Activity Plan Template for Supporting Study Science with Robotics and Programming

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Abstract. Today, specialists in engineering specialties are becoming increasingly popular on the labor market. In accordance with the requirements of society, the educational system is looking for opportunities to increase children's interest in the study of subjects in the natural and mathematical cycle. The article presents the experience of holding a summer camp for children for the purpose of attracting them to scientific research and acquaintance with the courses of STEM (science, technology, engineering, and math). The teachers of the STEM-school of the Kherson State University developed the "Summer Intensive" course to familiarize children with the basics of robotics, programming and physics. The course is designed for five days, each of which includes 4 lessons: from physics in practice and experiments, the basics of robotics, the basics of programming, needlework, as well as active games, walks in the park, excursions. During two years 188 children were trained, the article contains the justification for the selection of experiments in physics for children 6-14 years old, a detailed description of their conduct, organization of acquaintance with the basics of robotics using Lego Education WeDo 2.0, programming with Scratch. Particular attention is paid to the peculiarities of the organization and the generalization of the results of training in the summer camp in general and in the context of each subject.

Keywords: robotics, educational robotics, STEM, ICT, robotics school programs, summer camp, physics experiment, camp program.

1 Introduction

The rapid development of technologies, their active introduction into all spheres of society life implies a wide awareness of citizens about the opportunities, prospects and risks of using digital technologies to ensure successful self-realization. Under the influence of automation and robotics, the labor market varies considerably: some of the professions disappear, while the other changes substantially [1]. Instead, there are entirely new professions which require competencies related to work in the team, critical thinking, having ability to make decisions and be responsible for them. Also, requirements for the level of competence associated with the use of modern technology are significantly changing. There is an understanding that we are living in the era of digital technology and they change not only the tools of the usual professions, but also significantly change them. Today, in the labor market, particularly in Ukraine, there is an increasing demand for specialists in engineering professions. Accordingly, to the requirements of society, the educational system is looking for opportunities to make children interested in studying subjects of the natural-mathematical cycle. The STEM-oriented approach to learning is an urgent topic for the modernization of natural and mathematical education. The versatility of this approach contributes to the spreading of innovative technologies in education and popularization of engineering and technical specialties among young people. One of the ways to accomplish this task is to train children in technical circles. At the same time, the popularity of the circle of robotics for children began to grow rapidly.

Analysis of the educational services of the Kherson region on the implementation of STEM-education. Today, STEM-approaches are being implemented in many Ukrainian schools. Out-of-school STEM-education in the state is a diversity of Olympiads and the activities of the Small Academy of Sciences, other out-of-school establishments, and various competitions and events are: Intel Techno Ukraine; Intel Eco Ukraine; Sikorsky Challenge Science Festival; scientific picnics, hackathons and more. Great developments and interesting original approaches were made in Ukraine in this area. They are different, but have the same goal - the development of students' creative thinking [2].

In the law "On Extracurricular Education" [3], five main areas of extracurricular education are identified: artistic and aesthetic, tourist-lore, ecological-naturalistic, scientific-technical and pre-research and experimental directions [4]. It should be noted that out-of-school educational institutions working within last three directions have the opportunity to implement the principles of STEM-training.

In the course of the study, we analyzed the activities of out-of-school institutions in the city of Kherson, among which the following communal institutions of the Kherson regional council as the "Center of tourist and ethnographic creativity of student youth" [5], "Center of ecological and naturalistic creativity of student youth" [6], Center for Scientific and Technical Creativity of Student Youth [7], "Regional Aviation and Sports Technical Club" [8], "Small Academy of Sciences of Student Youth" [9].

None of the out-of-school educational institutions fully implements the research and experimental direction. However, most clubs offering municipal services in the city of Kherson have a close connection with STEM disciplines and may influence the further selection of professional activities of their pupils. However, they have the opportunity to cover a rather small part of the young residents of the city.

As for the study of the basics of robotics and / or programming, as one of the most requested directions for STEM education, it's necessary to note that a large chat group works with Arduino designers and sets of LEGO series, the most popular of which are LEGO Mindstorms and LEGO WeDo. However, today the market of designers to teach children the basics of robotics is actively developing. There are new ideas and startups in this direction.

