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CAN ROBOTS HELP INCREASE THE EFFICIENCY AND RETURN ON INVESTMENT OF EDUCATION?

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Abstract: Education is an important issue in every country, including Hungary. Regular PISA surveys show that Hungary is lagging significantly behind in all competences compared to developed European countries. This study is not intended to find a solution to this problem, but it is well known that the capital and time invested in education pay off, albeit slowly. It pays off for both the individual and the national economy. The educational achievements of Roma children, many of whom live in disadvantaged settlements, lag further behind those of average Hungarian children. This study provides an example of how disadvantaged pupils can be specially motivated and how their learning can be promoted with the help of robots.

Keywords: *robotics, competence development, disadvantaged children, motivation*

Return on education

In a globalised economy, the basis of competitiveness is knowledge, which is also the most important asset of companies, intellectual capital, based on the competences of individuals (Farkas et al., 2009). The human capital theory is that human knowledge has economic value. Continued investment in human capital is a necessary condition for operating and maintaining a knowledge-based economy and society. Learning can be seen as an investment in human capital that pays off for both the individual and society. The most important indicators of return are economic welfare, higher employment and social cohesion (Sándor Kriszt, 2016). According to (Thurow, 1970), human capital is defined as the productive capacity, talent and knowledge of an individual, measured in terms of the value of goods and services produced directly or indirectly by human capital. Thurow approached human capital primarily from the perspective of production as a relevant factor of production.

According to Szűcs (1999), the fundamental goal of knowledge management is to achieve the best business results, which he focuses on five strategic points:

1. Knowledge strategy: knowledge management, acquiring, exploiting and sharing the best knowledge.
2. Intellectual property management strategy: exploiting patents, creating an innovative climate, incentives.

3. Personal knowledge strategy: importance, exploitation, responsibility of individual characteristics.
4. Knowledge creation strategy: importance of organisational learning.
5. Knowledge transfer strategy: targeted, optimal knowledge transfer at the right point, with the right tools.

In the process of education and training, in addition to imparting knowledge, it is important to transmit values and behaviours that include the transmission of norms and rules and learning how to apply them, which help individuals to participate in social life and economic activity (Halász, 2001). It is important to clarify that it is worth distinguishing between different life stages in terms of the subsequent return on investment in education. The rate of return is highest in the early childhood phase and decreases over time. The rate of return is much higher for children from disadvantaged socio-cultural backgrounds, but the decline is much steeper, i.e. the probability of return declines more rapidly over time (Heckman, 2003). However, the benefits of education are not limited to improving economic productivity, as a good quality education contributes to social welfare in a number of ways. For example, people with higher educational attainment may have higher health, interpersonal trust and political efficacy, and may be more active citizens, for example, more likely to volunteer. The better educated take better care of their environment and consume culture more intensively (Csapó, 2011). In recent decades, the nature of workplaces has also changed. People with higher skill levels have an advantage in the labour market. Technology, mechanization and robotics are increasingly taking over work areas that can be performed with lower qualifications (Molnár et al., 2019).

Disadvantaged children in education

In Hungary, the social, economic and political changes that have taken place since the regime change have significantly transformed the structure of society, and the impact of increased social inequalities can be felt in all areas of education (K. Nagy, 2019). The socio-economic benefits that can be realised through education are most beneficial for children from disadvantaged social groups. If students from disadvantaged family backgrounds do not have the skills to enter the labour market when they leave the education system, they are unable to contribute to the public purse, or only to a limited extent, while generating costs for society, including unemployment, social and health care, and also the costs of the prison system (Fejes et al., 2020). However, due to the hierarchical stratification of society, schools today are not able to offer all children the opportunities and chances they need to develop optimally. There is the social group at the bottom of society, and there are schools where the children of this group study (Kertesi & Kézdi, 2016).

A significant proportion of Roma pupils have unsuccessful school careers. To explain the reasons for their failures, it would seem obvious to refer to cultural differences and the school's failure to take them into account (Fejes, 2005).

Motivation for disadvantaged children

According to the (Mourshed et al., 2007), the success of the education system is driven primarily by three factors. First and foremost is the talent of teachers in the joint

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task of education and training. The second is that teachers use teaching methods that are able to hold the attention of students and capture their interest. The third is to ensure that the education system is able to reduce and approximate the inequalities that arise from family backgrounds.

