be a source of joy by providing a sense of success, and the potential for failure may not be as intense since its effects may be dampened by the game atmosphere.

Although the theory of cellular automata dates back to the first half of the last century and it is associated with scientists such as János Neumann, they can even be considered as games, thanks to their simple set of rules. Their purpose was mainly to provide examples of artificial self-replicating systems. Nowadays, with the increasing computing capacity of computers, they can be used for discrete modeling of various systems, such as ecological systems, or even crystal growth processes (Biró-Geda, 2010., Geda, 2011., Biró-Geda, 2014.). First of all, it is expedient to interpret the cellular space itself. First of all, it is expedient to interpret the cellular space.

Although its dimension number can be any positive integer, in our case it is advisable to think of it as a plane for better clarity, since our fundamental aim is the development of the skills needed for the initial steps of algorithmization, not modeling. Thus, the cellular space itself can initially be imagined as a square grid whose individual slots are the cells themselves. Various parameters can be assigned to these to characterize their state. This model provides an opportunity to illustrate changes in a system over time. Since it is a discrete model of time, the change in time can be given by changing integers and characterizing it with generations. The initial state will be called generation 0.

Beyond the whole system's state of a given generation, it also makes sense to talk about the state of each cell within that generation. The state of the cells can thus vary from generation to generation. These changes occur depending on the state of each cell and its environment, according to a predefined set of rules.

The state of each cell can be visualized by its different coloring. The environment surrounding each cell consists of the surrounding cells. In the simplest case this can be characterized by the neighborhood relation of the cells, more generally the distance between the cells. In the case of square cells, we can distinguish cells that have a common side, or just a common vertex, with a pre-selected cell. These should definitely be treated separately. Thus, it can be said that, for square cells, a selected cell has 4 side neighbors and 4 vertex neighbors (Figure 1).

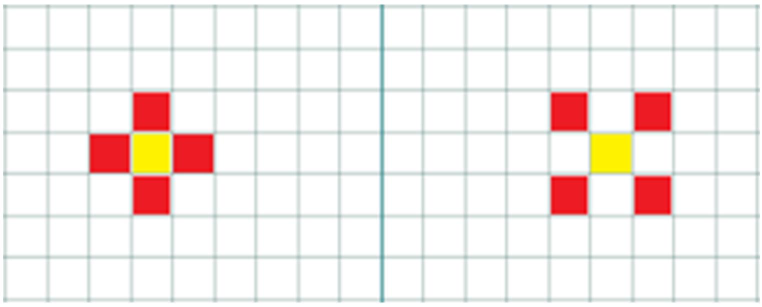


Figure 1. *The interpreted two neighborhood relations (side and vertex neighbors) for square cellular space*

Since the plane can be covered by other regular plane shapes (regular triangles and hexagons) as well, triangular and hexagonal cellular spaces can be used. Therefore, it is advisable to interpret the possible neighborhood relations in these cases as well.

In the case of hexagonal cells, it is obvious that only one kind of neighborhood relation should be defined, since in the case of a selected cell we can only speak of close cells that have a common side with the selected one (Figure 2).

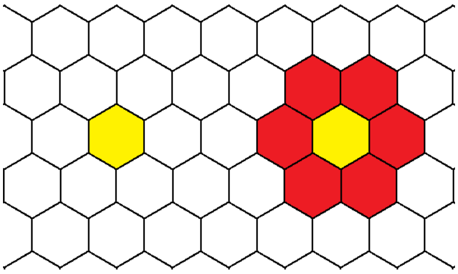


Figure 2. *Neighborhood relation in case of hexagonal cellular space*

We only define side neighbors. The possible neighborhood relations show a slightly more varied picture if the cells are regular triangles. It is possible to distinguish 3 side neighbors in the vicinity of a selected cell and it seems appropriate to distinguish between two vertex neighbors (Figure 3). One vertex of the selected cell has three triangles, all of which has one vertex common with the one in question, but is not a side neighbor of the selected cell. These include a triangle that has a common axis of symmetry with the selected cell, but the other two do not (Figure 4). The former is called symmetric vertex neighbor and the latter are called non-symmetric vertex neighbors. As shown in Figure 3, a selected cell may thus have 3 side neighbors, 3 symmetric vertex neighbors, and 6 non-symmetric vertex neighbors.

