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IMPLEMENTATION OF STEM-EDUCATION IN ELEMENTARY SCHOOLS VIA SCIENTIFIC AND EDUCATIONAL PROJECT "THE INTELLECT OF UKRAINE"

Irina Gavrysh, Victoria Ushmarova

H. S. Skovoroda Kharkiv National Pedagogical University

Resume:
The article considers trends in STEM-education, globally and in Ukraine. It reports that the general civilization tendency of the 21st century, which determines the development of humankind, is NBIC-convergence (convergence of nano-, bio-, information and cognitive technologies), which is the core of the sixth technological way. It is revealed that the world political and scientific elite consider NBIC-convergence as the new dominant of scientific and technological progress; the measures taken in the countries with powerful economics aimed at the formation and development of the sixth technological way are highlighted. The thesis that education is designed to satisfy the order of economy and production for fundamentally new, universal STEM-educated qualified specialists is substantiated, which led to the modernization of educational systems of leading countries of the world based on STEM-education. The issues of realization of STEM-education in secondary school and out-of-school education in Ukraine are covered. The theoretical and methodological foundations of STEM-education in the elementary school of the scientific and pedagogical project "The Intellect of Ukraine" are defined: a post-classical paradigm of education, which presupposes an organic combination of technocracy with humanistic priorities and cultural-centricity as a methodological base; formation of the basics of innovation, mathematical, information and communication, environmental competencies, as well as competencies in the field of natural sciences, technology as a conceptual goal; the fundamentalization of education, continuity, integrated subject-based learning on a cross-disciplinary and project-based approach, learning based on one's own discoveries and its practical focus, in-depth study of English as a characteristic feature. The results of the experimental realization of STEM-education in the elementary school of the scientific and educational project "The Intellect of Ukraine", aimed at the formation of interconnected STEM-competencies of students (mathematical, research and inventive, technological, informative competencies) as a unity of cross-conceptual, conceptual, operational, axiological competencies. The educational programs of the mathematical and

Анотація:
Гавриш Ірина, **Ушмарова Вікторія. Упровадження STEM-освіти в початковій школі в умовах науково-педагогічного проєкту «Інтелект України».**
У статті проаналізовано світові та вітчизняні тенденції розвитку STEM-освіти. Встановлено, що загальноцивілізаційною тенденцією XXI століття, яка визначає розвиток людства, є NBIC-конвергенція (конвергенція нано-, біо-, інформаційних і когнітивних технологій), що становить ядро 6-го технологічного укладу. З'ясовано, що NBIC-конвергенція розглядається світовою політичною та науковою елітою як нова домінанта науково-технічного прогресу. Вказано заходи, які здійснюються в країнах із потужною економікою і спрямовані на становлення й розвиток 6-го технологічного укладу. Обґрунтовано тезу про те, що освіта покликана задовольняти замовлення економіки й виробництва на підготовку принципово нових, універсальних STEM-освічених кваліфікованих фахівців, що зумовило модернізацію освітніх систем провідних країн світу на засадах STEM-освіти. Висвітлено питання реалізації STEM-освіти в закладах загальної середньої та позашкільної освіти в Україні. Визначено теоретико-методологічні засади STEM-освіти в початковій школі в умовах науково-педагогічного проєкту «Інтелект України»: постнекласична парадигма освіти, що передбачає органічне поєднання технократизму з гуманістичними пріоритетами та культуроцентричністю, – як методологічна база; засвоєння учнями основ інноваційності, математичної, інформаційно-комунікаційної, екологічної компетентностей, а також набуття ними компетентності в галузі природничих наук, техніки і технологій – як концептуальна мета; фундаменталізація освіти, неперервність, інтегроване навчання за темами на засадах міждисциплінарного та проєктного підходів, навчання на основі власних відкриттів та його практична спрямованість, поглиблене вивчення англійської мови – як характерні властивості. Висвітлено результати експериментальної реалізації STEM-освіти в початковій школі в умовах науково-педагогічного проєкту «Інтелект України», спрямованої на формування взаємопов'язаних *STEM*-компетентностей школярів (математичної, дослідницької і винахідницької, технологічної, інформатичної компетентності) як єдності наскрізних концептуальної, стратегічної, когнітивної, операційної, аксіологічної компетентностей. Наведено освітні програми математичної і природничої