The acquisition motives may be linked to direct learning at the beginning of school, possibly in kindergarten. If children do not experience the experience of acquisition, of gaining knowledge, during their first learning experiences - which is assumed in the case of Roma children - then untapped inherited drives, motives not reinforced by success, may be pushed into the background, replaced by motives not related to learning, and their function in school situations may cease (Józsa, 2002). In Gypsy families, doing well by children means giving them immediately what they want. Children are not forced to do anything, but rather they are lovingly waited until they are told, but then their needs are met immediately. In this way, they do not develop the skills of delay and self-control that are essential for good school performance (Fejes, 2005). The most sensitive measure of a society's openness is the opportunities it can provide for such children. (Kertesi & Kézdi, 2016) point out that today the disadvantages arising from segregation are consistent with a simple model of school choice, a model based on differences in the perceived quality of schools and selection by ability and family background. Experts agree that in Hungary, the problem of disadvantaged children who are lagging behind in learning and the compensation of their backwardness in school can only be achieved by a radical change and reform of education, and therefore, teaching methods that are suitable for children of all social groups should be sought (Ostorics et al., 2016).

The prolonged childhood of Roma children is not followed by normal adolescence, but by a sudden "miniaturisation" of adulthood between the ages of about 10 and 13. Instead of adolescent crises, they have adult problems. They expect help with family maintenance earlier than average. At home, they are treated as adults from adolescence, but at the same time they are treated as children in the eyes of the school. In particular, children who are over-age at school have problems with the role of the small adult, who cannot even communicate with classmates who are two or three years younger. This earlier adulthood is also linked to the fact that Roma children of secondary school age are traditionally considered to be ready to start a family (Liskó, 2002). According to (Fejes, 2005), the language socialisation of Roma pupils is an issue that deserves particular attention, as it can affect motivation to learn from two angles. On the one hand, the inadequate acquisition of the majority language and, on the other hand, the use of a language other than that of the middle class can separately hinder success in school, mainly through the self-image of learning. This may be particularly true in traditionalist schools where verbal intelligence is the basis for school success. These differences and difficulties cannot be overcome, or are very difficult to overcome, using traditional pedagogical methods and school tools.

The term robot was coined by Karel Capek in the science fiction drama R.U.R. (Rossum's Universal Robots) in 1921. The original meaning of the Czech word 'robot' was forced labour, slave labour, although at the dawn of human civilisation, in the 18th canto of the Iliad, there were also fantasies of talking, self-operating structures made of gold in ancient times. Yet it is primarily through Asimov (1942) that its modern interpretation has come into the public consciousness. A robot is defined in (Szabó et al., 2014) as an electromechanical device that can perform various tasks based on prior programming. It can be under direct human control, but can also perform its work autonomously under the supervision of a computer.

Thanks to the rapid development of science and technology in most fields, it is not yet known what knowledge students will need in 10-20 years to succeed in life. As a consequence, young school students need to be equipped with the skills to create new knowledge from existing knowledge and to support the application of previously acquired knowledge in new and different contexts (Molnár, 2006). The development of technology also affects the learning landscape from kindergarten to higher education (Molnár, 2021). Technology-enhanced educational processes, including educational robotics, can be used to change the processes of learning and teaching. The use of educational robots is a new and interesting answer to the questions posed by the 21st century and the information society (Majzik, 2020). The rapid technological development and changes of the 21st century have a significant impact on our daily lives, our communication, our communication opportunities, our shopping and entertainment habits (Molnár et al., 2020).

Playful teaching is a primary aspect of the development of children with special educational needs. Special Education Needs (SEN): a child or pupil with special educational needs who, according to the expert opinion of the expert committee, has a motor, sensory, intellectual or speech disability, or, in the case of a combination of several disabilities, a cumulative disability, an autism spectrum disorder or other mental development disorder (severe learning, attention or behavioural disorder). Act CXC of 2011 on National Public Education.

When a robot tool is presented to children, it can activate an intrinsic motivational base that is difficult to mobilise with traditional tools. We can easily motivate children with any kind of disability with a nice, perhaps talking, floor robot. With the help of robots, children can learn the basics of robotics and coding through gamification by doing different tasks. They learn different subject content through active, action-based activities with robots and develop different skills through developmental tasks with robots (Aknai, 2020). Educational robotics refers to the pedagogical development of hands-on, programmable tools, physical objects, and technologies (such as programmable LEGO or EDISON) that can be used to support understanding and concept formation in learning (Mező & Szabóné Burik, 2021). The robots help children develop their attention, memory, and thinking functions in a playful way. Emotion-based child-robot interaction helps to focus attention, improve information perception during learning, and verbalisation. This process has a positive impact on children's educational rehabilitation and develops their emotional culture when interacting with robots (Aknai, 2020).

