EXPERIENTIAL TEACHING AND LEARNING IN SCHOOLS APPLYING ROBOTS

Róbert Pántya – László F. Mucsics

Abstract

In the schooling system of the 21st century, there is a great need for new methods and tools that are capable of attracting and retaining the attention of students as digital natives, so experiential, experience-based teaching methods are particularly important.

The recent large-scale development of tools in many primary and secondary schools (mostly with the help of EU funding) has made available the educational robot kits that are essential for their everyday pedagogical use. Furthermore, besides the purchase and applications of robots, teacher training courses have helped to familiarise many teachers with these new tools and methods. The most important question for the successful implementation of new robot-supported methods is the extent to which the use of these modern pedagogical tools is embedded in the everyday practice of individual schools, and the extent to which teachers have the courage to actively involve these robots and, of course, the pupils in the educational process.

A good indicator of the successful use of robots in a school is the existence of a functioning robotics department and, unfortunately, inadequate practice can be indicated by the fact that these tools are kept in a locked, inaccessible cupboard, in such a way that pupils are often unaware of their existence.

Robot kits are an incredible motivator for learners, so our work is looking at how these tools can be used to make learning and teaching more fun for both learners and teachers.

This study will also show how a professional methodological support system and community can help teachers to use these modern 21st century teaching aids.

Keywords: *robotics, programming, experiential teaching and learning*
JEL: *C88, I20, O30*

Introduction

Recently, several projects and tenders have been implemented in Hungary to develop digital literacy, so many primary and secondary schools have had the opportunity to purchase educational robot kits, mainly Lego Education (WeDo, Spike, Mindstorms EV3). In addition to the purchase of equipment, teacher training programmes and courses were also launched to familiarise the devoted and curious teachers with the use and programming of these robot kits and the (supported) learning and teaching opportunities and environments combined with robotics.

Since we have more than 10 years of experience in leading robotics courses at all levels of the education system (Pántya–Mucsics, 2022a), and we have also produced several robotics tutorials (Mucsics–Pántya, 2014) and teaching aids (Kusper–Geda–Pántya, 2020), we have been involved in the realisation of such courses and the compilation of professional materials in the autumn of 2021. In cooperation with our colleagues from the teaching profession who participated in the courses, we implemented a number of very interesting ideas and projects.

In the following chapters, we will present in detail, through case studies, how these educational robot kits can be used in a way that makes participation in learning and teaching processes an experience for both students and teachers.

We will also discuss the professional methodological support system and community that helps teachers to use these educational robotic kits as 21st century teaching aids.

Application of robots in schools

The essential ingredients for successful use of robots in primary and secondary schools include:

1. the availability of robot kits,
2. the presence of innovative teachers,
3. the existence/operation of a robotics study club in the school.

The following chapters will elaborate on these essential components.

Robotic kits

In the 2000s, a growing number of educational robot kits were released by developers. They ranged from the simplest floor robots (e.g. BeeBot, BlueBot) to more advanced humanoid robots (e.g. Edbot), but one of the most popular product lines was the Mindstorms robot kits from the toy company Lego (NXT, Boost, EV3, etc.). These devices were acquired by the most innovative schools through various tenders or self-funding.

However, it is very important to have a sufficient number of robot kits available for educational use of robots in schools, rather than just one or two, usually of different types.

The real breakthrough in the mass availability of educational robot kits in schools was the EU Digital Literacy project (EFOP-3.2.4-16-2016-00001), which delivered nearly 16 000 Lego robot kits (mainly WeDo, Spike, Mindstorms EV3) and the same number of tablets to schools in the beneficiary municipalities in one of the sub-projects. These were mainly schools in disadvantaged areas that had not been able to purchase such kits on their own.

With this grant, we have been able to make a major contribution to equalising opportunities, so overall we can say that robot programming kits have become available in Hungarian public education. Of course, further expansion will still be needed in the future as new kits are developed, but the vast majority of kits for robot programming work are already available in schools.

Innovative educators

Without innovative, supportive teachers, the effective use of robotics in schools will not happen. The extent to which the use of robot kits is embedded in everyday practice in schools is a crucial issue. It is also important to what extent teachers have the courage to integrate these tools and their pupils into everyday teaching.

Some of the many questions that arise are highlighted below and will be addressed in the following chapters:

- How much energy and time should be invested in such projects and how can they be optimised in this fast-paced world?

- How can these tools be integrated not only in IT, but also in mathematics, physics, chemistry and biology, and even in history, Hungarian language and literature, foreign languages, music and singing, art and physical education?
- How can these robots be used to enrich old, well-established teaching methods, such as choosing the right one, practicing multiplication tables, or even questioning the acquired foreign words?

Robotics workshops, robotic study clubs

In addition to the components just described, it is also very important to have a format in the school that integrates robotics activities. This means preparing robots for lessons, preparing for and participating in competitions, organising and running workshops, demonstrations, etc.

This is typically a robotics workshop in each school. A good indicator of the successful and active use of robots in a school is the existence of a robotics workshop, and the absence of a workshop is usually an indicator of inadequate practice.

