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REVIEW OF TRENDS, APPROACHES AND PERSPECTIVE PRACTICES OF STEM-EDUCATION FOR TRAINING CENTER OPENING

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STEM is one of the most current educational trends, it provides young people training according to information society in the science, technology, engineering and mathematics. The leading ideas are interdisciplinary education by solving real practical problems, project work and cooperation. The state of STEM-education in the world and Ukraine is analyzed. Particular attention is paid robotics that enables to develop programming skills and design, and it is the integrator of all components of STEM. The range of services in robotics, constructors for learning is considered. The experience of STEM-center of Kherson State University is presented.

Keywords. *robotics, Educational robotics, STEM, ICT, LLL.*

Introduction

Technologies development greatly affects on all aspects of society, including the structure of labor market and requirements of employers. Under the influence of robotics and automation of processes in providing services and manufacturing a lot of professions will be disappeared, and others professions will come into being, e.g. service and development of robotic systems, data processing, virtual reality designing, SMART technologies and others. Lifelong learning has the important role. Today it is important to understand in what way the world will be changed and how to teach children and they will be successful in future. The understanding of these trends is useful for teachers, including knowledge of requirements for future employees.

Thus, at the World Economic Forum in Taoists in 2016, 10 skills were defined that are necessary for the Fourth industrial revolution and will be demand in the labor market in 2020 [15]:

1. Complex Problem Solving
2. Critical Thinking
3. Creativity
4. People Management
5. Coordinating with Others
6. Emotional Intelligence
7. Judgment and Decision Making
8. Service Orientation
9. Negotiation
10. Cognitive Flexibility

Five of ten skills are the ability to communicate with people, negotiate and manage them, understand and serve them (personnel management, interaction with people, negotiations, orientation on client, emotional intellect). Another 4 areas of 10 are the ability of brain: the ability of quick thinking, understanding the essence, to find the problems' solution, generating of new ideas and projects (complex problem solving, creativity, cognitive flexibility, critical thinking).

In accordance of educational system, it means the priority in choosing problem-oriented teaching methods, they are not oriented on typical tasks solving and the formation of a specific set of practical skills, and they should be focused on teamwork, learning through problem's study and finding the ways to solve it, gaining personal experience. So, they are oriented on skills' formation, demanded in labor market and they can ensure the successful fulfillment of person in a certain

profession. Learning in interdisciplinary manner forms in the child competences required for difficult problem solving. Analysis of tendencies of labor market development predicts a sharp increase demands for professionals in engineering, physics, mathematics and programming.

So, the main trend in modern worldwide learning is STEM - Science, Technology, Engineering and Mathematics. STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and the ability to compete in the new economy (Tsupros, 2009).

1. Related Work

STEM Education is the basis for training staff in the field of high technology. Therefore, many countries, such as Australia, Austria, Great Britain, Israel, Italy, Spain, China, Korea, Germany, Norway, Singapore, USA have the government programs in STEM-education. In particular, some of these countries have developed strategic plans of STEM-education development.

International projects in STEM-education: MASCIL, INSTEM, Mind the Gap, ER4STEM are aimed at solving the most important problem of the European countries - innovation promotion in the field of natural-scientific education.

In particular, ER4STEM (project is funded by the EU Horizon 2020) will refine, unify and enhance current European approaches to STEM education through robotics in one open operational and conceptual framework. Results of the project will be the development of large-scale repositories «ER4STEM» for teachers [4].

A large number of resources are designed to arouse students' interest in science, technology, engineering and mathematics (STEM), and describe the different teaching strategies and features collaboration tools to enable teachers to discuss and share effective instructional practices [2, 11, 12, 14, 16].

In Ukraine, for scientific and methodological support of experimental innovation activity on the basis of secondary educational institutions, establishing STEM-education the working group of introducing STEM-education, which is actively developing the concept of STEM-education and action plan for its introduction is set up by the Institute of educational content modernization, the department of STEM education and Ministry of Education and Science of Ukraine [6, 9].

In September 2016, STEM Education Coalition was founded. Among the founders of the Coalition are Ukrainian Nuclear Society, Samsung, Ericsson, Kyivstar, Syngenta, United Minerals Group, Microsoft Ukraine and Energoatom. The most important tasks of coalition are development of teaching recommendations in STEM disciplines, organization of career guidance projects for youth, teachers' training by innovative teaching approaches. The coalition plans to create opportunities for experimental and research work in schools, conduct scientific and technical contests, competitions, quests, hackathons etc.