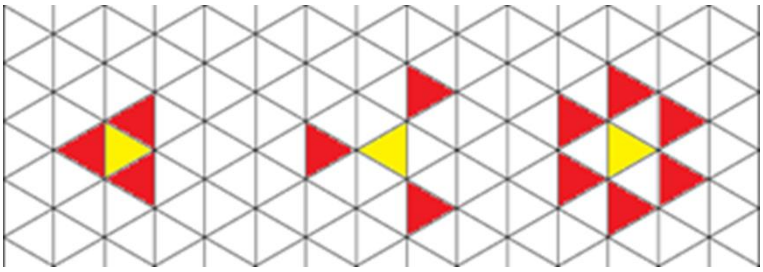


Figure 3. *The three possible neighborhood relations in triangular cellular space*

(The above figures also illustrate which cells may be 1st generation cells according to the rule to be described below, in the case of different cellular spaces, according to the selected neighborhood relation, if the yellow stained cell is considered 0th generation.)

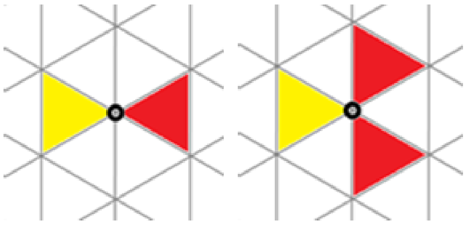


Figure 4. *Symmetric vertex neighbor and non-symmetric vertex neighbors for a selected vertex in triangular cellular space*

4.3. Cellular automata in algorithmization

In the following, we show how to formulate various rules that specifies how the state of individual cells change over time from generation to generation. The very first example shows that we only need to formulate a rule that specifies how the state of individual cells change step by step over time from generation to generation. An example to this is given below.

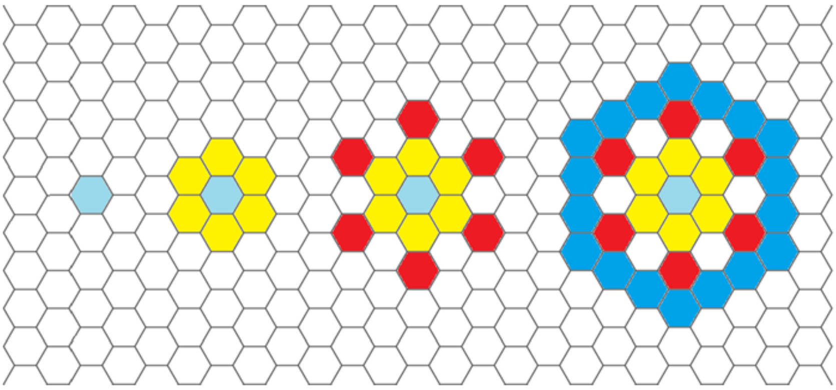


Figure 5. *The evolution of four successive generations (0-3) in hexagonal cellular space*