We suggest that it is definitely worth establishing a separate subject area in which these robot kits can be safely placed, and to choose a layout that can be visited very often, even on a daily basis, under the supervision of a suitable teacher.

Case studies

The following chapters present good practices that have been introduced to teachers in teacher training courses. What these robot projects have in common is that we have tried to make them as easy to use as possible for teachers who do not have a degree in computer science, so that they can be set up as simply as possible and the programming is not too complicated. The focus was therefore not on the complexity of the robots and the programs that run them, but rather on the pedagogical processes that we can support with these tools.

At the end of the course, the course participants were asked to produce their own projects, in which they were asked to demonstrate how they could use these educational robots in their own teaching activities. Many very good ideas were generated, and it was unambiguous that Hungarian teachers are very creative individuals and have implemented very interesting and innovative ideas. We believe that these good practices have justified both the very costly procurement of robots and the value of the course.

It is also important to point out that no prior programming or IT training is required for primary and secondary school students to understand and master successful robot projects. Thus, the assembly and programming of the robots presented can be a real experience for both students and teachers.

In the following chapters, the different robot arrangements will be presented in such a way that the basic idea (the construction of the robot and the operating program) will be presented first, followed by the possibilities that teachers can use to enhance their lessons with the robot.

The Wheel of Fortune

The first robot presented in the courses was always the Wheel of Fortune robot. This robot was used to select the participants for the course. The participants had to present themselves in the order in which the robot drew them. To make the robot, we used a pizza box with a paper disc cut out of the top. We divided it into as many coloured circles as there were participants in the course. We built the robot by driving a rotating shaft connected to a servo motor through the centre of this paper disc, and then attaching a pointer lever to it so that the motor could rotate it with different forces and therefore different degrees of rotation.

Figure 1 shows how we have fitted this mechanism to a Lego Mindstorms EV3 snake. The left image shows a pupil and the right image shows a multiplication table task selection. The infrared sensor representing the snake's eye (which can be used to detect various objects and measure distance) is also included in the layout, with the aim of triggering the draw, i.e. to start rotating the lever when an obstacle (e.g. the draw person's hand) is detected within 20 cm.

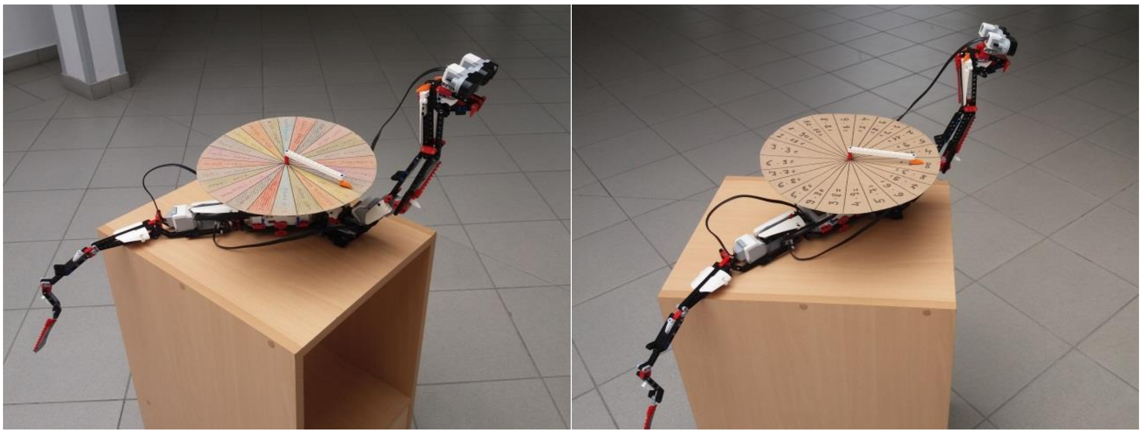

Figure 1. The Wheel of Fortune – draw with EV3 snake

Source: own construction

The program of the lottery robot written in LabView is shown in Figure 2. In an infinite loop, the program always waits for the signal from the infrared sensor connected to port 4 of the robot, which will let the program continue if the distance to the obstacle is less than 20 cm. The cube symbol in the red block represents the generation of a random value, which returns a random integer value between 720 degrees (2 rotations) and 1080 degrees (3 rotations). This value will be the number of degrees that the robot controller will drive the motor A and thus the robot arm. After rotating the arm, the program stops again, waiting for a new trigger signal (hand, obstacle).

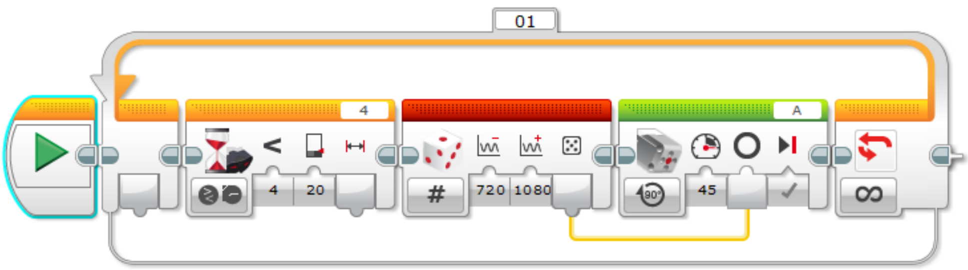

Figure 2. The programme of the Wheel of Fortune

Source: own construction

This robot layout proved to be very popular in the course, as best demonstrated by the fact that this basic idea had the most suggestions for use by the participating teachers.