In research [10] the authors analyzed the introduction of innovation forms experience of STEM-education into the educational process: hackathons, games, electronic virtual laboratories, science museums, platforms for international design and research activity.

One of variations of STEM is STREM (Science, Technology, Robotics, Engineering and Mathematics); adds robotics as a field. Educational robotics develops the programming and designing skills, it is integrator of four STEM components [3].

The domain of robotics represents a multidisciplinary and highly innovative field encompassing physics, maths, informatics and even industrial design as well as social sciences. Moreover, due to various application domains, teamwork, creativity and entrepreneurial skills are required for the design, programming and innovative exploitation of robots and robotic services [4].

Problem Setting

Thus, the development of STEM-education, including robotics, is education trend which is actively developing and can provide specialists' training in science, mathematics, engineering and technologies, demanded in the labor market and they should have competencies in accordance with

requirements of information society. However, there is no sufficient experience of the implementation.

Purpose of the article is the analysis of international experience, researches of development and identifying the ways of implementing of innovative STEM-education in Ukraine.

The tasks of the article are:

— analysis of methodological, technological and administrative problems of innovative forms implementation in the educational process organization for the implementation of STEM-education task;

— analysis of existing programs in robotics for research activity;

— presentation of Center of STEM-education in KSU.

The main tasks of learning are changed according to the technologies that had been developed or are developing at this time. In primary period of information technologies usage in education there was the task of information's accumulation, content creation. The second period of technologies' development was designing of services for different educational problems execution. CMS and LMS systems for supporting the learning process were developed. At the third stage the concept of semantic worldwide network was developed, the abilities to find, analyze information, to work as a team is very important.

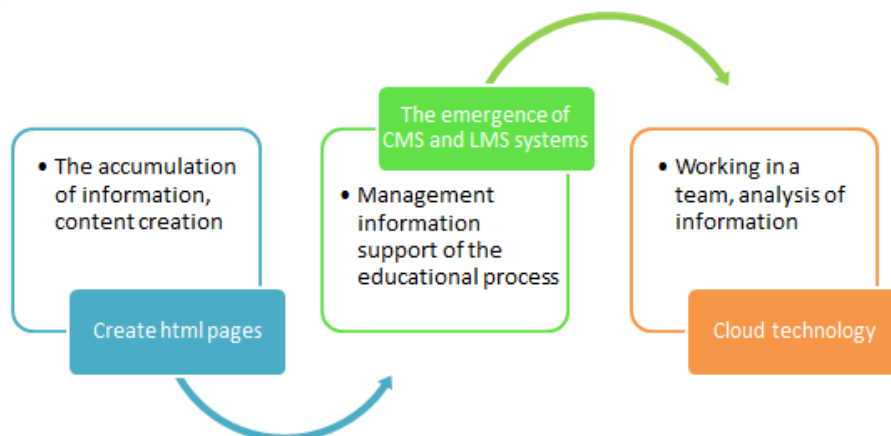


Fig. 1. The influence of technologies' development on training tasks

Low motivation of pupils in mastering natural and mathematical sciences and engineering is explained by the fact that children do not realize in what specialties they could use the knowledge in future, and at what sphere they will realize the potential. Therefore, the important aim of STEM-education is to familiarize children with various professions, specific examples of professionals' work who use knowledge of mathematics, physics, technology and engineering. In particular, it may be video- interviews with the professionals: Climate Scientist, Sports Technologist, Spacecraft Engineer, Structural Engineer, Snowboard Designer, Radio Producer, Planetary Scientist, Marine Biologist, Lighting Designer, Games Developer, Food Technologist, Environmentalist, Energy Analyst, Digital Designer, Cosmetics Specialist" [13].

An interesting trend of STEM-education implementation is teaching children in robotics'. This trend makes the practical implementation of modern trends such as «making» and interdisciplinarity. We know that the majority of pupils is kinesthetic and visual learner, they are the leading type of perception of surrounding world through the senses, touch and observation [1]. Making something by yourself, the experience and emotions will contribute to acquire knowledge.