The leaders in the educational services market in this direction in Kherson are private organizations: Academy Step (working in Kherson since 2016), RoboHause(since October 2015), ISchool (working since January 2018), and others. It is worth noting that the cost of training is 100-120 UAH per academic hour. Only in the last 6 months in Kherson 3 more private circles offering study of the basics of robotics for children 6-10 years by means of LegoWedo 2.0 were opened. Among the peculiarities of various private training courses, it is worth noting the teaching of the basics of robotics in English, the additional study of the English language, the study of the course "Fundamentals of Effective Communications", etc. The analysis of government agencies has shown that during 2017, Lego Wedo 2.0 and Lego Mindstorms for the regional station of young technicians (lessons for free) were purchased, as well as Arduino and Lego Wedo 2.0 for the STEM-school of the Kherson State University operating since January 2017 (cost academic hours is 40 UAH).

Therefore, society needs and interested in preparing children for professions that are in demand in the future. In recent years, the market for educational services has been growing rapidly. However, there is a significant lack of specialists capable for organizing effective STEM training. Also, it should be noted that secondary schools are trying to organize circles for the study of the basics of robotics. At the same time, there is a significant number of children who want to try themselves in the making of robots and programming. Therefore, the teachers of the STEM-school of KSU developed the program "Summer Intensive".

2 Related Work

The experience of summer camp.A general description of the program and the results of the summer camp. It should be noted that this format of combination of recreation and STEM-education was held in the region for the first time. The main tasks were to combine the rest of children with the interest in the study of physics, astronomy, programming and robotics. For two years, the summer camp was attended by 188 children, of which there were girls –43%, boys –57%. By age, the distribution of participants was as shown in Figure 1.

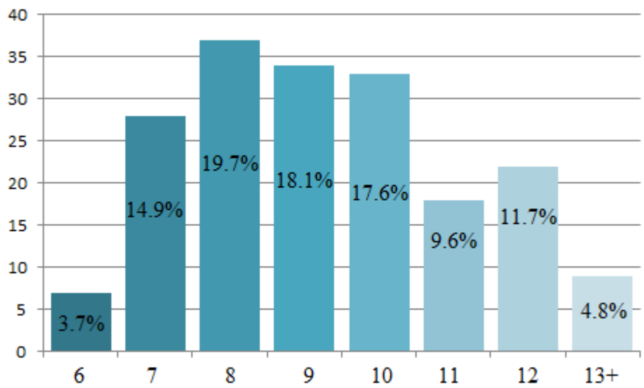

Fig.1. Distribution of children who have attended the camp by age

The greatest number of children were under the age of 10, as at the time of summer holidays, these children need to organize their activities and supervision from adults.

The course includes five days. The children were in the camp from 8:30 to 16:00. Each day consisted of four classes that could take turn each other: programming, robotics, power design (in particular drawing with a 3D pen), physics in tests and experiments. Active games, walks in the park, excursions (in particular, to the observatory, the laboratories of the KSU) meal times (the second breakfast and the complex lunch) were held between these classes according to the schedule. For the senior group, instead of maker programming, C ++ classes for Arduino were conducted.

Among organizational aspects it should be noted the role of the leaders - students of KSU, future teachers who played with children, accompanied them on excursions and rides, and helped in classes together with the teachers of the STEM school. In the work of the STEM-school for the "Summer Intensive" course, teachers from the Department of Informatics, Program Engineering and Economic Cybernetics, the Department of Physics and Methods of its Training (Faculty of Physics, Mathematics and Informatics) and the Department of Preschool and Primary Education (Faculty of Preschool and in-time education) were involved.

