Educational resource of studying Robotics in STEM learning system as a factor in mastering student engineering and creative skills

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Abstract. The aim of the study is to find out the educational potential of studying Robotics in STEM educational system as a factor in mastering learners’ engineering and creative skills. For the pedagogical experiment, the authors arranged the control and experimental groups of children at the age of 9 to 12 years old (30 people each) in the 2019/2020 academic year. The study included testing, evaluating intelligent background criteria, and a survey among learners and educators. It resulted in the conclusions made. Robotics is a key activity in developing engineering thinking. The technique used for conducting classes in learning Robotics consists of the following components: initiating relationships, design engineering, reflection / after-action review, and development. STEM education can be based on LEGO constructing. LEGO constructing academic studies are focused on the development of verbal, creative, and engineering skills. An instructor can introduce some software to learners that allow them to design constructions and models using the tools of manual and computer-assisted three-dimensional constructional LEGO Digital Designer. This part of the course is aimed at developing general learning skills. Further development of engineering design is connected with the Arduino microprocessor control unit. It targets schoolchildren well for their study. They can launch small electronic projects. Students can master programming skills through ‘learning by doing’, as well as learn the basics of circuit technology using this platform.

1. Introduction
A special trend in the development of present-day education is action research of new approaches and methods that allow integrating elements of Engineering and Technology and Information Technology education for teaching learners. The general involvement of children in studying and applied mastering of the basics of Engineering specialities were the beginning of their common incorporation according to federal and regional syllabi being developed.

There is a notion STEM learning emerged. It is an innovative technology that implies the introduction of scientific, technical, and practice-centered components in education. In this regard, the term STEM
refers to a methodology in the field of education and curriculum selection in schools. The aim of it is to improve competitiveness applicable to science and technology development. It is the idea of teaching four particular subjects (Science, Technology, Engineering, and Mathematics) using a transdisciplinary and applied approach.

The issues of using Educational Robotics in motivating students to be endowed in STEM education, regardless of gender, from a young age, through training and competitions within regular and extracurricular activities, Robotics clubs and camps are dynamically explored [1, 2, 3]. Many researchers make good use of Educational Robotics to master children’s skills [4, 5, 6]. In this regard, the potential contribution to promoting Robotics as an educational tool in schools is studied in the works [7, 8], and future research prospects related to Educational Robotics are determined in the work [9].

The research aims at examining the educational opportunities of studying Robotics in STEM learning system as a factor in mastering student engineering and creative skills.

2. Methods

The foundation of STEM education is the fulfilment of the system-wide action approach, student independent research in project/design modelling activities. A person needs to accumulate knowledge from several fields of scholarly beliefs when it is required to solve a working or household problem. The students apply their proficiency from various fields in STEM: Mathematics, Engineering, Physics, IT, and Natural Science to solve operating objectives [10, 11].

The hardware used for teaching children Robotics at schools combines suits with Arduino intelligent microcontroller, Lego Mindstorm and Vex IQ. When students work with physical patterns, there may be some difficulty because of a few classroom hours, a lack of the required tools in the classroom, or narrow resources. Then, it is possible to replace them with simulators that can perform tasks as real physical robots in a similar way for familiar programming environments.

For the pedagogical experiment on Educational Robotics, the authors arranged the control and experimental groups of schoolchildren at the age of 9 to 12 years old (30 people each). They were engaged in comprehensive school clubs, in gymnasium No. 1 in the city of Saratov, in the 2019/2020 academic year. The scholars verified the mastered skills before and after the experiment. The experimental group had a fair number of classes on Robotics as a component of STEM. The result was obtained by testing [12], evaluating intellectual action criteria [13, 14], and a survey among students and educators.

3. Results and Discussion

Gradually, teaching each of certain specific subjects comes down. It is not by accident. Learning only in the form of information transmission becomes senseless since today any student can browse the Internet and find all the necessary or missing information about the subject of study. An opportunity to use this information properly, and put it into practice is a skill that STEM should provide [5, 11, 15]. Nowadays the authors can highlight several popular multidisciplinary endeavours: Robotics (LEGO, WorldSkills, VEX); modelling and 3D printing; introduction to digital electronics (Arduino): projects Smart Home, Internet of things (IoT), Environment, etc. [16].