Аннотация:
Гавриш Ирина, Ушмарова Виктория. Внедрение STEM-образования в начальной школе в условиях научно-педагогического проекта «Интеллект Украины».
В статье проанализированы мировые и отечественные тенденции развития STEM-образования. Установлено, что общецивилизационной тенденцией XXI века, которая определяет развитие человечества, является NBIC-конвергенция (конвергенция нано-, био-, информационных и когнитивных технологий), составляющая ядро 6-го технологического уклада. Выявлено, что NBIC-конвергенция рассматривается мировой политической и научной элитой как новая доминанта научно-технического прогресса. Приведены примеры мероприятий, которые проводятся в странах с мощной экономикой и направлены на становление и развитие 6-го технологического уклада. Обоснован тезис о том, что образование призвано удовлетворять заказы экономики и производства на подготовку принципиально новых, универсальных STEM-образованных квалифицированных специалистов, что обусловило модернизацию образовательных систем ведущих стран мира на основе STEM-образования. Освещены вопросы реализации STEM-образования в заведениях общего среднего и внешкольного образования в Украине. Определены теоретико-методологические основы STEM-образования в начальной школе в условиях научно-педагогического проекта «Интеллект Украины»: постнеклассическая парадигма образования, предусматривающая органическое сочетание технократизма с гуманистическими приоритетами и культуроцентричностью, – как методологическая база; формирование у учащихся основ инновационности, математической, информационно-коммуникационной, экологической компетентностей, а также компетентности в области естественных наук, техники и технологий – как концептуальная цель; фундаментализация образования, непрерывность, интегрированное обучение учащихся темам на основе междисциплинарного и проектного подходов, обучение на основе собственных открытий и его практическая направленность, углубленное изучение английского языка – как характерные свойства. Представлены результаты экспериментальной реализации STEM-образования в начальной школе в условиях научно-педагогического проекта «Интеллект Украины», направленного на формирование взаимосвязанных STEM-компетентностей школьников (математической, исследовательской и изобретательской, технологической, информатической компетентности) как единства сквозной, концептуальной, операционной, аксиологической компетентностей. Приведены примеры образовательных программ в математической

natural educational branches, which make up the semantic block of experimental work, are given; educational technologies that allow to realize the subject content of STEM-education in elementary school in the educational environment of the scientific and educational project “The Intellect of Ukraine”: multi-disciplinary integration, enhancement of the natural learning process, the presentation of learning in cohesive units, interactive educational technology and critical thinking, reading and reflection.

освітніх галузей, що становлять змістовий блок експериментальної роботи; освітні технології, що дають змогу реалізувати предметний зміст STEM-освіти в початковій школі в умовах освітнього середовища науково-педагогічного проєкту «Інтелект України» (технологія міждисциплінарної інтеграції, технологія збагачення освітнього процесу, технологія цілковитого засвоєння навчальних одиниць, інтерактивні освітні технології та технології критичного мислення, технологія раціонального читання).

и естественной образовательных отраслях, которые составляют содержательный блок экспериментальной работы; образовательных технологий, позволяющих реализовать предметное содержание STEM-образования в начальной школе в условиях образовательной среды научно-педагогического проекта «Интеллект Украины» (технология междисциплинарной интеграции, технология обогащения образовательного процесса, технология полного усвоения учебных единиц, интерактивные образовательные технологии и технологии критического мышления, технология рационального чтения).

Key words:
NBIC-technologies; NBIC-convergence; STEM-education; elementary school; interdisciplinary integration; mathematical education; natural sciences education.

Ключові слова:
NBIC-технології; NBIC-конвергенція; STEM-освіта; початкова школа; міждисциплінарна інтеграція; математична освіта; природнича освіта.

Ключевые слова:
NBIC-технологии; NBIC-конвергенция; STEM-образование; начальная школа; междисциплинарная интеграция; математическое образование; образование.

Introduction. A broad program of reforms has been introduced in Ukraine, in response to the sharp political and economic challenges facing the nation. In reforming of the educational system some important steps have been taken. However, this process is quite uneven and slow. It needs strengthening in response to economic and technological development.