3 Experimental Results

Peculiarities of physics class preparation in tests and experiments

The main purpose of the classes was to make children interested in physics, their familiarization with various physical phenomena, states of matter, some physical properties of matter and some physical laws, as well as their involvement in research and experimental activities. Moreover, the main thing was not only demonstration of the experiment by the teacher, but involving each child to the problem, implementation and explanation of the experiment. The students had the opportunity to put forward their own hypotheses, on the posed problems, to check these hypotheses in a lukewarm manner, to draw conclusions, to put forward ideas, make predictions about the future use of physical knowledge. It gave children the opportunity to feel themselves as the makers of the future, since they allowed them to be involved in discussing scientific issues that could affect the development of technology and the life quality in general.

Taking into account different age of children who were studying at the Sum-mer Intensive course, children were divided into two age groups: from 6 to 12 years old and from 13 to 14. Children of the first group received only a few individual physical knowledge at school during the study of natural science, but physics has not been studied yet, children of the second group - has already been studied physics at school at different levels. The different age of children, on the one hand, made it difficult for teacher to set the task of selecting material and further conducting of the experiments and their explanation at different levels of students' preparation in the classes, on the other hand, allowed the children to show themselves in mutual assistance, explaining and helping their colleagues-children during the lesson.

To conduct classes, we have selected appropriate experiments that meet the requirements: security, accessibility (cognitive and financial), the ability to be reproduced at home, clarity, brightness, ease of execution, curiosity, and scientific.

During the selection of interesting tests we carried out the analysis of educational and methodical literature and popular literature on physics (Perelman Ya. I., Entertaining physics, etc.)and Internet resources. This made it possible to conclude that there was a large number of relevant literature.

When selecting and testing the experiments we encountered a number of problems. The most common ones were: 1) lack of precise instructions on equipment and consumables; 2) the lack of nuances that are necessary for the most successful performance of the experiment; 3) the description of the explanation of the experiments should be clear to the children, but it is quite scientific, because it should cause interest to science, and not just entertain.

Example:

- in the existing "Handgum" instructions, the mark of glue has not been specified, it has led to complications during the development of the experiment at the preparatory stage, particularly: the performance of the experiment according to generally acceptable and descriptive instructions in various sources did not yield the expected result; we made the experiment using glue PVA of five different manufacturers, silica glue from four different manufacturers were tested; the only successful experiment was made with only one PVA and all silicate glues of varying degrees of quality;
- during the preparation for the "Fire Tornado" experiment it turned out that there are no precise indications regarding the size of the meta-left mesh cylinder (ratio of height and diameter of the cylinder) and speed of its rotation; There is no clarification what type of fuel (solid, liquid, and what exactly) is the best way to carry out experiments; We tested dry alcohol, liquid alcohol, and a mixture of liquid alcohol with boric acid (giving a green color). The most spectacular look was with liquid alcohol and its mixture;
- some non-Newtonian [complex] fluid explanations contradict each other, the complex scientific explanation for children is not yet clear, and the simplified explanations given on some sites are not always correct.

The "Summer intensive" course of each group took place during 5 days, hence the number of physics classes also equaled five, but their sequence, and the sequence of experiments during a separate lesson in different groups was different, depending on the set of group and individual characteristics children. The list of subjects in physics and their content is given in Table 1.

Table 1. List of subjects in physics and their contents

Topic of the lesson	Elements of physical knowledge	The list of experiments and their discussion
The Lord of element Unknown fluid	Getting familiar with various physical phe-	Non-Newtonian [complex] fluid and its diversity, different types of "hand-