Making is one more tool of STEM-education connected with «makerspace». The makerspace — sometimes referred to a hackerspace — is often associated with engineering, computer science, and graphic design. The idea of collaborative study group's space for creative endeavors has caught hold in education, forms a compelling argument for learning through hands-on exploration [7]. There are a number of new trends in education, for example, Minecraft in the classroom, which is being implemented by individual teachers and groups. Some centers conduct educational workshops of these trends in education.

Analysis Robotics STEM-Centers in Ukraine

One of the promising ways to develop STEM-education is STEM-centers opening. Its aim is preparation children and young people to the profession and work, which is not still exist. In 5-10 years there will be new technologies and professions. Today, most jobs require knowledge of information technologies, algorithm approach. Teachers, who are engaged in STEM education, always have new information about the current state of science, the practical significance of scientific facts, data. And they teach children not to lock up on the making of product. Projects are designed to be useful for person and have economic components. There are tasks of implementation and promotion of the product at the market.

Implementation of STEM-education approaches in secondary education institutions requires the systemic educational activity of teachers, development of teaching methods, scenario of activities. Changes of curricula are unnecessary due to lack of teachers able to implement these approaches. It is easy to introduce STEM-education in out-of-school educational establishments. However, it is also requires certain financial outlay for equipment and teachers-innovators, ready to acquire independently new branch, develop learning materials and conduct learning. Teaching of robotics requires mechatronics knowledge – branch of science and technology based on combination of units of mechanics and electronic, electric and computer components.

Centers STEM-education in higher education institutions will increase interest in the study of engineering and natural sciences among schoolchildren, give possibilities for students and pupils to make the research capacity on the base of specially created scientific laboratory in the university. It will attract the best graduates of schools to enter the university. Opening of such center at the university has advantages:

for university:

- University prestige, career guidance work, competitiveness of graduates;

for teachers:

- mastering of modern, required technologies on job market;

for students:

- higher competitiveness on the labor market due to possession of modern technologies;

for pupils of secondary school:

- high quality education, expansion of knowledge and skills, adapting of future entrants to research activities.

Department of STEM-education was established in DNU «Institute of the content of education modernize». The higher education institutions not technical profile, in which STEM-centers were created are:

- Borys Grinchenko Kyiv University (Lego, Strawberry, Matrix, 3-D принтер)
- Ternopil Volodymyr national pedagogical university (<http://www.tnpu.edu.ua/news/206/> LEGO, Arduino)
- Oles Honchar Dnipro National University ([Engineering School](#))
- South Ukrainian National Pedagogical University named after K.D.Ushynsky (Internet of Things laboratory)

One of instruments of implementing STEM-education is robotics. In support of curricula in robotics the festivals and competitions are hold in Ukraine. The biggest events are conducted by LEGO. There are few events:

1. Festival ROBOTICA - for children 6-18 year.
2. Scientific and technological tournament in international First LEGO League i First LEGO League Junior - for children 6-18 year. ([interactive map of teams](#))
3. [World Skills Competition in mobile robotics](#) (Kyiv).
4. Competition of children's projects «Boteon Robotics Challenge» (Kharkiv, "Boteon")
5. Festival [Ferrexpo Robot Fest](#) (Gorishni Plavni, Poltava region.)
6. Robots competition "Smart Robo Fest" (Dnipro)
7. Youth IT-festival "[Vesna-soft](#)" (Kropivnitskiy)
8. Olympiad in electronics (Chernigiv) – for students.
9. All-Ukrainian student olympiad in robotics (Lviv).
10. Intel Techno Ukraine

11. Intel Eco Ukraine;
12. Science festival Sikorsky Challenge

There are tournaments, olympiads, festivals and competitions with the help of STEM-centers.

We created and continually complemented map of innovation centers, schools and clubs in robotics with the possibility of commenting, available at link map of STEM-education centers (fig.2) [8].