The following is a list of ideas on how the teachers were able to incorporate this robotic device into their pedagogical processes.

The most obvious solution might be to select the responsible student using the basic idea. In this case, the wheel of fortune is divided into as many slices as there are pupils in the class and the pupils are drawn by lot to decide who will be in charge, who will be allowed to do what, etc.

What the following uses have in common is that we place a task from the given topic on each of the circular slices (some of them with stickers, some of them simply with paperclips) and the robot will randomly choose the task to be solved:

- mathematical use can be e.g.: practising the multiplication table or the multiplication table, calculating the results of operations (e.g.: 226 – 109 =) and then finding the neighbours of the numbers (ones, tens), practising Roman numerals, etc.
- in Hungarian language and literature, this arrangement can be used to find the word tree of a given word, to collect words with a related meaning to the given word, or even words with opposite meanings. It can also be used to practise the use of the letters *ly* and *j*, to collect words beginning with a given syllable by indicating and drawing lots for the given word-members. But you can also draw just one letter from the alphabet and play country-city-boy-girl games with the children.
- in a music lesson, it can help to decide which of the songs on the carousels to sing. You can also put different rhythms on the roundelays to choose what the children should clap along to.
- in a history lesson, different concepts or years can be asked randomly from the pupils in this way.

Another interesting use could be to work with two robotic arms. In this way, clock reading can be practised by randomly rotating the hour and minute.

In maths class, the types of angles (acute, right angles, obtuse angles) can be practised by having a fixed and another arm that moves randomly depending on the draw. The student's task is to decide what angle these two arms make with each other.

In a physics lesson, another interesting example is the uniform the study of uniform circular motion, angular rotation and circumferential velocity and circumferential angles.

And in geography, you can practise the cardinal points This can be done by labelling the paper disc with the compass points (N, NE, E, SE, S, SW, W, NW) and finding out which way the draw points after the robot arm.

The programming of Lego Mindstorms EV3 robots possesses very many and varied aids, e.g., (Kiss, 2014) and (Griffin, 2014), so programming of these sets.

Small car

In this section, we show a popular and very useful robot, a small car (Figure 3), which can be built very easily in 30 minutes or less using the WeDo kit. The car has a motion sensor on the front, which can be used to trigger the program.

This robot can be used for all the tasks described in the previous section on random selection of tasks, e.g.: in front of the small car robot shown in Figure 3, a sheet of paper is placed on which multiplication tables are printed. The tasks can be other mathematical operations, Roman numerals, but also English words, historical years and any other concept, besides the fact that with this tool it is easy to select the person in charge.

9 · 8 = ?	4 · 9 = ?	8 · 6 = ?	9 · 5 = ?	6 · 7 = ?	2 · 8 = ?	3 · 7 = ?	7 · 9 = ?	8 · 7 = ?	3 · 4 = ?

Figure 3. Small car robot
Source: own construction

The car program is shown in Figure 4, which can be created using the WeDo application. The control unit (hub) on the small car can be controlled via Bluetooth, e.g. by an application running on a tablet.

The principle of the program is similar to the Wheel of Fortune exercise. When the application is started, an infinite loop is entered, and the program will wait until the motion sensor signal is received. If you move your hand in front of the car so that it detects it, the program will continue. In this case, this means that a random amount of force generated by a random number (the first frame symbol and the green back-edge motor force symbol) in a given direction (to make the car move forward) will rotate the motor for a given amount of time (the amount of time indicated by the second frame symbol). This will cause the car to stop somewhere on the paper plate. The student has to answer the question indicated by the nose of the small car. After the car is back on the starting line, the car can start again, another question for another pupil.

Figure 4. Small car program
Source: own construction

This car can be used in physics lessons as well as for the above-mentioned purposes, for example to measure the distance travelled and the time elapsed, and it is very easy to measure speed.

But you can also set up an arrangement whereby objects/objects passing in front of the car's motion sensor can be counted by the car.

As we have seen above, the applications of this small car are also very wide. In our experience, teachers who have already actively integrated robotics into their pedagogical processes have always had this robot in their toolbox.

Other interesting Lego WeDo project ideas can be found in the work of Diego Galvez-Aranda and Mauricio Galvez Legua (Galvez-Aranda–Galvez Legua, 2021).

Dog robot

One of the most popular robots is the dog robot, which has been implemented on a wide variety of platforms and from a wide variety of robot kits in our more than 10 years of experience (Pántya–Mucsics, 2022b).

A Lego Spike version of the dog robot is illustrated in Figure 5. A great favourite of many robot demonstrators, this robot is equipped with eyes (an ultrasonic sensor for obstacle and distance detection), a nose (a push-button sensor) and a colour sensor between the large wheels representing the front legs, directed downwards.

