EXPLORING ENGINEERING SKILLS WHEN WORKING WITH LEGO ROBOTS

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ИЗСЛЕДВАНЕ НА ИНЖЕНЕРНИ УМЕНИЯ ПРИ РАБОТА С LEGO РОБОТИ

Abstract

Results of short training sessions conducted in August 2023 on building robots with the LEGO Spike Prime Set are presented. Participants of different age, gender and professional field took part in them. During the STEM session, the trainees went through an engineering cycle - planning, constructing, programming, testing, debugging. The participants' work steps and some problems they encountered are described. The results of the interviews conducted before and after constructing and programming regarding their knowledge, skills and attitudes towards working with robotic systems are analyzed. Such short trainings are suitable for technical inclusion, through practical application of basic principles of mechatronics and programming to people without technical training.

Keywords: *STEM; LEGO; Robotic Systems; Engeneering; Programming; Short Training; Key Competence.*

INTRODUCTION

The rapid pace of technological development in modern society requires a wide range of digital and technical competences. For people without the necessary training it is difficult to adapt to the world of robotic systems that surround us both in everyday life and in work processes [1], [2], [3]. To create conditions for the development of STEM knowledge, and more specifically engineering skills, it is appropriate to organize short trainings with robotic systems that allow a quick feedback [4], [5]. For example, working with robots that require pre-construction allows students to go through an engineering cycle – planning, construction, programming, testing, debugging [6], [7], [8], [9]. The various ready-made model schemes offered by the manufacturer LEGO include variants of real technical devices used in modern society. This allows to give a concrete example of the applications of robotic systems and how they help to solve problems in a person's everyday life.

Here we will present some results of short trainings on constructing LEGO robots with people of different ages, genders and professional field. The aim is to explore the process of technical inclusion through practical application of basic principles of mechatronics and programming, and to compare the results of the participants.

ABOUT THE SHORT TRAINING

In August 2023 several short training sessions were held during which each participant had the opportunity to create a model of a LEGO robot. The LEGO Spike Prime Set was used. The set includes 528 colored parts (including light matrix, motor, color sensor, distance sensor, force sensor, gyro sensor), ready-made software with block programming, based on

Scratch, and Python coding capability [10]. The components are simplified, but close to those actually used in robotics and allow the accumulation of knowledge through practical problem solving. Each participant chose one model to assemble from the ready-made resources available at: https://spike.legoeducation.com/#/prime/models/ (last view: 01-08-2025). Everyone worked independently, under the supervision of a trainer in the field, without being informed about the choice of the other participants in the experiment. The following individuals participated in the study:

- A) 27-year-old woman with a Master degree in Arts who works in the same field;
- B) 56-year-old man with a secondary school degree who works as a security guard;
- C) 54-year-old woman with a Bachelor degree in Public administration who works in the same field;
- D) 12-year-old female student in a general education class;
- E) 12-year-old male student in a specialized class "Robotics and Virtual Design";
- F) 56-year-old man with a secondary school degree in Electrical engineering, who works in the same field.

INTERVIEW WITH PARTICIPANTS BEFORE THE TRAINING

At the beginning of each training, an interview was conducted with the participants regarding their knowledge, skills and attitudes towards robotic systems, including the following questions:

- Have you worked with LEGO before?

Answer A) "Yes. I have a friend who builds many objects with Lego. He showed me the ready-made schemes for assembling small and large objects, names of specific elements - double, triple, corner, etc."

Answer B) "No."

Answer C) "No."

Answer D) "No."

Answer E) "Yes. I have made towers, cars, a helicopter; I have also had children's Lego since I was little."

Answer F) "No."

- Have you ever worked with robots?

Answer A) "Yes."

Answer B) "No."

Answer C) "No."

Answer D) "No."

Answer E) "Yes, at school. I made one robot, which can follow lines, another had some kind of sensor and tweezers that it could grab. We also worked with a few applications that could express emotions."

Answer F) "No."

- If you had a robot, what would you want it to do?

Answer A) "Prepare some type of food, a cooking robot, make pancakes in the morning."

Answer B) "I would like a kitchen robot – to be able to wash dishes, cook."

Answer C) "Instead of me? - To clean windows, although similar ones already exist. Maybe to mow the lawn to relieve me."

Answer D) "To help me with my homework, to do the housework."

Answer E) "To write my homework."

Answer F) "To help with the housework."

- If you had a drone, what would you want it to do?

Answer A) "To carry food. I own a drone, but it can't carry food."

Answer B) "I would use it for observation; to look at interesting objects – out of curiosity."