An example of the rule's interpretation in hexagonal cellular space is shown in Figure 5, which illustrates first 4 generations' typical states. The cell of Generation 0 is light blue. It has six Generation 1 neighbors (Figure 2), since all cells marked in yellow are neighbors of the light blue one from Generation 0. Generation 2 cells are marked in red in Figure 5. Only the indicated cells meet this condition, since any cell between two red ones already has two Generation 1 (yellow) neighbors. Generation 3 cells are marked in darker blue. They all have exactly one Generation 2 (red) neighbor. (Apparently, cells of the same generation can be adjacent to each other, since they are created at the same moment.) Of course, colors previously used can be reused to mark cells of higher generations. This can also be done by defining the order of the colors first, and switching to the next color when switching generations, cyclically using the colors of the scale. Examples of this are shown in Figures 6, 7 and 8. The path to developing algorithmic thinking mentioned in the title can be quite diverse. Its diversity can be determined by many factors that are dependent on and independent of the individual. This diversity is also supported by the method's flexibility, which manifests itself in the choice of cellular spaces, besides the variety of neighborhood relations interpreted in them, as well as in the variability of the applied color scales. In accordance with our objectives, now we are only focusing on the initial steps.

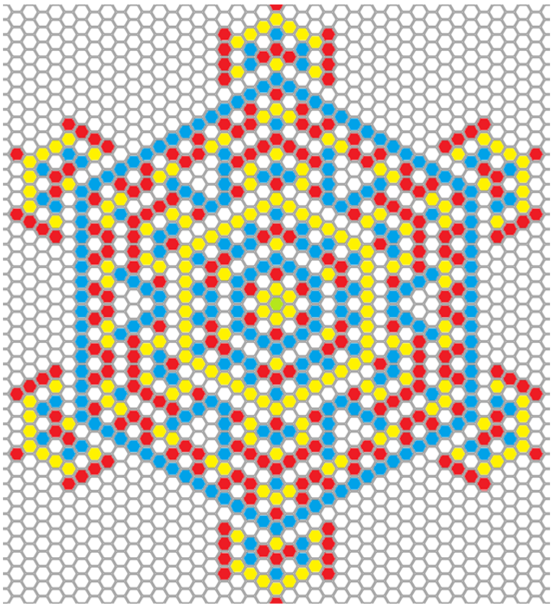


Figure 6. *Pattern of 21 generations in hexagonal cellular space*

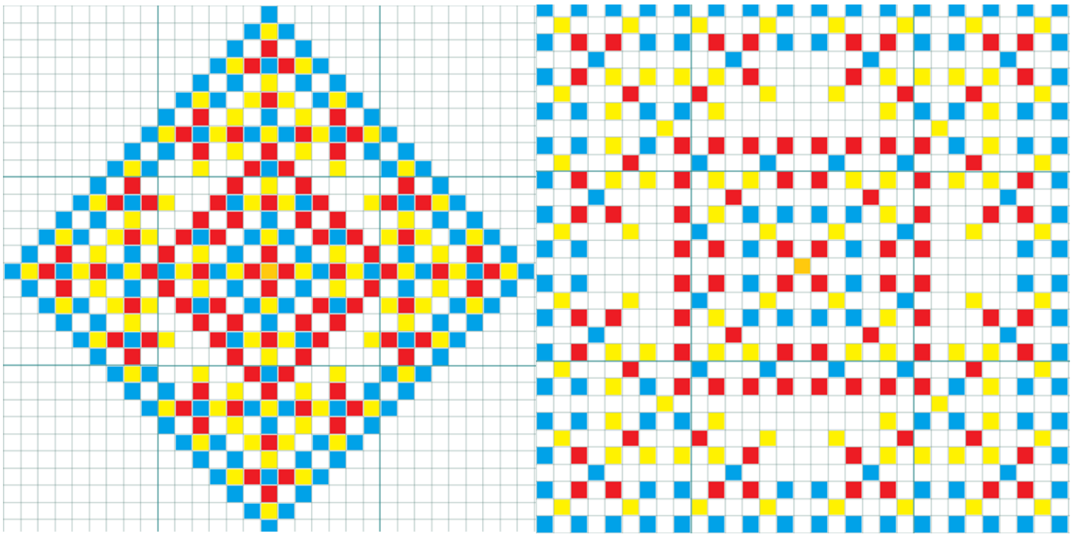
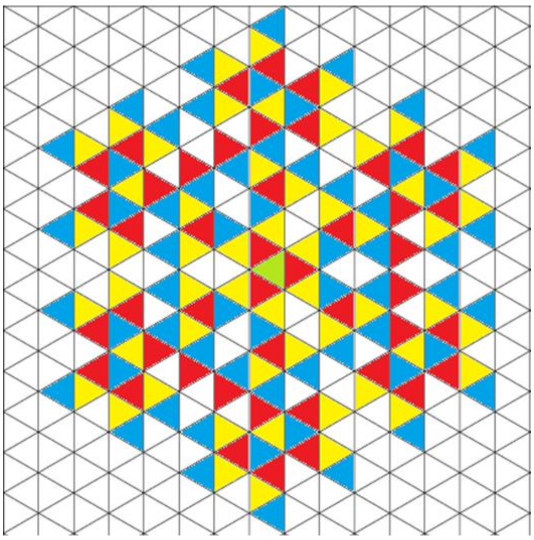