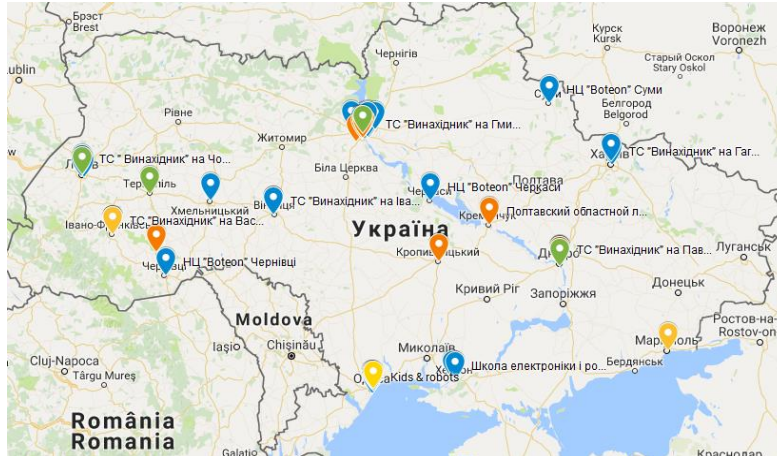


Fig. 2. Interactive map of STEM-education centers and robotics in Ukraine

There is a process of classrooms equipping to implement STEM-education in universities and secondary educational establishments. Also, there are scientific study groups in robotics in Junior Academy of Sciences. On site of Ministry of Education and Science there are curricula that have been tested and have stamp «Recommended» (elective curricula in labor studies and technical work for 5-9 grades of secondary schools «Technology of electronic instruments designing» (S. Dzuba, I. Kit etc., 2013 p.)), «Robotic systems management technology» (S. Dzuba, I. Kit., 2013p.), elective course «Robotics Bases» (authors T. Lysenko, B. Shevel, 2014), curriculum of study groups «Technical design of Ukrainian state centre of out-of-school education (D. Kozhemyaka ,S. Kucher, 2009p.).

One of the main problems is professional training of teachers who are willing to carry out such studies. Teacher should have the basic knowledge of algorithmic fundamentals, physics and programming. But lessons in robotics can be conducted not only experts in this sphere, for example, teacher of English Margarita Kalyuzhna, Halyna Levko, teacher of world literature and art Lina Olefirenko. It is necessary to understand the importance of qualitative changes in education to reform the educational process. In addition, the teacher should be willing to learn all the time.

The analysis of services, including study in robotics in Ukraine showed that this sphere is actively developed. Today there are children's centers, clubs, technical studies, courses in IT companies, STEM-education centers at universities. The list of study groups in robotics for children under 6 years is presented in Table 1.

Table 1.

Technical study groups, which study robotics basics

Name	Site	Equipment
IT Smart School Dnipro	http://www.itschool.dp.ua/our-events/robototekhnika	Lego Technic, Lego WeDo, «Знаток»
Technical Study group "Inventor"(Kyiv, Lviv, Dnipro, Vinnytsia, Ivano-Frankivsk, Odessa, Kharkiv, Brovari, Bucha)	http://www.vynahidnyk.org	Lego WeDo, Mindstorm

Computer Academy STEP (22 cities of Ukraine)	http://itstep.org/ua/	Lego, Arduino
Training Center Boteon Education , (Kharkiv, Kyiv, Odessa, Lviv, Khmelnytsky, Cherkassy, Dnipro, Chernovtsy, Irpen, Sumy, Ivano-Frankivsk)	http://boteon.com/ http://edu.boteon.com/	Boteon Education PhysTech Junior, Boteon Education PhysTech Profi, Arduino
Programming School III++, Kropivnitskiy	http://programming.kr.ua/ru/courses	Arduino
HUB School The educational center for children and adults (robotics club of John Shyhat-Sarkisov) Vinnitsa	http://hubschool.com.ua/ https://www.facebook.com/hubschoolvn/about/?ref=page_internal http://project131244.tilda.ws/	LEGO WeDo 2.0, LEGO Mindstorms EV3
RoboClub - club in robotics and programming for students.	http://technic.in.ua/ https://bigggidea.com/project/roboklub-dlya-ditej-ivano-frankivska/	LEGO Mindstorms ta WeDo
Courses Arduino Robotics Ivano-Frankivsk	https://www.facebook.com/arduino.if/	Arduino
RoboCode (Kyiv, Irpin)	http://robocode.com.ua/	Fischertechnik, Arduino UNO
RobotSchool (Kyiv, Poltava)	http://www.robotschool.com.ua/	Lego WeDo, Fischertechnik, Bender-A, Arduino
RoboUA (Kyiv);	http://roboua.org/	Arduino, Lego Mindstorms
BroBots — Brovary IT Hub (Brovary).	https://www.facebook.com/brobots.hub/	Arduino
RoboHouse - School of Electronics and Robotics (Kherson)	https://www.facebook.com/robohouseKs/?fref=ts	Arduino
RobotSchool (Kyiv, Poltava)	http://robotschool.com.ua/	Arduino
« Smart School » from Microsoft	https://www.imena.ua/blog/smart-school-ua/	Arduino, Raspberry Pi