Development, motivation and robotics activities

At the beginning of the school year, we always start the tuning process with BeeBots, which develops algorithmic thinking and helps children to anticipate (Figure 1). BeeBot's memory can be programmed up to 40 steps and BlueBot's up to 200 steps. BlueBot can be controlled from a smart device or PC. Unlike BeeBot, BlueBot can turn 45 degrees when

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controlled from a smart device. The code generated on the device can be sent to the robotic bee via a direct Bluetooth connection. Of course, BlueBot can also be used in BeeBot mode (Aknai, 2020).

Figure 1 Children working with BeeBot and BlueBot

Source: taken in the classroom

Besides BeeBot, other popular floor robots are Edison and Ozobot. Edison robots are motivating tools for playful learning. The advantage of this robot is that it can be programmed in several languages, from small ones with built-in barcode through block and icon programming to ED-Phyton, which is "understandable" for users with a more advanced background. It develops problem-based problem solving and algorithmic thinking (Mező & Szabóné Burik, 2021). The colour codes tell the Ozobots what to do. The colour codes teach basic coding principles such as cause and effect, critical thinking and debugging. The bots use sensors to follow the lines and read the colour codes made with markers (or stickers). For "colour" programming, we use a colour-coded board" (Aknai, 2020).

In many cases, school deficits mean that some computer literacy training is needed such as, how to copy, save and open applications and how to shut down the computer properly. To develop mouse use and dexterity, we get students to edit 3D designs for the 3D printer. Using one of the software programmes, students design items such as small keychains or a name coin for a shopping trolley. They then ‘slice’ their design and print them using the 3D printer. These items are also a big hit in the run-up to various holidays. For Christmas, we 3D print small pine ornaments, and for Easter, we 3D print colourful egg holders. The children are delighted to take these small objects home as gifts for their parents.

To promote programming skills, we create a simple, fun, funny few-step program in Scratch. Here, students can practise block programming. Scratch does not require any tools or robots. All you need is a computer or laptop. Most students write the first program of their lives in this program, which they can try out immediately. Scratch is loaded with many visual elements to make sure that the result is really spectacular and appealing to children. The first, and perhaps simplest, task involves a fish swimming in a fish tank, which, when it reaches the wall of the tank, turns around and then does the same thing again at the other wall, so that you see the fish swimming back and forth in the tank. It is a simple task, yet the screen shows a spectacular, moving picture where children can choose the aquarium itself, the plants in it, the other animals and the fish itself to move. The task is very simple yet requires some programming elements. The other big hit is when children draw a maze using a paintbrush. Then they have to move the chosen figure (costume) from the start to the finish using the down, up, right, left keys. In case the figure reaches the wall of the maze, it jumps back to the starting point.

The microbit is a great success in all cases, as it is now a device that has been brought to life with programs written by the students and that children can actually use. microbit A printed circuit board with two micro switches 25 LEDs, with a built-in gyroscope, with a motion sensor. This tiny device, the size of a simple matchbox, can be expanded with countless devices, starting with simple texts in smileys, but gradually deepening the knowledge, even a compass, protractor, pedometer can be programmed. Later, microbit accessories will be added to the sessions. For example, building and programming an automatic irrigation system, with the help of which the humidity sensor, when it detects that the potting soil is dry, sends a signal to the microbit, which starts the mini-pump and the plant is watered through a pipe. This is where the various variables appear, the operation of the motors and, not negligibly, environmental education are all part of the task. Every year, the compass is a great success, where, in addition to the cardinal points, the repetition of the degrees is practised, thus helping to develop mathematical competences.