A generally accepted trend of the XXI century, which defines human development, is NBIC-convergence (convergence of nanotechnology, biotechnology, information technologies and cognitive science). This is central issue to the sixth technological structure. A complete merger of NBIC-technologies, with union, mutual penetration, and synergistic enhancement as a result of convergence, is driving significant changes in the demand for skills and sharpening the need for strong and balanced skill-sets across all areas. Education is required to meet the demands of economy and production for fundamentally new, cross-disciplinary experts. These must be able not only to develop and operate advanced equipment and technology, but also hold interdisciplinary skills and abilities that allow them to create new technologies, equipment and materials needed in almost all areas of production.

Despite educational reforms and implementation of state educational standards and programs, the content of education in Ukrainian schools needs further improvement. It is still implemented in line with the needs and realities of the economy and production of former (industrial) technological structures. This is highlighted in particular conclusions of the World Bank report on the condition of Ukrainian education “Key quantitative indicators of Higher educational system in Ukraine” (2019): “however, skills demanded by the expanding sectors are different than those supplied by the education system” and “education is not contributing its full potential to the wider economy” (Gresham, & Ambasz, 2019, p. 4; p. 11).

The Ukrainian education system has to change radically and constantly to keep pace as a driving force of economic growth of the state. These changes should be in the direction of specialization and from inter-disciplinarity to multi-disciplinarity.

These trends are embedded in national development strategies of STEM-education in the USA, EU, Japan, China, South Korea, Singapore and others.

Analysis of the latest investigations and publications. Issues around STEM-education are actively included in the range of scientific and educational investigations of domestic scholars.

Conceptual and theoretical aspects of introducing STEM-education in Ukraine are being investigated by N. Morse, K. Postova, O. Patrykeev, N. Polihun, I. Slipuhina, O. Stryzhak, I. Chernetskiy, and others. A separate cluster of investigationsis centred on scientific publications on teaching methods for natural sciences and mathematical disciplines in secondary education institutions, in the context of STEM-education: physics (O. Voronkin, O. Kuzmenko), geography (O. Ishchenko, N. Goncharova), chemistry (O. Grechyn), biology (L. Danilenko), mathematics (T. Lytvynenko) and others. Professional competence of teachers in the STEM-education system is being investigated by N. Goncharova. Experience of implementing of STEM-education in the EU and the USA is revealed by O. Kovalenko. Features of STEM-education of preschoolers are studied by K. Krutiy, I. Stetsenko and others.

Scientists report that a STEM-oriented approach to learning is important in the innovation of Natural Sciences and Mathematics. It is based on an interdisciplinary approach to the construction of disciplines and individual teaching elements (integrated education according to certain topics or current problems) and aims “to form key professional, social and personal competencies in young people, that determine their competitive

ability in the labor market: the ability and commitment to solving complex problems, critical thinking, creativity, cognitive flexibility, collaboration, management, implementation of innovation and so on" (STEM-osvita: Problemy ta Perspektyvy, 2018).

The purpose of this article is to analyze global and domestic trends of STEM-education, to identify theoretical and methodological foundations and to provide intermediate results of experimental realization of STEM-education in the elementary-school scientific and educational project "The Intellect of Ukraine".

The theoretical basis of research. The first decade of the XXI century is marked by understanding of needs in STEM-educated skilled professionals (Science, Technology, Engineering, Mathematics). These professionals should possess not only theoretical knowledge but also practical skills with complex technological objects. Researches revealed significant problems and contradictions. The traditional educational system does not meet the requirements and needs of education for training of specialists of XXI century, particularly those who related to science, technology, engineering and mathematics. At the same time, there is a decrease in motivation to study STEM-subjects and in the choice of mathematics related professions. There is lack of ability to solve real problems that require the knowledge and applications of STEM-subjects (Stryzhak, Slipukhina, Polisun, & Chernetskyi, 2017).