Answer C) "I would use it not so much to see from above, but purely for information purposes, to take pictures of objects or landmarks, places that I like and haven't seen."

Answer D) "To see and film beautiful views."

Answer E) "I don't know. I had a drone. I got one small, for kids use, as a gift a few years ago. It used to crash very often."

Answer F) "To look at things that can't be seen from the ground and to go to inaccessible places."

- What do you think will be difficult for you today?

Answer A) "The electronics part. At school, I was never able to turn on my light during science and technology classes. But I guess it will be well explained here. I'm not into fidgety/ tinkering activities in general, so I prefer to have a scheme that I can follow."

Answer B) "I don't know, I'm about to find out now."

Answer C) "I can't guess, I've never dealt with such things before."

Answer D) "I don't know."

Answer E) "I have to be careful with the parts and where they are so I don't have to go back, which is very annoying. Once I almost had to start from the beginning."

Answer F) "I don't think anything will be difficult for me."

BUILDING LEGO MODELS

After a brief discussion on key terms and current issues in working with robotic systems, each participant reviewed the finished models from the "Build" section at https://spike.legoeducation.com/#/prime/models/ (last view: 01-08-2025). All participants made their choice based on the image of the models, except for participant E), who opened the scheme with the instructions for 3 models before making a decision. The models that the participants chose are (Fig. 1):

- A): Break Dancer (Legs + Body), requiring 33 steps for assembly;
- B): Robot Hand, requiring 28 steps for assembly;
- C): Break Dancer (Legs + Body), requiring 33 steps for assembly;
- D): Break Dancer (Legs + Body), requiring 33 steps for assembly;
- E): Super-Safe-Deposit Box (Box + Door and arm), requiring 83 steps for assembly;
- F): Rhino (Body +Head), requiring 27 steps to assemble.

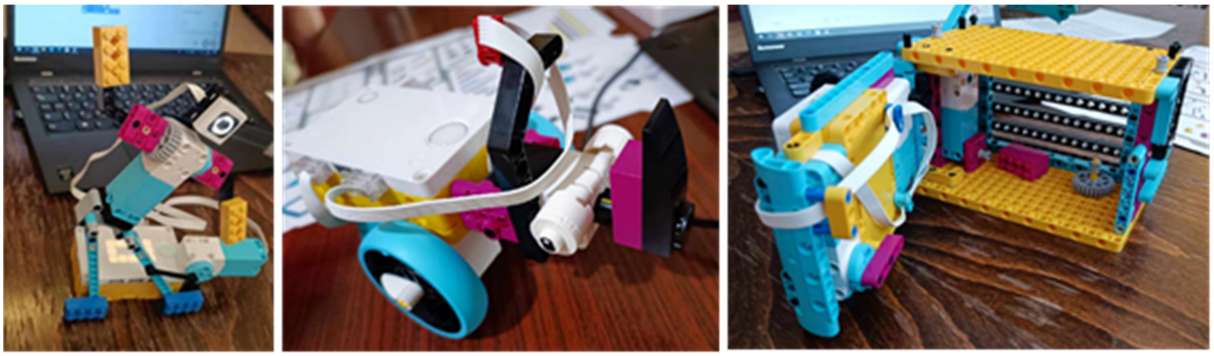

Fig. 1. Some models of participants (from left to right - Break Dancer, Rhino, Super-Safe-Deposit Box)

All participants had difficulty recognizing the required bolt due to their small size in the diagrams. Fig. 2 shows connecting elements included in the used set. In the work stage, the participants found that the colors of the schemes from the site match the physical Lego parts themselves. They expressed a positive assessment of this division and how much difficult it would be for them if the parts were only in one color.

Fig. 2. Connecting elements in the LEGO Spike Prime set

All participants were shown the option to enlarge the image in the lower left corner of the screen. The trainer repeatedly reminded all participants of this help during the work stage.

A common error was observed when placing an element of the type shown in Fig. 3.

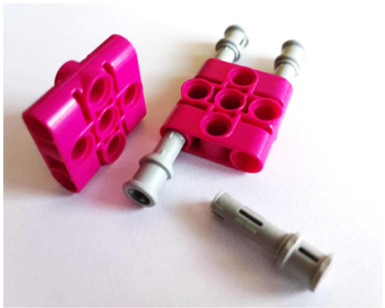

Fig. 3. Item most commonly misplaced at 900 angle

During the work with the models, two parts stood out, which were particularly difficult to be separated. During the work stage, the participants came up with an option for separating them by pushing from the other end (Fig. 4).