	nomena State of matter. Mechanical phenomena. Viscosity. Properties of the liquid. Newtonian and non-Newtonian fluids. Ferromagnetic fluid. Surface tension. Capillary phenomena. Pressure. Density of liquid.	gums". Ferromagnetic fluid. Experiments and their discussion: water in a glass (turning a glass of water covered with paper); wetting napkins; "Cowhide pepper" (sprinkle in water with ground pepper and cute). Change of fluids of different density in places (with a lower density up, with a larger - bottom). Lava lamp
The Lord of fire	Thermal phenomena. Pressure. Traction. Mechanical phenomena. Aerodynamics	Experiments and their discussion: Fire tornado. Video "The Most Odd Weather on Earth". Tornado. Discussion of the fire causes and ways to prevent them Experiment with paper snake and candle. Experiment "Ponder the candle behind the obstacle", Experiment "Aerodynamic pipe"
Physical illusions	Optical phenomena. Lens. Electrical phenomena. Sound phenomena.	Self-made lens from water (three ways). Rainbow. Optical mixing of colours. Why is the sky blue? Strange optical phenomena in nature and their explanations. Experiment "Put a bird into the cage" (rotation of a picture). "Sorting by electrification" experiments. Discussion: where we are faced with the phenomenon of electrification in life, in technology, in production Sound from the glass.
Flight preparation	Mechanical movement. Reactive movement. Speed Attraction	We make and launch missiles. Reactive movement. Kinds of fuel. We discuss what are the conditions of bigger range ability, which is necessary for the rocket to fly to space
A human being in the Universe	Astronomy Gravitation Attraction The structure of the solar system Theories of the structure of the universe	Model of the Universe Excursion to the Astronomical Observatory. Excursion to the physical laboratories of KSU

Each lesson included the following steps:

- introductory speech of the teacher (revealing features of the group at the first lesson);
- creating problem situations;
- discussion, hypothesis;
- demonstration and performance of the experiment by each student;
- discussing and summarizing the results of the experiment;
- forecasting the possibilities of using the acquired knowledge;
- summary of the lesson, (reflection).

Conducting experiments in different groups revealed the following:

- the same experiments had different successes among the children of the same age, (not all children were equally interested in the same experiment). Some children preferred experiments where creativity could be demonstrated (for example, creating a snake for the study of thermal phenomena); others showed interest in experiments where motion was needed (for example, the launch of a rocket);
- the arriving children had different preferences and different levels of preparation for research and experimental activities (for example, some children showed activity during the hypothesis, discussion of the experiment, offered their versions, others only repeated the experiment);
- some children expressed a desire to take the course twice, and even three times.

It required from teacher to prepare much larger number of experiments (the duration of which would be 1.5 hours) to each session (duration of 45 minutes) in such a way as to having been focused on the first lesson at the qualitative composition of the group, and having chosen exactly the experiments that most responded to this group of children.

Examples of the different pupils' preferences of different age groups regarding the experiments discovered during the course are given in Table 2.

Table 2. Children preferences of different age groups as for different experiments

Name of experiment	**Age 5-6**	**7-9**	**10-11**	**12-16**
Non-Newtonian [complex] fluid	+++	+++	+++	+++
Turning a glass of water covered with paper	++	+++	+++	+++
Lava lamp	++	+++	+++	++
"Cowhide pepper"	++	+++	+++	++
Experiment with paper snake and a candle	+++	+++	++	+
Fire tornado	++	+++	+++	+++
Self-made lens from water (three ways)	++	+++	++	++
Sorting by electrification	+++	+++	+++	++
Make and launch rockets	++	+++	+++	++
The model of the Universe	++	+++	+++	+++
Excursion to the Astronomical Observatory.	+++	++	++	+++
Sound from the glass.	++	++	+++	+++

Reasons of different students' preferences are related to the following:

- the physiological capabilities of children (for example, the palm of a 5-6-year-old child is small, so turning a glass of water, covered with paper, was difficult for them for the first time);
- level of preparation (experiment with a snake on fire for some older children was known, but very much liked by the younger ones, because it included the creative component - the preparation and coloring of the snake);
- personal preferences of children (among the older children, many were interested in astronomy).

But all children liked to do experiments on their own, as well as to feel them-selves as inventors, who are listened to, to feel successful.

Peculiarities of classes preparation the basics of robotics

Previously, materials for each type of training were prepared and analyzed. All results were collected on the online resource www.ksuonline.kspu.edu.

For the classes on programming and robotics, the following software and platforms were considered:

Scratch has a GNU GPL license, which is free. This programming environment can be downloaded freely and used freely at school or extracurricular education.

Arduino (Arduino) is an open source Arduino Software (IDE) platform.

Scratch for Arduino (S4A) is a Scratch modification that allows easy programming of the Arduino open source hardware platform.