This led to a reduction in the number of qualified STEM-trained professionals. The World's state leaders, political figures and representatives of business think that there is a shortage of STEM-workers. National security and competitiveness of countries are perceived to be at risk. Brad Smith, Microsoft's general counsel and executive vice president, said at a press briefing that the lack of qualified job applicants is "approaching the dimensions of a genuine crisis" for tech companies (Microsoft: Shortage of tech Workers…, 2012). "... Leadership tomorrow depends on how we educate our students today – especially in science, technology, engineering and math," Barack Obama said (Science, Technology, Engineering and Math…, 2015). Israeli Education Minister N. Bennett (2015) warns: "If we do not create our own engineers, scientists, high quality graduates, in 30 years in Israel there will be neither flourishing hi-tech nor Nobel laureates, nobody will create "Iron Dome" and modern medicines" (Просвещение «по стандартам спецназа», 2015).

The need to solve the problems mentioned above accelerates the need to reform the traditional educational system, particularly in the direction of STEM-education, as is observed in the USA and in other countries.

Leading countries have developed educational strategies that offer solutions in STEM-education. They include various specialized programs for primary, secondary and higher education. Australia, England, Scotland and the United States published national reports which contained recommendations on reform of STEM-education. Australia, China, England, Korea, Taiwan and the USA are working on development of K-12 STEM-curriculum, which is designed as a set of integrative interdisciplinary approaches in each of the STEM-subjects. Much attention in these educational programs is given to the fact of realizing by pupils / students how STEM-learning can affect careers in the professions (Launching the 21st century American Aerospace Workforce …, 2008; Pitt, 2009; Project Lead the Way (PLTW), 2021). France, Japan and South Africa's institutions of secondary education and out-of-school professional organizations develop informal programs of STEM-education (summer camps, after-school activities, competitions, etc.) that attract the attention of students to STEM-occupations and provide opportunities for learning different directions of STEM-education (Preparing Future Engineers Around the World…, 2011; Reaching New Frontiers in STEM Education…, 2012).

Using the USA as an example, we characterize the level of practical implementation of STEM-education.

In 2005, fifteen leading US business communities gathered in an informal coalition "Tapping America's Potential" (TAP) in search of ways to preserve the global scientific and technological leadership of the USA. TAP made the following commitments: strengthening the motivation of American students to enter STEM-specialties, systemic quality assurance of school education in natural sciences and mathematics, teachers' training, provision of financial incentives for gifted students, and attraction of private businesses to interact with universities and engineering colleges (Tapping America's Potential…, 2008).

In 2011, the National Research Council offered a new structure of secondary education in natural sciences, under which in 2013 updated standards of secondary education in science for students of grades 2-12 were introduced. Items that were standardized:

- *Practices*. Scientific and engineering skills: formulating researchable issues and tasks (engineering); creating and using models; planning and investigating; analysis and interpretation of data; the use of mathematical and computational system; constructing of explanations (science) and designing solutions (engineering); building of arguments based on facts; acquisition, evaluation and correct interpretation of information.

- *Content*. Basic knowledge of physics, chemistry, biology, geology, astronomy, engineering, technology and applied sciences.
- *Crosscutting concepts*. Patterns; cause and effect: mechanism and explanation; scale, proportion, and quantity; systems and system models; energy and matter: flows, cycles, and conservation; structure and function; stability and change (Люблинская, 2014, с. 6–23).

The USA adopted a national program to train more than 100 thousand teachers in the STEM-education sphere for the next 10 years (Charting a Course for Success…, 2018). Only those teachers who have received appropriate training and preparation in STEM-disciplines may deliver teaching under the STEM-concept.

Analysis and synthesis of research and practical experience helped to isolate the main approaches to the development of programs to master STEM-literacy:

1. Extending learning experiences in specific STEM-subjects, using problem-oriented learning activities. These analytical concepts are applied to real world problems in order to enhance students' understanding of difficult concepts.
2. Integrating knowledge from STEM-subjects, with the purpose of better understanding their content. This aims to empower the students in the future to choose a technical or scientific career.
3. Versatility, providing integrative learning of STEM-subjects as is done in real conditions. In this way, scientists can apply their knowledge to solve the problems of poorly structured processes which obstruct technical capabilities. The students can rapidly acquire skills of highly organized thinking. This learning is supposed to build on the basis of projects and technical design, combining scientific principles, technology, engineering and math in a single STEM-training program.
4. Innovation in teaching methods of separate STEM-subjects and integration in which the basic concepts of science, technology, engineering and mathematics are included in a curriculum are identified clearly as STEM.