LEGO construction can combine 3D modelling and Robotics for younger learners. Academic studies on LEGO construction are mainly focused on the development of verbal, creative, and designing skills. Each child participating in performing the proposed task expresses his attitude towards the work performed and speaks on the progress in performing the task, and the purpose of the completed project.

One of the types of constructive engagement is the design of three-dimensional models with LEGO-constructors. They can help students come up with a rather complicated idea. The robot structure can be developed through three-dimensional modelling, and then constructed with a robotic structure.

The experience gained by a child while being involved in the constructing activity is important from the point of view of developing learning skills of exploratory behaviour. LEGO construction develops the ability how to learn, achieve the necessary results, gain new knowledge about the world around, and prepares the ground for learning activities that are very important for a child.
Educators can initiate students into the software that can help to design structures and models using manual and automated three-dimensional construction tools, such as LEGO Digital Designer. This software lets them create various 3D objects based on virtual LEGO parts. As in the real constructor, only virtually, a learner can use the great variety of on-the-day LEGO elements.

Metasubject results of learning the course on the construction models in LEGO Digital Designer environment are the development of universal learning skills: to determine, differentiate, and define the software tools and operating techniques; to develop models according to criteria defined by the instructor, according to the pattern specified by the scheme; to be aware of learners’ knowledge system: to distinguish new information from the one that is already known; to process the information received; to be able to work on the proposed instructions and make up their own; to be able to state their personal views in a clear logical order, defend their point of view, think through the situation and find the answers to the questions independently by logical reasoning.

Let the authors point out two main kinds of construction: according to the model and the conditions (design/idea) used in virtual reality modelling.

Pattern construction is used when there is a ready-made model of what needs to be built. A child turns around the structure at the desired angle, determines the pieces and builds a model. Another option is to transfer the invented physical model to virtualization to present in subsequent instructions on how to build it or import the model into another three-dimensional model.

This program mode provides direct transfer of readily available knowledge to children, methods of actions based on imitation. Such construction can hardly be related directly to creativity promotion, but it is possible to find out the basis in it to develop creativity later. Anyway, a child has to consider all the structural connections, implement them, and probably offer options for elements that are not distinctive in the proposed picture.

The students are given a model as a sample. It can be a photo, a drawing of the finished object, or a physical version of the structure. The children should reproduce this model in a three-dimensional modelling simulator.

Therefore, a learner is offered a specific task, but without explaining the way to solve it. And that is a fairly effective means of their thought-provoking. A learner draws only upon his knowledge. In fact, his goal is to produce an object projection from one environment to another.

When solving this problem, the learners develop the ability to disaggregate a model into its constituent atomic elements mentally, so that they can reproduce it in their structure, selecting and applying the items proficiently. If the child does not find the appropriate pieces, he is to think over the options to replace them. It means that they shape engineering thinking. During such a construction activity, the learners can be taught the competencies of realizing conditions and the arrangement of their hands-on experience.

When designing according to the offered terms, a learner is given only a certain set of specifications (ideas, assumptions) that should meet the structure. LEGO designing by the terms involves developing a completely new object in the software. In this design, the learners are informed neither on the content nor the work methods used in constructing. This is a complete research and non-routine issue. As follows from the declared suggestions, the purpose and kind of the object, the learners can consider a constitutive plan on their own and supported by their background experience. It is assumed that the learner makes up an image of the future robot in a virtual setting/environment independently and then produces using the available work material. This type of design develops creativity better than others.