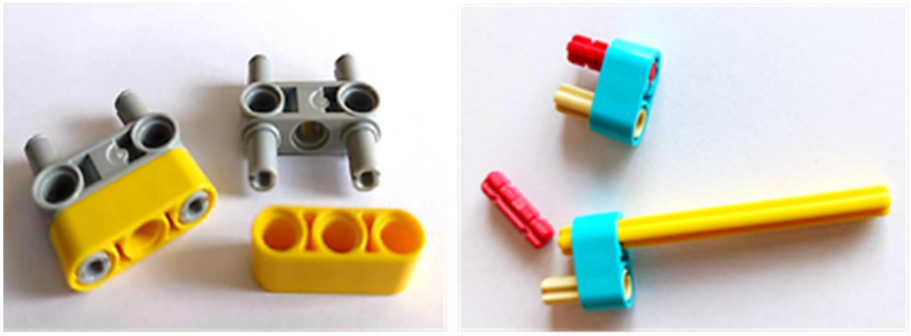

Fig. 4. Lego parts dofficult to disassemble and a way to separate them by pushing

In half of the cases, the incorrect positioning of such elements posed a problem for the entire model and the participant would have difficulty discovering his mistake later. Wrong direction of an element also proved to be important in the placement of the motors. For proper start-up, the drive motor must be in the zero position relative to the tire (Fig. 5). Only participants E) and F) noticed these instructions on the scheme and followed them without being directed or reminded.

Fig. 5. Positioning motors in start mode

Some of the models involved assembling two repeating elements (two wheels, two arms, two walls). All participants expressed dissatisfaction that they had already done this part of the model in previous steps. They shared that it was more convenient to have "x2" indicated on the model and to assemble two similar elements at the same time.

After completing the model, each participant estimated how long it took them to complete the entire construction. The time recorded by the trainer and the estimated time by the participant are shown in Table 1.

Table 1. Time for assembling models by participants

Participant	Time recorded by trainer	Guessed time by participant
A)	"Legs" – 22 min.; "Body" – 16 min.	50 min.
B)	37 min.	33 - 35 min.
C)	"Legs" – 29 min.; "Body" – 32 min.	60 min.
D)	"Legs" – 20 min.; "Body" – 22 min.	50 - 60 min.
E)	"Box" – 25 min.; "Door and arm" - 45 min.	40 min.
F)	"Body" – 11 min.; "Head" – 16 min.	15 - 20 min.

Participants E) and F), who had previous experience in construction, based on education and practical experience, indicated less time to create their model than the actual one.

PROGRAMING THE LEGO MODELS

Only participant E) had experience from school with turning on and connecting a robot to a computer application. On average, the participants programmed for 20-30 minutes, testing all the sensors and motors included in their model. For example, each of them freely made several figures using the "Light Matrix" (Fig. 6). All participants made the first letter of their name (their initial), as well as at least one other free figure, which was always symmetrical.

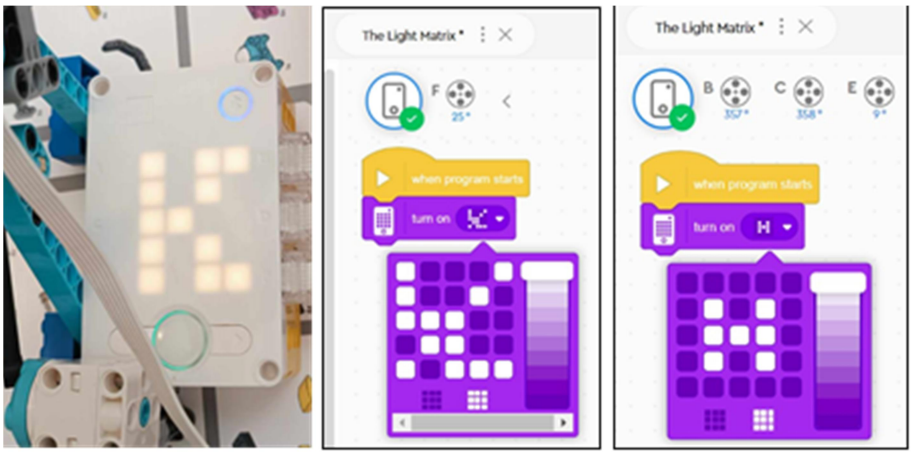

Fig. 6. Author's figures using "Light Matrix". From left to right - participants A), B) and E)

The participants chose to set a different number of commands and speed of movement through block programming. They followed different logic in driving the arms, legs, wheels, etc. Some variants are shown in Fig. 7.