Many of us would think that all children like LEGO, but I was surprised to find that these disadvantaged children do not. The reason is that they do not have the skills, they don't have the dexterity, they do not have the creativity. In many cases, putting together a building block causes problems. This is why LEGO Spike is a great way to develop dexterity. It develops their dexterity and creativity when they have to build a tiny car, for example. Later, we bring this tiny car to life and program it. During the program, the different motor control operations, angles, occurrences and different conditions are displayed again. For example, if you show the car a green card, the colour sensor detects this and the robot starts and then drives until it detects a red colour. With this knowledge, children can easily program robots they have built themselves, such as a robot vacuum cleaner or a sumo robot, and the game Codycolor, which they know from the Internet, is repeatedly adapted to Spikes, which is always a great success and the children enjoy it, as well as the fact that their digital competence has been improved, along with their mathematical and other skills. In the case of the Spikes, it is definitely worth mentioning the development of foreign language competences, where the commands are available in English, but this only initially comes as a surprise to the children. They will soon realise that they have to match the different programming instructions in the same way as in the English programs used before. In this case, the pupils are working with English words,

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both wittingly and unwittingly, and building the program from English words, so they learn them by playing.

Table 1 illustrates how robotics education can help children to develop different skills that can be useful not only in science and technology, but also in other areas of life.

Skill	Area it develops
Critical thinking	Problem solving, logical thinking, analytical skills
Creativity	Innovation, idea generation, design skills
Programming skills	Knowledge of basic programming languages, algorithmic thinking, software development
Teamwork	Working together, communication skills, division of roles
Technical knowledge	Mechanical knowledge, electronics basics, engineering approach
Autonomy	Working independently, solving problems on your own, taking responsibility
Project management	Time management, planning, setting goals, prioritizing tasks
Mathematical skills	Calculations, measuring, geometry, data management
Patience and perseverance	Recognizing and correcting errors, following long-term projects, perseverance in overcoming difficulties
Communication	Technical writing, making presentations, clear expression of ideas and results

Table 1 Skill development with robotics

Source: edited by author

To investigate the effectiveness of the sessions (the research)

To find out whether the robotics sessions had a demonstrable impact, whether the students acquired useful knowledge, whether the knowledge acquired contributed to the development of any of their competences, the students completed an online quiz (questionnaire) with graphical elements on two occasions during the school year. This was part of the experiment, which I will describe below.

Methodology

To assess robotics knowledge, an online 10-question questionnaire was created in both semesters, which followed the lessons learned during the semester, closely related to the topic, but still playful and illustrated with pictures to make the children think. You can see some of these questions as you read further into the study. The quiz was created on quizziz.com. In addition, a 10-question questionnaire was used to ask the children if they liked going to classes, if they had learned anything they hadn't learned at school, and if they were learning English at school. The answers have been exported from quizziz.com to a spreadsheet and the statistical results can be found here. Descriptive statistics, namely means, modes and medians, were used to explore the relationships.

There were some factors that could not be clearly identified through the questionnaire, such as things related to children's behaviour, socialisation, or what and how they actually learn at school. These questions were answered by teachers who knew and taught the children, in order to get more accurate and objective results (qualitative).

The question given to the children was "Do you like to go to robotics class? It should be remembered that the aim of play sessions is learning and they are always held in the afternoon, after school, when most students are tired.

Results

Out of the 40 students who responded, only four said they didn't like it, while 36 students answered yes to the question, so 90% of students like robotics. When asked the question "Have you learned anything that you did not learn in school before?", without exception, all students answered yes, so in all cases the robotics sessions showed and taught something new to the participating students. Did they gain an understanding of concepts that they had previously struggled with at school, but which they successfully mastered during the robotics sessions? For example, they learned about the analogue clock. They got to know the clock and its hands by assigning angles to them, which they calculated using microbits. The students' deficiency was highlighted by the fact that they often asked what time it was because they had to catch the bus. This showed that they were not familiar with analogue clocks. So when they were asked if they had understood something during the sessions that they had not previously understood at school, thirty-two children said that yes, they had.

In addition to the general questions, they were also asked whether the children understood what they had learned in the session and how it related to their everyday knowledge at school, using the programs and programming languages they had learned. The figure below illustrates one of the tasks of the online quiz. The question was: Which block rotates the Lego robot?

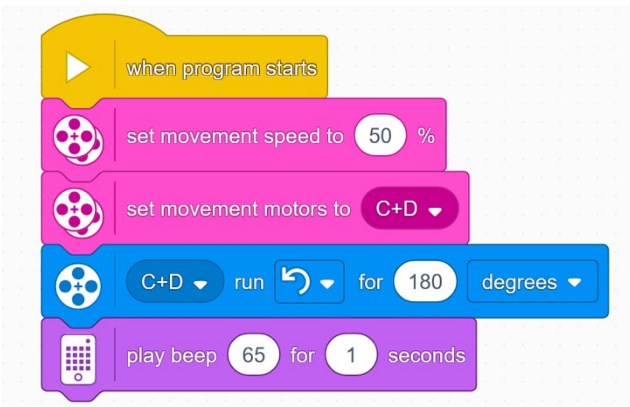

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Figure 2 The format of the question in the programme.