The majority of centers have commercial basis, but there are not commercial centres, for example RoboClub – club in robotics of Ivan Shyhat-Sarkisov, III ++ in Kropyvnytsky and others.

Many centres in robotics are based on bases (clubs) of young technicians in cities of Ukraine. For example, in February training center in robotics were started in Kherson, club of young technicians «Academy» is working in Kyiv <http://academician.kiev.ua/robotics.php>.

Analysis of constructors for robotics bases study

A lot of centers in robotics are working with constructors Arduino and sets of LEGO, the most popular among them is LEGO Mindstorms and LEGO WeDo. However, today on the market there are many constructors to study robotics bases. There are new ideas and startups in this area. The list of constructors that can be used to teach children is presented in Table 2.

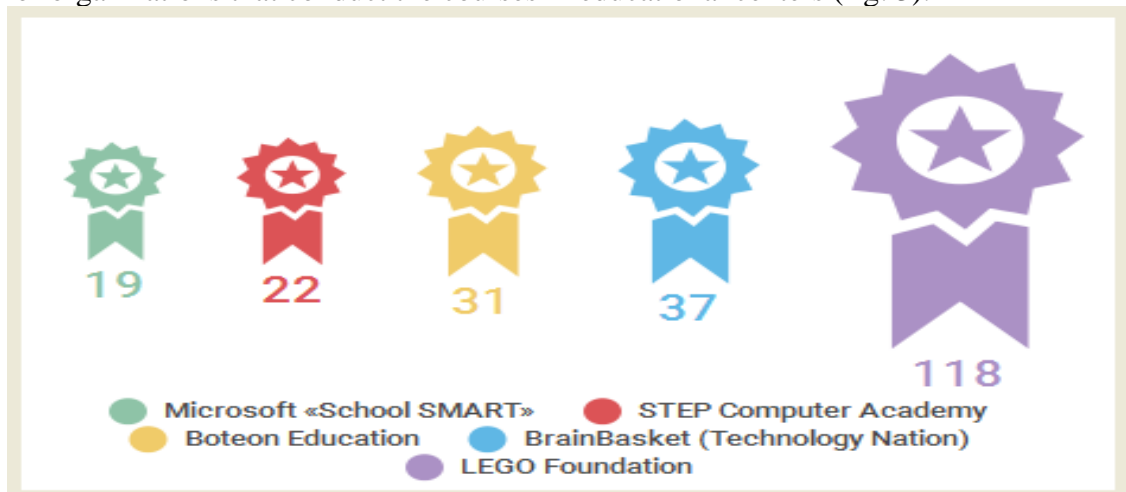
Table 2.

Educational robot manufacturers and platforms

Constructors	Age	Peculiarities	URL
Dash and Dot product of Apple	6+	Using easy-to-learn code on an iPad Comes preassembled and ready to play All of Wonder Workshops' free apps for iOS or Android	https://www.makewonder.com/dash
LittleBits	8+	Compatible with Arduino	http://littlebits.cc/
Makey Makey	6+	Makey Makey Classic uses resistive sensing and Makey Makey GO uses capacitive sensing	http://www.makeymakey.com/
Robo Wunderkind		Lego adapters Coding becomes accessible to children with visual programming apps for smart phones and tablets	http://robowunderkind.com
Lego WeDo Robotics	6+	The brick set contains more than 150 LEGO® elements, including Motion and Tilt Sensors, a motor, and the LEGO USB Hub. The accompanying icon-based drag-and-drop software provides an intuitive programming environment.	http://www.legoeducation.us/en/g/categories/products/elementary/lego-education-wedo
Lego Mindstorm NXT	8+	The system includes the EV3 Intelligent Brick, a compact and powerful programmable computer that makes it possible to control motors and collect sensor feedback using the intuitive icon-based programming and data logging software that is delivered with the set.	http://www.legoeducation.us/en/g/categories/products/middle-school/robotics
Boteon Education	8+	Maker – Ukraine Maker of micro controllers is Atmel, Microchip, ARM, languages S4A, C/C++, Assembler	http://boteon.com/