Modelling - there is an online resource called Tinkercad to create Arduino sensor connection schemas on the docking board, as well as to create mobs that will be printed on a 3D printer.

Schematics - there is an on-line resource Easyeda or CircuitLab for the creation of electronic circuits.

Lego WeDo 2.0 - software for implementation of training projects of Lego motorized models.

A number of author programs on robotics and programming approved by the Ministry of Education and Science have been established in Ukraine. They are generally intended for the work of out-of-school circles, or for training courses and technical creativity of choice. We have analyzed [9-13].

Lego Wedo 2.0 construction sets were chosen for children aged 6 to 10 years for classes on robotics. Appropriate methodological support was used, but elements of the competition were added to the format of classes, for example, race of collected cars.

The course Lego WeDo2.0 offers the use of educational constructors LEGO and hardware-software as a tool for teaching students in the design, modeling and computer management in Lego-design classes.

Robotics of LEGO combines the possibilities: the development of fine motor skills by working with small parts of designers; mathematics skills (comparing parts by size); skills of construction, familiarity with the fundamentals of mechanics and propedeutics of engineering education; first programming experience; teamwork (the robot is done by 2-3 pupils); skills of presentation (when the project is completed, it is necessary to present it).

The purpose of Lego Wedo 2.0 is: the organization of employment of schoolchildren in after-hours, the logical thinking development; construction skills development; motivation to study the sciences of the natural-science cycle: Physics, Computer Science (programming and automated control systems) and Mathematics. At each lesson the following tasks were realized: familiarization with the basic principles of mechanics; familiarization with the basics of programming in the Lego Wedo 2.0 environment; development of the ability to work according to the proposed instructions; development of the ability to do the task creatively; development of the ability to bring the solution of the problem to the working model; the development of the ability to express thoughts in a clear logical sequence, defend the point of view, analyze the situation and independently find answers to questions through logical reasoning, development of the ability to work on a project in a team, effectively allocate responsibilities, training for Lego-design competitions.

The result of the work of students in classes Lego Wedo 2.0 is the creation of real models of robots; control behavior of robots with the help of simple programming; practical application of design, engineering and computing skills.

In classes on robotics we picked classes so that they were consistent with the subject of physical experiments. In the case when the child has already collected the model previously planned, we proposed that it improve the algorithm of the model and complement its functionality. At the beginning of the classes, the children collected the basic models that are in the designer's software. After that they were offered other models, some of which are given in Table 3.

Table3. Suggested models from Lego Wedo 2.0 by themes

Topic of the lesson	Devicemodel	Elements of physical knowledge
The Lord of element Unknown fluid	Windmill, windfarm, mixer	Gearsdownshiftingandupshifts
The Lord of fire	Fan, helicopter, dam	Torque, speed and direction
Physical illusions	Piano, swing, caterpillar	Sound, soundcharacteristics, balance, centerofmass, reliabilityofstructures
Flight preparation	Catapult, plane, racingcar	Speedandtrajectoryofmotion, determiningthepath, time, speedoftransport
A human being in the Universe	Solarsystem, dinosaurs	Lawsofgravity, heliocentricsystem

In the classroom, the project methodology was used. The topics of the projects were related to the modeling of animals (frog, bee, crocodile) and their behavior; building models of modern machines and mechanisms, studying the principles of their work (car and truck, helicopter, crane, etc.) and programming robots to carry out their tasks. The important aspect of the implementation of each project is research activity.

Peculiarities of class preparation in programming

When choosing a program for programming classes, benefits were provided for programs that meet the criteria:

- Free Software
- Easy to study and use.
- Ability to study programming structures (cycles, branches, etc.).
- Game story.
- Ability to create finished software product in a short time.

Among all the options, Scratch is served best by these criteria - an introductory programming language that allows young children to create their own creative games, interactive stories.

For the classes, a Scratch program library was created with instructions how to complete each assignment. In addition, the resources of the Ukrainian National Volunteer Clubing Network Code-Code (https://codeclub.com.ua/) were used and the training resources of the site www.Code.org were used at separate lessons.