Source: own editing

Out of the 40 children who replied, 37 correctly answered that block 4 rotates the robot. It can be seen that not only knowledge of the program, but also basic foreign language vocabulary is needed to solve the task correctly. In this short block programme, degrees, percent and time are also shown as necessary knowledge. Similar playful questions helped me to get a relevant picture of whether the students had mastered all or part of what they had learned in the sessions, whether they understood it and could apply it correctly.

Some sample questions from the questionnaire are the following (Figures 3–5):

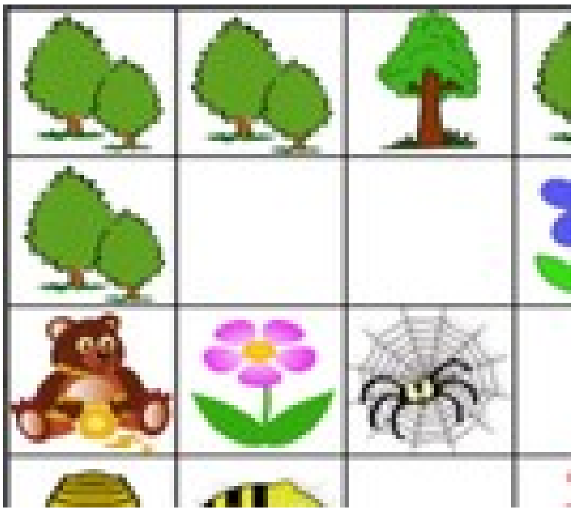
What animal does this robot imitate?

a. mouse
b. beetle
c. cat
d. bee

Figure 3 The format of the question in the programme.

Source: own editing

Where does the Bee-bot go when it receives these commands: forward, forward, left, forward, forward?



a. blue flower,
b. mushroom,
c. red flower,
d. spider

Figure 4 The format of the question in the programme.

Source: own editing

Is it true that a microbit can send information to another microbit even if they are not connected by a cable?

a. true
b. false

Figure 5 The format of the question in the programme.

Source: own editing

It may be fair to ask whether this knowledge was really acquired during the sessions or whether the children already knew it before? In this case, the testimonies of their teachers were taken into consideration, who stated that the children were almost without exception poor learners, with learning difficulties, and their knowledge was therefore very incomplete. The majority of the students did not have these basic competences. There are no robotics sessions in school, no robotics or programming in IT lessons, so the knowledge of programming languages, the commands learnt there and the correct linking with school knowledge are all the results of the robotics sessions. In several cases, teachers reported that students reported having acquired knowledge that they had not previously learned at school and explained that they had learned it in robotics lessons.

Conclusion

Based on the questions answered by the 40 students in the two locations, it is clear that the children like to attend robotics sessions, and they themselves appreciate, see and feel that they have gained new knowledge and understanding of school curricula that they could not learn at school before. The results of the questionnaires showed that children develop other competences in addition to programming. It can be seen that they are skillful at linking fractions with coding or, equally, that they can see through the coordinate system by means of a sequence of instructions. The surveys showed that children have become familiar with different IT tools. They are confident and aware of using different smart devices such as laptops, tablets, and smartphones.

In addition to quantitative research, it is important to mention what the teachers say, that the children are happy to come to the sessions, and that they themselves see and feel the benefits. So, the answer to the question of whether it makes sense to provide playful sessions with robots for disadvantaged children, many of whom have learning difficulties, to develop their digital competence and other basic skills, is yes, it makes sense, it is

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worthwhile, the children acquire usable knowledge during the sessions. As to the question of whether all this pays off - referring back to the introductory section where we said that knowledge generates a return - it is clear that these children are more likely to go on to further education, gain a profession, and find a place in the world of work with the knowledge they gain here. The income they earn supports their own families, and the taxes they pay on that income add to the national economy. One of the most effective ways of reducing poverty and alleviating many social tensions is to promote education among the most marginalised. Equitable education can contribute to a more economically advantaged, healthier, more democratic, more inclusive society with lower levels of social tension.

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