Arduino	8+	Open-source electronic prototyping platform enabling users to create interactive electronic objects. Own software (IDE), programming language C++	http://arduino-ua.com
Fischertechnik Robo	5+	Incl. BT Smart Controller, Fischertechnik ROBO TX Controller Standard C compiler for software, Libraries for Visual Studio	http://www.fischertechnik.de/en
Raspberry	8+	processor used in Raspberry Pi Official programming language — Python	https://www.raspberrypi.org/
Cubelets	6+	Cubelets are a line of construction toys manufactured by Modular Robotics	http://www.modrobotics.com/cubelets/
Makeblock	6+	Makeblock is an educational programmable electronic robot kit building platform that helps you to learn STEM or DIY robots Robot-constructors are compatible with LEGO	http://www.makeblock.com/
Robotis	7+	Own controller, programming language C++	http://en.robotis.com

In Ukraine the big companies as Microsoft (software, curricula in software programming), Samsung (equipment, training), LEGO Foundation (play sets, curricula in software programming) and the fund BrainBasket (curricula in software programming) cooperate with educational institutions in implementation of information technologies, robotics and programming. There are a number of organizations that conduct the courses in educational centers (fig. 3).



Pic. 3. Companies - leaders in Ukraine engaged in education of children in robotics and programming

In 2016 the Ministry of Education and Science of Ukraine and LEGO Foundation (Denmark) was prolonged Memorandum of Understanding till 2020. The memorandum was first signed July 10, 2010 under the program «Education Contribution». Ministry of Education and Science of Ukraine and Charitable Foundation LEGO Foundation came to an agreement in implementing and expanding the network of pre-schools and educational complexes involved in the project of LEGO-design, and program's implementation in primary school. Now 118 educational institutions are involved in the project. Under this memorandum the program «Learning by activity» is implemented. The programs «LEGO design for preschoolers» and «Mindstorms Robotics» were approved by Ministry of Education and Science of Ukraine and recommended for study in educational institutions of Ukraine. The first Ukrainian school started working using LEGO Education programs since 2008 [6].

In April 2014 the decision of opening the Fund BrainBasket which develops the educational market in IT industry [18] was made by a group of leading Ukrainian IT companies with participation of the Ministry of Economy of Ukraine, Kyiv City Administration. There were established training centers in 31 cities of Ukraine. There is collaboration with 37 educational institutions. The fund created and it supported seven educational projects (Technology Nation, Technology Nation Kids, Introduction to IT, Brain TV, IT Moms, Hour of Code, Coding for Future), four of them were opening for children of school age. During the year it was created 100 IT learning groups in all regions of Ukraine.

In November 2016, Microsoft presented the innovative project «School SMART», the main goal is to realize the concept of Internet of Things (IoT), using microelectronics [17]. Ten educational institutions take part in the project. Teachers and students created eco-projects, «smart» modules for home and school. In March 2017 the second period of projects was started. The company is involved in digital transformation of schools. Today the list of Microsoft exemplary schools includes nine schools, which have the personalized learning using modern technologies.

In our country there are a number of festivals, seminars and workshops, which help quickly and successfully master the new means of introducing STEM-education and they are the informal places where all participants have possibility to socialize, exchange experiences, to discuss problems so on. It is All-Ukrainian project «Cloud services in education» (Microsoft), Ukrainian Festival of pedagogical ideas using ICT, workshops of Centre of Innovative Education (Kyiv, <https://www.ukraine-teacher.com/>), Center of new education of Ivan Ivanov (Kyiv <https://www.facebook.com/groups/ict.in.ua/?fref=ts>), all-ukrainian forum «Teachers School» of Center of Robotics «Boteon».

Development of STEM-robotics in KSU

In Kherson State University work of STEM-education introduction was started, including the study group «STEM School» at Center of post-graduate education.