This robot can be trained for a multitude of tasks and "missions". From these, we highlight two projects and thus two different groups of possible uses.

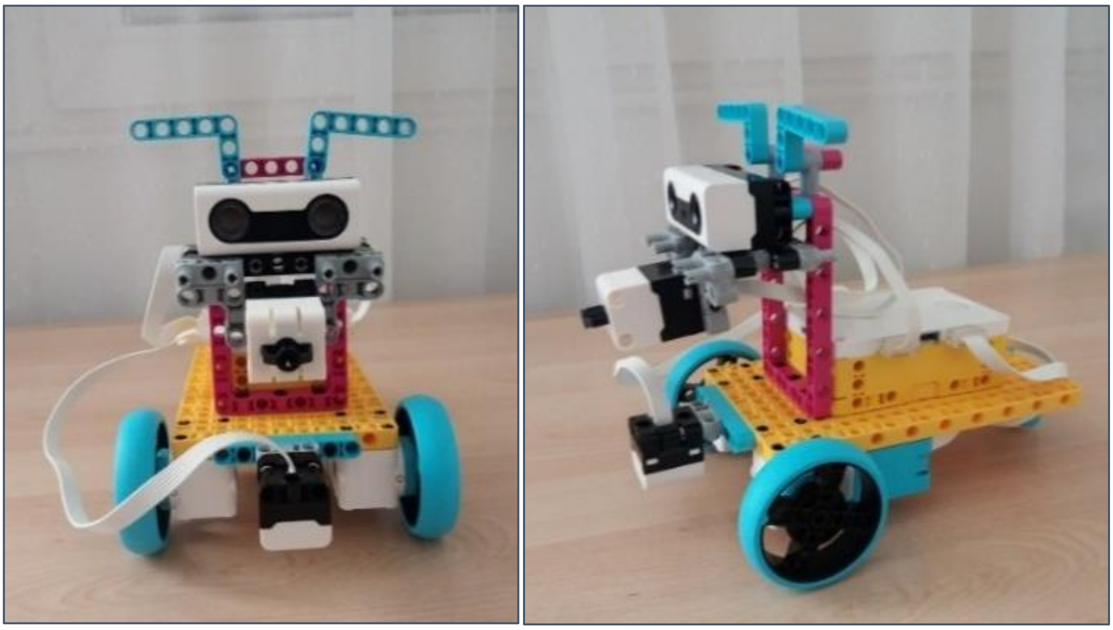

Figure 5. Dog robot

Source: own construction

The yellow control unit (hub), which represents the dog's body, can now operate independently, without the need for a permanent connection to a computer. This small control unit now has a display and a speaker, so you can multiply your options. Figure 6 shows a program for a musical dog created using the Lego Spike app. The pre-loaded music track is the well-known children's song "Boci boci tarka ...".

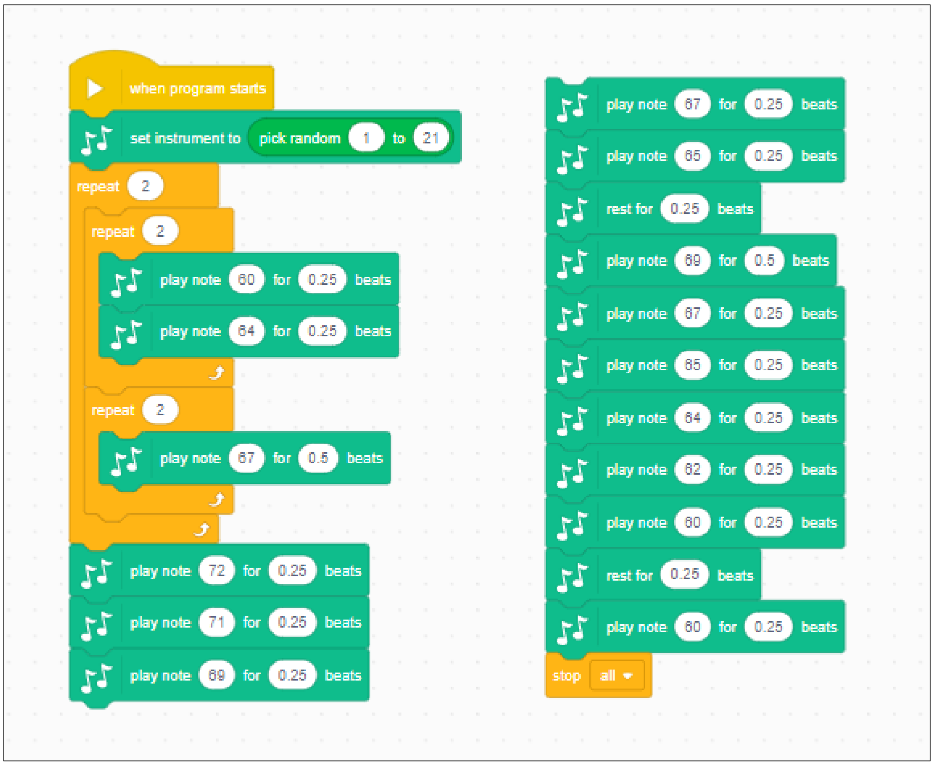

Figure 6. Musical dog robot program
Source: own construction

At the start of the program, a random number generator is used to choose an instrument from a possible 21 (ranging from piano including cello to saxophone). The different notes chosen (Note 60 is the note C, Note 62 is the note D, Note 64 is the note E, etc.) are then played for different durations (0.25 beats, 0.5 beats), depending on the beat to be played. The repeat command allows us to repeat the playback of certain notes, while the rest command makes us wait for the music to play for a certain time (pause signal).