What typical problems have been arisen (for example, a repeated visit, the desire to continue walking and the third time, but for another program).

The course of studying programming is based on the age categories of children and has three levels of different projects:

1. Initial course - for beginners, also for the age group of 6-8 years. The basics of programming in Scratch and its commands are studied.
2. The main course - to master the skills of making the main stages of the game. Contains step-by-step tools for creating programs.
3. Programming games - for advanced users. Age category "10+". Contains step-by-step instructions for creating a game in the form of explanations for the implementation of game logic ("algorithms") without the script's details.

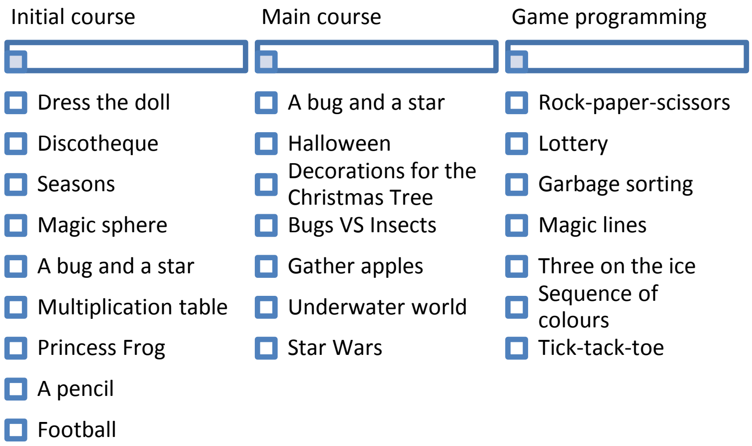

Fig.2. The names of Scratch game programs that match each level

Each of the classes took place in five stages:

- demonstration of a finished project by a teacher (up to 5 minutes),
- discussion of new commands in the program, project scenario - rules of sprites' behavior and the order of events (5-10 minutes),
- creation of own project by children (30 minutes) - with a break on sport activity,
- testing-correction (5 minutes),
- demonstration (presentation) of the project (10 minutes).

Each project is designed for 1 hour of work. Each step is important. In the process of creating their own projects children have an opportunity to choose their own heroes, the scene, as well as create their own rules of heroes' behavior of the project. Therefore, the final stage of the demonstration of its project is obligatory.

There are different ways to demonstrate your projects:

- Demonstration of the game to other students in the group - can play a game of each other.
- Publish on the Scratch Community site at https://scratch.mit.edu/.
- Inviting parents to submit projects.

It is also a great opportunity to develop communication skills. Children can leave comments and suggestions on improving projects to each other, as well as ask questions during the presentation of works.

Initial and basic course projects contain step-by-step instructions that simplify the stage of building a self-project and training in general, without limiting the scope for implementing additional project scenarios. These tools help form students' confidence in their abilities and provide the basis for success.

Game programming projects also go through five stages of creation, but do not include step-by-step instructions. They contain only steps to create game logic ("algorithms") and separate blocks of scripts. Such projects allow you to create a personal game with similar logic of behavior of sprites and events. Each student can create their own version of the game according to their own preferences. The purpose of such projects is not in the reproduction of the model, but in helping implement certain steps of the logic of the game.

4 Conclusions and Future Work

The experience of conducting the training at the Summer Intensive course showed the high interest of children in studying STEM: 3 children attended three sessions of five, another 12 - two sessions (despite the fact that the curriculum did not change significantly), 26 children continued their studies at STEM-school on a permanent basis from October 2017. Parents expressed interest in attending classes on the autumn and winter holidays. The next direction of work for organizing classes next summer is the development of thematic changes that are inspired by one idea. It will also provide the opportunity to expand the range of STEM subjects and to diversify learning in different ways.

The pace and breadth of the STEM movement, as well as the support and interest of the state in Ukraine, show that, within three to five years, STEM-based methods and tools will be almost fully integrated into school curricula. At the same time, the material and technical support, as well as the professional development of teachers, are crucial for the pace of integration

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