Figure 7. *Patterns in rectangular cellular space according to different neighborhood relations*



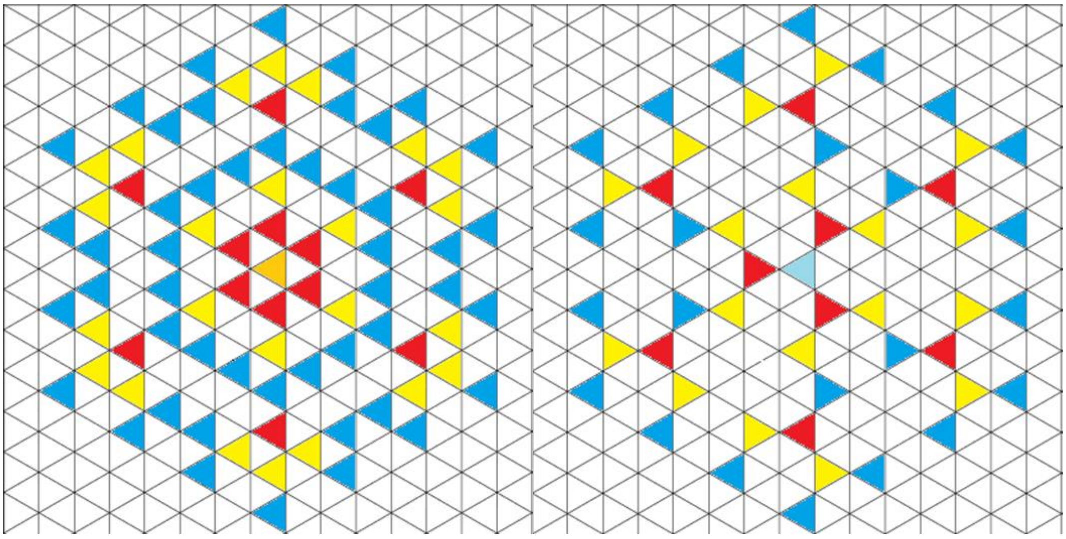


Figure 8. *Patterns in triangular cellular space according to different neighborhood relations*

5. Students while solving assignments

Teachers participating in the trainings Logic-Based Subprogram could get to know the techniques described above, and try them as well. Based on the feedback, it can be said that, students were happy to solve these types of tasks, regardless of whether they were available printed on paper (Figures 9 a-b), or in a graphic editor as PNG or GIF (or other lossless compression) graphics files (Figure 10 a-c),. Of course, you also need colored pencils or felt-tip pens on a sheet of paper, while using a computer, the fill function of the editor can be used to color the desired cells properly, and any incorrect coloring can be corrected more easily. The benefit of this type of exercise is the opportunity to provide students with an aesthetic experience that might appeal to more people, and it enhances their tolerance for monotony. At the same time, their ability to follow rules is improved, and their creativity can be enhanced as well, for example, by assigning colors to generations independently.