Despite the variety of available approaches, almost all scientists are united in the opinion that STEM-education is a modern educational phenomenon associated with the understanding of quality of discipline assurance by students of science, technology, engineering and mathematics. The aim is to prepare students for more effective application of knowledge to solve professional tasks and problems.

Therefore, STEM-education belongs to the innovative educational systems that fully meet the global trends of modern education. In developed countries it is becoming a systematic approach to introduce STEM-education to the national educational community, including the practice in schools.

In Ukraine, the modernization of certain sectors of general secondary education on the basis of STEM-education, in our opinion, is extremely important.

The Ministry of Education and Science of Ukraine and the Institute of Education content modernization have already taken the first steps on the theoretical and methodological reflection and generalization of experience on the issue under discussion. The necessary regulatory and legislative documents governing proceedings of STEM-education have been prepared: "Regulations on procedure of innovative educational activities" (2015) and; "On the foresight of socio-economic development of Ukraine for the medium (2020) and long term (2030) time horizons" (in the context of human capital) (2016), orders of the Ministry of Education and Science of Ukraine for implementing STEM-education in Ukraine in 2016-2018 (2016), the decision of the Board of Ministry of Education and Science of Ukraine "On conducting the experimental work nationwide level on "Scientific and methodological principles of creation and functioning of Ukrainian scientific-methodical virtual STEM-center for 2017-2021" (2017) and others.

A Memorandum of STEM-education Coalition in Ukraine was signed in 2015. This is an initiative of the Center for Corporate Social Responsibility, with a coalition joining Kyivstar, Syngenta, United Minerals Group, and NNEGC Energoatom, Samsung, Ukrainian Nuclear Society, Microsoft Ukraine, Creative International Children's School, Kyiv University of Culture and Arts, and others – 16 participantsin in total.

The coalition has accepted 6 key tasks: to prepare recommendations to the Ministry of Education and Science of Ukraine concerning the application of disciplines that are part of STEM-cycle; implementation of programs to introduce innovative teaching methods in schools; providing opportunities for pupils and students to conduct research and experimental work using modern equipment; creation of information platforms; career guidance; the development of international cooperation.

STEM-education is getting more and more popular in Ukraine. Integrated STEM-approaches are implemented in many schools and out-of-school establishments (the work of Junior Academy of Sciences, various programs, contests and competitions: Intel Techno Ukraine; Intel Eco Ukraine; Festival of Science Sikorsky Challenge; research picnics, etc.)

With the support of MES Ukraine and the Institute of Education, teaching content modernization through the scientific and educational project "The Intellect of Ukraine" is becoming popular in our country. It aims at improving the technology of STEM-education in Ukrainian education today.

The investigations of scientists and educators made it possible to identify theoretical and methodological foundations of STEM-education in elementary school through the scientific and educational project "The Intellect of Ukraine":

1. STEM-education in primary school should be based on the post-nonclassical educational paradigm in which conceptual educational purposes recognize the conditions for self-actualization and creative self-identity in a complex, changing world. The basic ideas of the national education policy paradigm are post-nonclassical technocracy in an organic combination of humanistic priorities and culture-centricity, representing such typical features as cultural identity, spirituality, national consciousness, cultural tolerance, positive thinking, developed emotional intelligence, etc. (Андрущенко, & Булах, 2018).
2. Continuity: STEM-education begins in the first grade of elementary school, based on the STEM-education in the preschool years, and continues in core high school and throughout life. Early involvement of the child to STEM-education does not only promote creative thinking and formation of research competence, but also provides socialization and development of communicative competence while working as a team.
3. STEM-education is a "bridge" between the education of students and their career. Scientists have estimated that in the future 9 of 10 most popular and highly paid professions belong to NBIC-section will require applicants who have a high level of interdisciplinary competencies in the field of STEM-subjects.
4. The purpose of STEM-education in elementary school is development of students' interest in subjects in mathematical cycle and the formation of interrelated competencies, including conceptual (understanding natural science and mathematical concepts, operations and relations); strategic (the ability to formulate and solve scientific, technical and technological problems); cognitive (the ability to think logically, to explain, to argue and capacity for reflection); operating (ability to do transaction neatly); axiological (the ability to view an object as useful while being able to believe in its own effectiveness.)
5. STEM-education in elementary school is characterized by:
   - Education fundamentalization that gives in-depth study of subjects of the mathematical cycle;
   - integrated training in topics, not subjects, based on interdisciplinary (STEM-subjects) and project approaches;
   - learning from students' discoveries aimed at formation of research competence, mastering algorithms of innovation strategies in project development;
   - practical orientation training (based on knowledge gained in class, students create prototypes / models of real objects, processes or products of modern industry);
   - increased attention to learning English, as the most significant scientific print and electronic resources are created in this language (Завалевський, 2016, с. 3–7)..