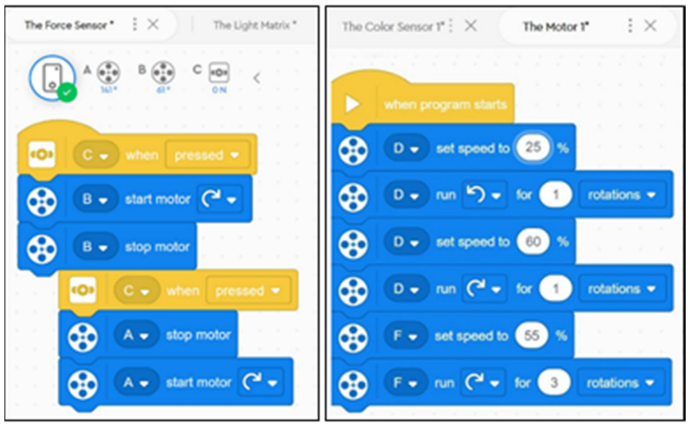

Fig. 7. Some commands for movement of participants

At the end of the short training, the participants were asked the following questions:

- What was difficult for you today? (for comparison with the pre-launch interview)

Answer A) "I couldn't see some of the small elements well, but as zoom-in, I could see them better. Maybe it would be better on an even bigger screen or even if it was projected. I didn't have any difficulty assembling them, but as I went on to the next steps, I could immediately see where I made mistake."

Answer B) "When I made mistakes and you had to show me how to put them in."

Answer C) "You have to focus before you start, to aim at the parts and their exact location, so you don't have to go back and redo them often, as I had to."

Answer D) "Maybe while I was making the hands, because they were the same, but I didn't realize that I had to mirror them and I had to start one from the beginning."

Answer E) "When I had to put the little parts in. I had to put a lot of the little black screws in a lot of places. My fingers were hurting at one point."

Answer F) "Nothing."

- Who would you recommend to take the training?

Answer A) "Maybe my cousin, who is a student and is in such a class. He will probably do much better than me."

Answer B) "I was very worried while working and programming, because it was my first time doing it and it was very stressful. I don't know who to recommend it to, but anyone who hasn't done it before will definitely have a hard time."

Answer C) "I would recommend it to my daughter's classmates and friends. They haven't worked with such things at school, but I think they will find it very interesting. From the schemes I chose, there were models for both boys and girls."

Answer D) "I would recommend it to my friends and teachers at school. Especially to those who teach "Technology and Entrepreneurship" and "Information Technology" – we haven't done anything like that in these classes."

Answer E) "To everyone. Only the first time is difficult."

Answer F) "To anyone who has the desire and the financial means."

DISCUSSION

During the work of participant E), the experience from previous work with robots at school was evident - he checked whether the parts were fully inserted and inspected the entire model to see if there was any displacement after the next added part. Only he reviewed all the steps of the instructions form the scheme on the site before choosing a model to assemble. All participants made a mistake at least once and used the help sheet describing the number and location of parts in the Lego set. Only participant C) wanted to disassemble the created model after programming it in order to go through this step.

The Lego online platform with ready-made models, including the construction steps, has a light and accessible interface, with which all participants worked quickly and intuitively. We note that the small size of some elements and the need to constantly increase the screen size is a demotivating factor that was indicated by the participants. They gave a positive assessment of the color separation of elements, both in the online platform and for the physical components.

CONCLUSION

Working with Lego robots does not require prior technical knowledge and skills.

Previous experience working with robotic systems is evident in two of the participants – the student in a specialized class "Robotics and Virtual Design" and the worker with technical education - specialty "Electrical Engineering". The participants who were constructing robots for the first time made similar errors– incorrect location of an element (component rotated on 900 and/or placing a connecting element in an adjacent hole); incorrect construction of mirror elements (two arms, two legs, two walls). Of great interest to the trainees were the available sensors, especially the "Light Matrix". With its help, they created numerous pictures, and everyone depicted their initial and a symmetrical figure at least once.

When constructing using the components from the Lego Spike Prime Set, engineering knowledge and skills are naturally accumulated. Going through the entire process of choosing

a model, constructing it, programming, testing, allows the user to experience an engineering cycle at their own pace. The presence of intermediate errors in the stages of construction helps learners build key skills - observation, critical thinking, self-organization, teamwork, adaptability, etc.

The next step when working with a LEGO educational set or other robotic systems that allow free construction is to create an authors' own models.

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