Problems arisen at opening the study group are:

- Lack of staffing for the full activity.
- The necessity of material-technical base, its support, updating, an insufficient number of sets to ensure continuity and development of opportunities in the work.
- Development of teaching and didactic materials in different topics for different ages.

The regulation about «STEM School» and curricula were developed. The educational constructors Arduino are used in the learning process. Two pilot groups: Students of Faculty of Physics, Mathematics and Computer Science and pupils started the study. The regular study will start on September 2017. At present period the teachers' training is conducted, learning materials are developed, the curricula is tested curriculum.

For learning materials development we use these electronic resources Arduino:

- www.arduino.cc – developer website.
- www.dfrobot.com – lessons on the board compatible with DFRduino.
- <http://arduino.ua> – representative office in Ukraine.
- <http://arduino-kit.com.ua/> - thematic site has material for work with the devices.

—<http://arduino-diy.com> - thematic site has lessons for beginners and projects for advanced users

—<http://boteon.com> -training Center "Boteon" presents materials for teaching Arduino.

—https://robotics.ua/build_robot - instructions for creating simple and complex robots. Use of material requires knowledge of electrical engineering.

There are also a number of interesting foreign sites which present standard lessons, projects using this platforms (eco-projects, smart home projects, unmanned vehicles and other [5]).

Conclusions and Outlook

Therefore, STEM is a modern trend of education development in the world, which will allow providing increasing needs of society by highly qualified specialists in the field of science, technology, engineering and mathematics. Leading ideas of this trend is learning in an interdisciplinary manner by solving real practical problems, project work and cooperation.

The main objective of the trend is to train children and youth to successful mastering of skills of research and analytical work, experimentation and critical thinking. In curricula of STEM-education the natural scientific component with support for innovative technologies are increased. Main trends of STEM education are integrated, interdisciplinary curricula; robotics and engineering designs; «smart devices» of Internet of things; 3D-modeling. In the world there are STEM-centers, which is a kind of design laboratories.

Today there is a demand for educational services of STEM education, especially robotics. However, the development of this trend has some problems associated with lack of required number of trained teachers, managers of the study groups and material resources for training. Another promising task of development of this trend is the development of educational materials on interdisciplinary base adapted for different age.

For successful implementation of STEM-approach it is necessary to integrate all parts of education: pre-school, secondary, extracurricular, higher and postgraduate.

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ОГЛЯД ТЕНДЕНЦІЙ, ПІДХОДІВ ТА ПЕРСПЕКТИВ STEM-ОСВІТИ ДЛЯ ВІДКРИТТЯ НАВЧАЛЬНОГО ЦЕНТРА

STEM є однією з найсучасніших освітніх напрямків, вона надає молодим людям навчання в галузі інформаційного суспільства в галузі науки, техніки, інженерії та математики. Провідні ідеї - це міждисциплінарна освіта шляхом вирішення реальних практичних проблем, проектної діяльності та співпраці. Проаналізовано стан STEM-освіти у світі та Україні. Особливу увагу приділено робототехніці, яка дозволяє розвивати навички програмування та конструювання, і є інтегратором всіх компонентів STEM. Розглянуто спектр послуг у сфері навчальної робототехніки та конструктори для навчання. Представлено досвід STEM-школи Херсонського державного університету.

Ключові слова: Робототехніка, освітня робототехніка, STEM, ICT, LLL.

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ОБЗОР ТЕНДЕНЦИЙ, ПОДХОДОВ И ПЕРСПЕКТИВ STEM-ОБРАЗОВАНИЯ ДЛЯ ОТКРЫТИЯ УЧЕБНОГО ЦЕНТРА

STEM - одна из самых современных образовательных тенденций, она обеспечивает подготовку молодых людей в соответствии с требованиями информационного общества в области науки, техники, инженерии и математики. Ведущими идеями являются междисциплинарное образование путем решения реальных практических задач, проектной деятельности и сотрудничества. Проанализировано состояние STEM-образования в мире и Украине. Особое внимание уделяется робототехнике, которая позволяет развивать навыки программирования и конструирования, а также является интегратором всех компонентов STEM. Рассматривается спектр услуг в сфере учебной робототехники и конструкторов для обучения. Представлен опыт STEM-школы Херсонского государственного университета.

Ключевые слова: Робототехника, образовательная робототехника, STEM, ICT, LLL.