The software applied to produce various 3D objects and based on virtual LEGO parts makes it possible to get children acquainted with the basics of three-dimensional modelling, the basics of developing instructions for models, and preparing engineering documentation for models developed in the classroom session. These classes promote spatial awareness. The learners develop their own models or improve just about ready models. Children can encourage flexible thinking, be open to new things, and able to master. A course on three-dimensional software modelling can become an integral part of the general course on Robotics.
One of the most popular areas is also schoolchildren’s work with Arduino microcontroller kit. It is well suited for students to study, and they can design small electronic projects – Smart Home elements, competition robots, and helpful household devices. Programming is performed using text typed in a specialized integrated development environment. The Arduino project is always a combination of an electronic circuit, some related hardware and mechanical devices, a power system, and software. Therefore, when getting to work, a student should be surely aware that he becomes a programmer, an electronics engineer, and a designer [17]. The projects on which learning is based are divided into two groups: training for beginners and the one assisting them in automated individual activities. The performance of training projects for beginners contributes to looking into the platform and is not of practical importance. These include flashing light-emitting diodes (LEDs), projects with sensors, games involving operating with sensors, information log and display devices, servo-driven and stepped motor machines and devices, various types of wireless switching devices. There are the projects for the computer-assisted applied human activity of the following kind: Smart Homes equipped with Arduino, specific elements of home infrastructure control, a variety of autonomous machines and robots, nature study and agricultural sector automation, and infotainment projects.

This platform for educational institutions allows learners to develop practice-oriented programming skills, as well as learn the ropes of circuits engineering. The proposed course allows students not only to cope with the basic techniques of developing hardware and software for autonomous automated systems, but also to expand creative talent and engineering thinking. Schoolchildren’s developmental growth in the context of extracurricular /supplementary education becomes more effective when teaching and learning activities are focused on research and project activities and the use of modern training resources [18].

The method of conducting classes in Educational Robotics comprises the following components:

- Relationship making. The educator’s short story at the beginning of the lesson is intended to let students understand the problem and try to find a way to solve it.
- Design. The principle for implementing ‘learning by doing’ which means that students assemble models bit by bit.
- Reflection. Students learn to make conclusions while doing research, and compare experimental results.
- Development. Students’ creative activity and the experience gained serve as drivers for generating new ideas and ongoing studies.

Finally, the implementation of the system-activity approach supported by Educational Robotics allows the authors to embody basic universal learning skills successfully.

STEM is becoming a universal practice-oriented approach, which is focused on project activities prevailing that allow students to deal with tasks of any complexity degree. Observation shows that students learn not only to think (theoretical underpinning) of scientific facts but also proves their practical actualization. Students are getting ready to research and start independent projects. According to the results of the pedagogical experiment, it can be noted that students’ motivation for studying Mathematics, Physics and Technology increased in the experimental group, and they improved the academic achievement greatly.

4. Conclusion

STEM education seems to be a need of contemporary society, educators and parents. It provides an opportunity for a child to decide on a future career, prepare for entering educational institutions, and spend their leisure time outside school hours.

STEM can be organized by LEGO design. Training sessions on LEGO design are focused on mastering verbal, creative, and design skills.
Educators can let children study the software that allows them to design structures and models with LEGO Digital Designer tools of manual and automated three-dimensional construction. The main focus is on training universal learning activities.

The design development stands for operating with Arduino microcontroller. Using this platform for educational institutions allows the learners to develop programming skills practically, as well as learn the basics of circuits and electronics.

The method of planning classes on Educational Robotics is composed of the following constituent parts: relationship making, designing, reflection, and development.

Teaching forms, methods, and technologies are renewed through the introduction of subjects related to Robotics study into the education space. It can stimulate students’ creative, research activity and their involvement in ‘Imagineering’ (engineering and technical creative work).

Robotics is a principle activity in shaping engineering thinking. It stimulates cognitive activity, promotes an active social and personal education, teaches communication and cooperation skills; combines playing with research and experimental activities, and provides students with the opportunity to explore and create their own world.

Robotics is a microcosm of technologies that support STEM education. Mastering Robotics requires boosting knowledge in various fields of Science, Technology, Engineering, and Mathematics. In addition, students do not even realize this learning model is project-based. Robotics is regarded as a simplified approach to the application of electronics that primary and secondary school students can manage.

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