We can also create our own sound files and texts, which can be used for the following purposes:

– in Hungarian language and literature lessons, this layout can be used for pen recitation. We can record texts and words of different spelling difficulties using a voice recorder and then use the robot to sentence them so that the pupils can write them down.
– in foreign language lessons, the robot can also be used to practise other new words, for example, or to describe colours and numbers by ear.
– in a singing music lesson can help you to learn different instruments, recognise and repeat rhythms, and of course other songs. By using several robot kits, you can even create and program a pop-rock band for your students' enjoyment.

We can connect the three different sensors mentioned above to your built dog robot as follows: the ultrasonic sensor on port A represents the eyes, the force (or more simply push-button) sensor on port B represents the nose, and the colour sensor on port E is located between the front legs at the bottom. These can be used to solve very interesting tasks with this robot. Figure 7 shows a roaming dog program, also created using the Lego Spike app.

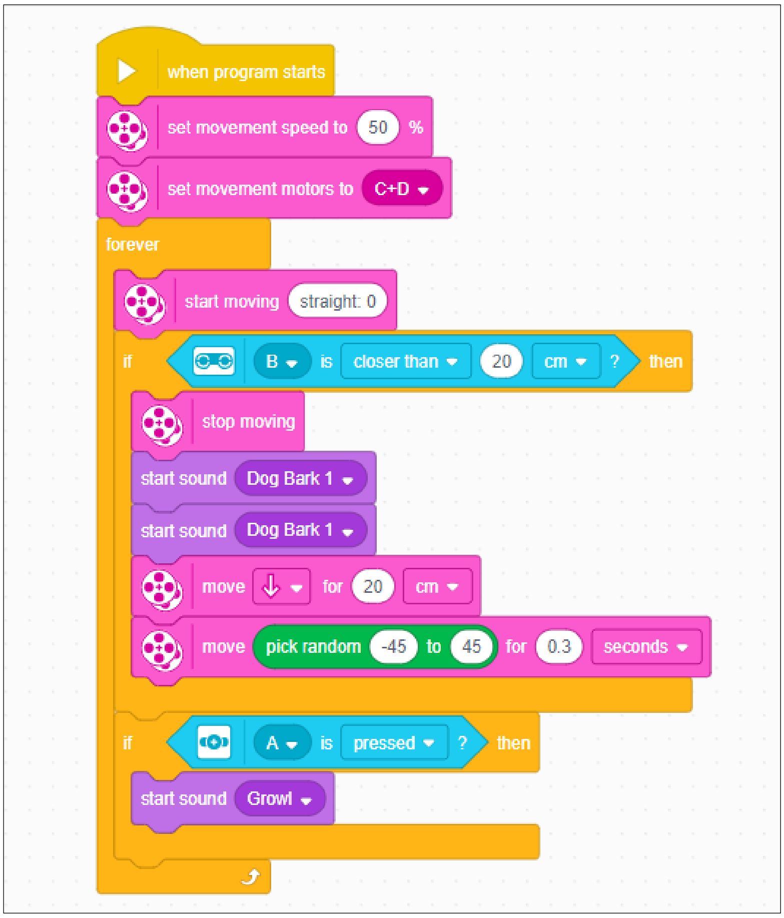

Figure 7. Roaming robot dog program

Source: own construction

The dog moves forward at a given speed (driven by motors connected to ports C and D). If its ultrasonic sensor detects (on port B) that there is an object within 20 cm, it barks twice, then after a small 20 cm shift, it randomly turns either to the right or to the left, with some degree of angular rotation (between -45 and +45 degrees), determined by a random number generator. It then continues to move in a straight line. If its nose is pressed by someone or something (the sensor detects pressure on port A), it will growl until it is released.

This robot can be used in the following ways for different subjects:

– in biology lessons to talk about animals that are oriented by ultrasound (bat, dolphin),
– in a technology lesson to demonstrate the radar of a reversing car (ultrasonic sensor),
– in physics, to demonstrate force - counterforce with the force sensor (push button).

The robot also has a colour sensor, so it can be used:

– in chemistry class to sort different coloured waste (selective waste collection).
– In science class, to sort ripe (red or blue) or unripe (green) fruits.
– in art class, to recognise the different colours and
– like the following robot: tracing a path.

Further interesting project ideas can also be found for Lego Spike kits (Dwivedi et al. 2022) and the very similar Lego Robot Inventor kits (Isogawa, 2021), which are mainly designed for individual projects.

Path finding robots

The easiest way to study the use of the robots' colour sensor is to use the tracking robots. Figure 8 shows a Lego Mindstorms NXT 2.0 robot at a Night of Museums event. In the museum lobby, it was able to follow a path marked with a dark-coloured stripe throughout the evening, much to the delight of visitors.