Taking into account the age specifics of different age groups, we have developed a methodological recommendation and a collection of tasks for this activity-oriented tool. This, we briefly introduced to the instructors involved in the trainings.

The following pictures were taken by Csaba Bede, a teacher of informatics at the Hunyadi Mátyás Primary School and Primary School of Art in Lőrinci. Figures 9 a-b and 10 a-c show how children solve various cellular machine-based assignments on paper and on a computer.

Figure 9-a **Figure 9-b**

Figure 9 a-b *Students while solving assignments (paper-based) (Bede, 2018)*

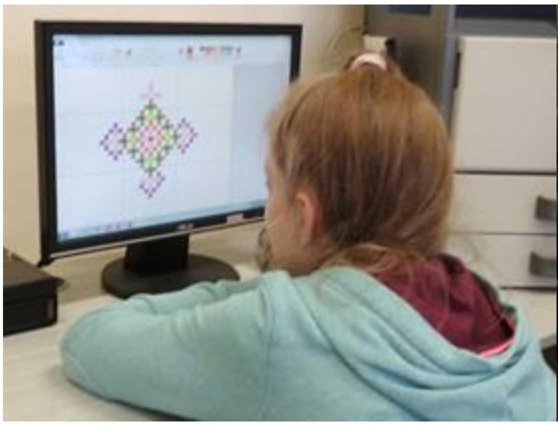


Figure 10-a **Figure 10-b**

Figure 10-c

Figure 10 a-c. *Students while solving assignments (using a computer) (Bede, 2018)*

6. Conclusion

In the last few years, the cellular automation-based activity-oriented tool and methodology we have developed, for it have been tested in several primary schools in Hungary. Pedagogues were asked to briefly share their comments with us. Fortunately, a number of feedbacks were received. After the analysis and combining the similar opinions the obtained result, without claiming completeness, just taking into account the most relevant observations are summarized as follows:

- Develops IC.T competencies.
- Helps to teach certain function of different graphics applications for instance Paint program.
- Improves concentration.
- Develops children's dexterity and fine motor skills.
- Develops algorithm and problem-solving thinking.
- Develops reading comprehension.
- It can be used very well at the beginning of the lesson, it helps the students to attunement on it.

In summary, based on the feedbacks, it can be said that, both children and educators satisfied and used it pleasure.

7. Further opportunities of development

Our further objectives are formulated in the light of the quote below.

“Although they cannot transform education by themselves, digital technologies do have huge potential to transform teaching and learning practices in schools and open up new horizons. The challenge of achieving this transformation is more about integrating new types of instruction than overcoming technological barriers. Digital technology can facilitate:

Innovative pedagogic models, for example based on gaming, online laboratories and real-time assessment, which have been shown to improve higher-order thinking skills and conceptual understanding and in many cases have enhanced students’ creativity, imagination and problem-solving skills.” (OESD, 2016)

The above is considered to be a flexibly configurable pedagogical tool that can be tailored to the specific target group by properly specifying the parameters. For example, parameters allow you to select the cellular space and neighborhood relationship, or to define the working environment, but these parameters can also be the initial state of the cellular space or the time available for the task.

As mentioned earlier, we developed a methodological recommendation and a collection of tasks. Based on feedback, the purpose of further research is to recasting the methodology of this activity-oriented tool and to fine-tune it appropriately. With this tool, we want to target a wide range of age groups, from primary school to higher education. It is ongoing, the developing a web-based tool for surveying and developing different skills. Firstly, we would like to compare the results of the tests taken at the beginning of the semester, with the results of the logic, mathematics and programming courses taken at the end of the semester. Later, we would like to assess algorithmic skills as widely as possible (in all age groups).

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Authors

Geda, Gábor, Eszterházy Károly University (Eger, Hungary), geda.gabor@uni-eszterhazy.hu

Biró, Csaba, Eszterházy Károly University (Eger, Hungary), biro.csaba@uni-eszterhazy.hu

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