Figure 8. Path-finding robot at Night of the Museums
Source: own construction

The picture also shows how the members of the folkdance group that performed during the evening spontaneously joined in the game. This illustrates the very powerful motivational role of robots and thus of robot programming.

Figure 9 shows the program created in LabView, where a bifurcation is placed in an infinite loop. If the sensor of the colour sensor connected to port 1 detects a dark (black/dark blue/brown) colour, the robot turns a little to the right, otherwise a little to the left. Since a thin (about 2 cm) dark strip forms the path, the robot moves left and right with a wobbling motion, which results in it always pushing itself a little bit forward. Properly adjusted, this motion will cause the robot to move along the dark strip.

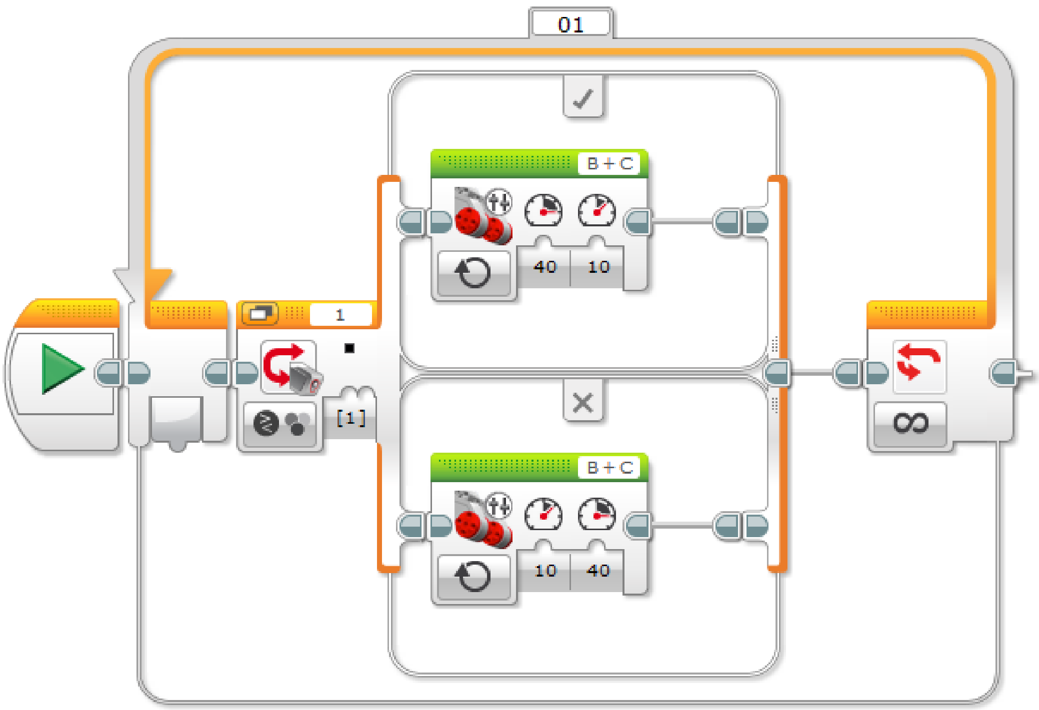

Figure 9. Path-finding robot program

Source: own construction

Of course, this robot can also be upgraded, for example, to stop on a red light, prepare to move on a yellow light and start on a green light. This can be easily achieved by connecting another colour sensor and arranging it in the right way (so that it looks ahead). An additional task could be to make the robot avoid an obstacle, for example, if there are different obstacles. For this purpose, an ultrasonic sensor can be inserted in the solution.

More tasks and interesting project ideas can be found in (Kiss, 2016).

Further ideas

A great help for teachers is the support page, which helps them to implement new ideas.

This professional methodological support system and community helps teachers to use modern, 21st century teaching tools.

Figure 10 shows a tutorial for making a dancing robot, a break dancer, from the Lego Education portal. This robot is great to use in e.g. physical education lessons, where children follow the programmed movements of the robot. But they can also dance with it at a music and dance party, and it can also emit different coloured lights to set the mood for a dance afternoon or evening.

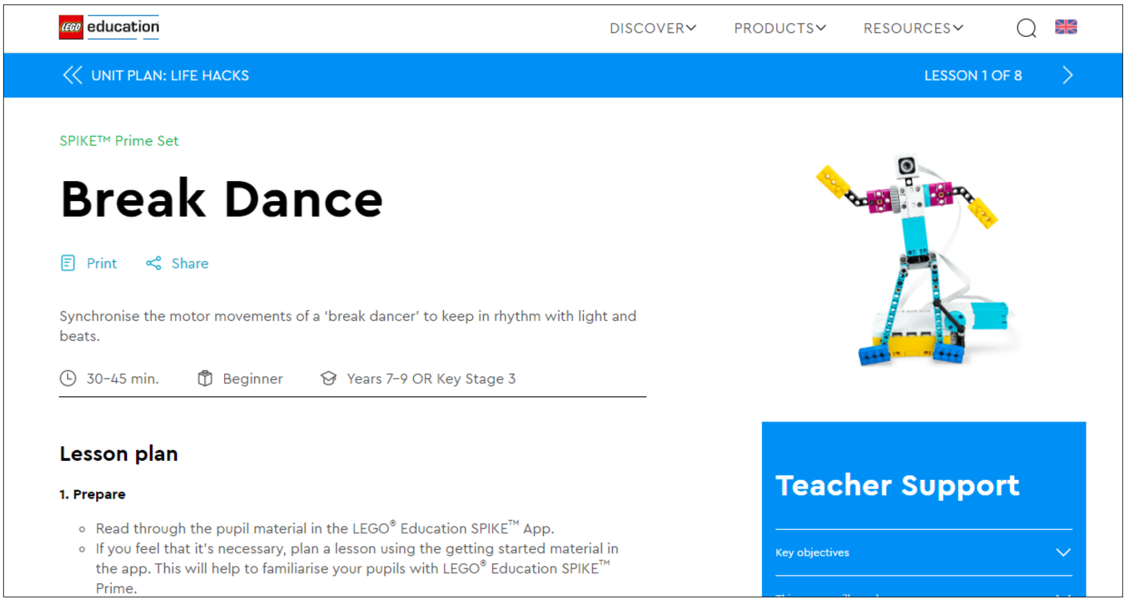

Figure 10. Dancing/Doing Gymnastics robot

Source: [*https://education.lego.com/en-us/lessons/prime-life-hacks/break-dance*](https://education.lego.com/en-us/lessons/prime-life-hacks/break-dance)

A very useful tool is the portal of the Digital Pedagogical Methodology Centre (Figure 11), which, in addition to its digital pedagogical knowledge base, also contains a wealth of ideas for digital theme weeks in schools, for example.

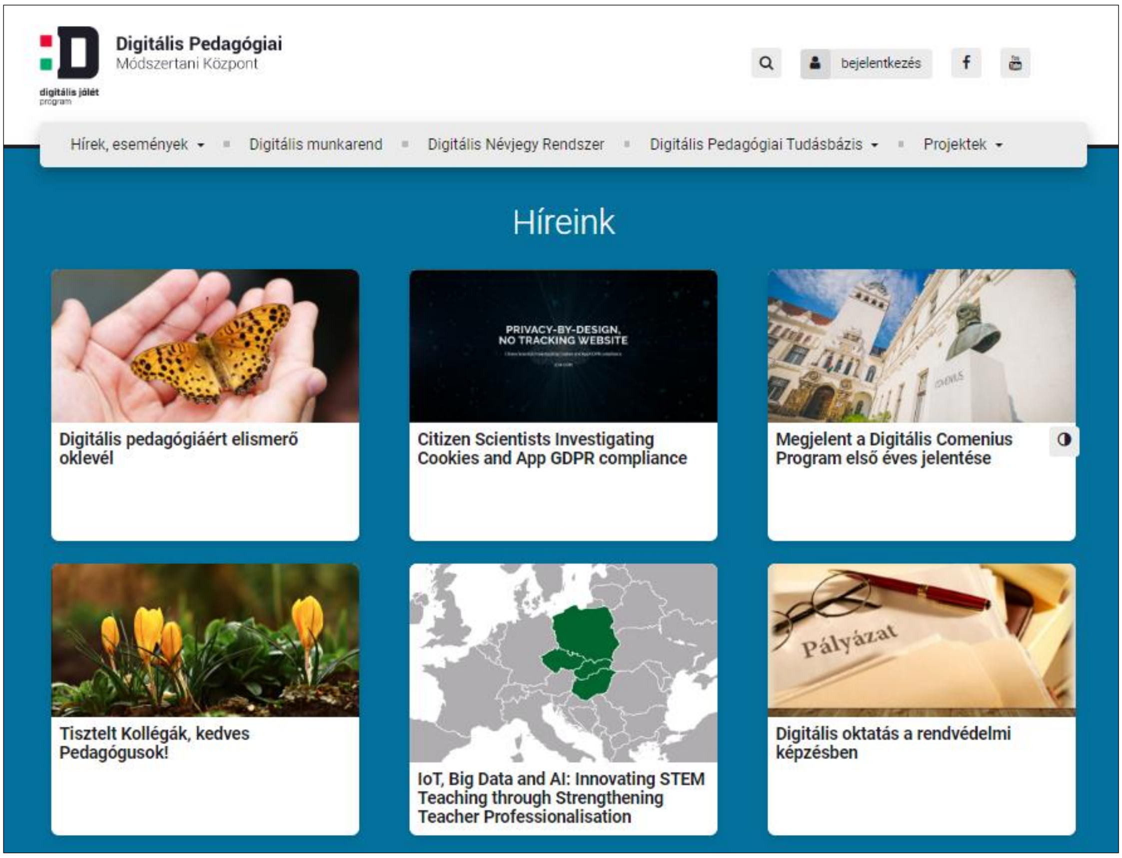

Figure 11. The website of Digital Pedagogy Methodology Centre

Source: [*https://dpmk.hu*](https://dpmk.hu)

Conclusions

In conclusion, the availability of robot kits, the presence of innovative teachers and the existence of a robotics club in primary and secondary schools, preferably in a separate classroom, are essential ingredients for the successful use of robots in schools.

As a result of the developments in Hungarian schools over the last decade, educational robot kits are now available, the presence of which is essential for the success of new, innovative methods.

Organised teacher training courses on robot programming have been a real help to many teacher colleagues in learning about these tools, and there are still many courses available for enterprising teachers (https://tanfolyam.uni-eszterhazy.hu). In addition, it can be concluded that Hungarian teachers are very innovative, regardless of their profession, age or place of residence, and are therefore fully capable of using robots in their everyday pedagogical work.

Among the many good practices and case studies presented in the courses, the arrangements that were most popular and that teachers can continue to rely on in the future were highlighted and will always have a very positive impact on the groups of learners. Such arrangements were the selection of the responsible one using the random number generator with the wheel of fortune or the small car robot, and the selection of a random task with the same robots. The dog that can play music with different instruments, different songs, the dancing robot that we can move with, will always motivate the children, whatever their age. And robots with different sensors (small cars, trackers, dogs, etc.) will always have enough excitement to keep children occupied, even in the highly stimulating world we live in.

It is particularly gratifying that the pedagogical use of these new tools is supported by an established pe-educator support system, both from Lego Education and from the Hungarian education authorities, which provides a good support to actively promote the implementation of experiential teaching and learning with robots in schools.

References

Digitális kompetencia fejlesztése: EFOP-3.2.4-16-2016-00001. Download date: 04/04/2024. source: URL: https://kk.gov.hu/digitalis-kompetencia-fejlesztese

Digitális Pedagógiai Módszertani Központ. Download date: 04/04/2024. source: URL: https://dpmk.hu

Dwivedi, R. – Dwivedi, I. – Dwivedi, B. (2022): The LEGO Spike Prime Discovery Book: Mechanisms, Robot Architecture, Design, Programming and Game Strategies for FLL, WRL and WRO

Eszterházy Károly Katolikus Egyetem, Pedagógus továbbképzési portál. Download date: 04/01/2021. source: URL: https://tanfolyam.uni-eszterhazy.hu/

Galvez-Aranda, D. – Galvez Legua, M. (2021): Robotics Models Using LEGO WeDo 2.0: Design, Build, Program, Test, Document and Share

Griffin, T. (2014): The Art of LEGO MINDSTORMS EV3 Programming

Isogawa, Y. (2021): The LEGO MINDSTORMS Robot Inventor Idea Book

Kiss, R. (2014): A Mindstorms EV3 programozásának alapjai, H-Didakt Kft, Budapest

Kiss, R. (2016): ROBOTIKA FELADATGYŰJTEMÉNY, 111 feladat LEGO® MINDSTORMS® EV3 és NXT robotokhoz, H-Didakt Kft, Budapest

Kusper, G. – Geda, G. – Pántya, R. (2020): LEGO robotokkal támogatott programozás, Eszterházy Károly Egyetem, Eger, egyetemi jegyzet

LEGO Education, Get ready with Lessons. Download date: 04/04/2024. source: URL: https://education.lego.com/en-us/lessons

Mucsics, F. L. – Pántya, R. (2014): Rubik Robot at KRF In: WPCF 2014. Konferencia helye, ideje: Gyöngyös, Magyarország, 2014.08.25-2014.08.29. Paper n.t.

Pántya, R. – Mucsics, F. L. (2022): 10 éves a Robotika szakkör a Gyöngyösi Károly Róbert Campuson, In: Bujdosó, Zoltán (szerk.) XVIII. Nemzetközi Tudományos Napok [18th International Scientific Days] : A „Zöld Megállapodás" – Kihívások és lehetőségek [The 'Green Deal' – Challenges and Opportunities] : Tanulmányok [Publikcations]., Gyöngyös, Magyarország : Magyar Agrár- és Élettudományi Egyetem Károly Róbert Campus pp. 483-489. , 7 p.

Pántya, R. – Mucsics, F. L. (2022): Robotkutya építése és programozása Arduino platformon, In: Bujdosó, Zoltán (szerk.) XVIII. Nemzetközi Tudományos Napok [18th International Scientific Days] : A „Zöld Megállapodás" – Kihívások és lehetőségek [The 'Green Deal' – Challenges and Opportunities] : Tanulmányok [Publications]., Gyöngyös, Magyarország : Magyar Agrár- és Élettudományi Egyetem Károly Róbert Campus pp. 490-496. , 7 p.

Authors

Róbert Pántya
ORCID: 0009-0009-6325-1660
PhD
senior lecturer
Department of Methodology for Business Analysis, Faculty of Commerce, Hospitality and Tourism, Budapest Business University
pantya.robert@uni-bge.hu

László Mucsics F.
ORCID: 0009-0007-3855-1886
lecturer
Department of Mathematics and Modelling, Institute of Mathematics and Basic Sciences, Hungarian University of Agriculture and Life Sciences
mucsics.fulop.laszlo@uni-mate.hu