Methodology of research

In 2015, experimental work was started in elementary schools, using the scientific and educational project "The Intellect of Ukraine". This educational project is aimed at forming the interconnected STEM-competencies of students (mathematical, research and invention, technological, IT competencies) as a unity of conceptual, strategic, cognitive, operational, and axiological competencies (Бачинська, Ушмарова, & Седеревічене, 2013). In 2019, an intermediate section was conducted to determine the level of formation of STEM-competencies according to the criteria shown in Table 1.

The grouping of participants in the pedagogical experiment was carried out according to four levels of STEM-competencies: high, sufficient, basic, initial.

Experimental work was carried out according to theoretical and methodological guidelines stated above. It included the implementation of technologies of STEM-education in mathematical, scientific, technological and ITeducational sectors "I Study the World" (Grade 1, 9 hours a week), "The Man and the World" (Grades 2-4, 2 hours a week), "StudyingTogether" (Grades 2-4, 2 hours a week) and "Eureka" (Grades 2-4, 1 hour a week).

These are the educational programs of the Mathematics and Natural Sciences education sectors composing the content block of experimental work. We have drawn up educational programs according to the main peculiarity of STEM-education – fundamentalization. It provides in-depth study of the subjects of mathematics and natural sciences cycle beginning from the 1st grade, and knowledge formation of such crosscutting concepts as patterns, scale, proportion, value systems, system models, matter, energy, structure and function, stability and variability, etc.

Table 1. The level of formation of STEM-competencies according to the criteria

STEM-competencies	Criteria
conceptual	understanding of natural sciences and mathematical concepts, operations and relationships
strategic	the ability to formulate and solve scientific, technical and technological problems
cognitive	the ability to think logically, to explain reasons, the capacity for reflection
operational	the ability to perform operations neatly and flexibly
axiological	ability to consider objectively, simultaneous with the ability to believe in their own efficacy

Mathematics education sector

The purpose of mathematics education in our Project is to form students' mathematics competence in the unity of interrelated components (knowledge, skills, values and attitudes), and other key competencies; the development of mathematics skills, logical thinking, creativity, the ability to use the acquired knowledge in everyday life).

According to the State standard of primary education, the overall results of mathematics education in our project includes the ability of students:

1) to investigate a situation and isolate problems that can be solved using mathematical methods;
2) to model processes and situations, to develop strategies (plans) of actions for solving various problems;
3) to evaluate data, process and outcome of education and solve practical problems critically;
4) to apply mathematics experience for the knowledge of the environment.

Following the purpose and objectives of the mathematics education field, we identify the following content lines: "Mathematics around me", "I study math processes and phenomena", "Critical data assessment and own mathematics activity", "The world investigation by means of mathematics".

Following the state standard of primary education, the goals of the leading content line of "Mathematics around me" is defined: "the development in students of grades 1-2 of a sustained interest in mathematics, understanding of mathematics as part of human culture, as a method of learning environment, understanding the importance of mathematics to further social progress; create conditions for the formation of logical and abstract thinking of children; providing their intellectual development". Achieving these goals is shown in the ability of children to recognize the situations in their lives which require the ability to count objects, to measure quantities, calculations; to analyze difficult situations in their lives; to determine a group of interrelated qualities to solve everyday problems of mathematics content; to predict the result of arithmetic operations.

The main purpose of the content "I study math processes and phenomena," according to the state standards of primary education, is defined as "fundamental mastering by students of a system of mathematical knowledge and skills needed to continue mathematics education in elementary school and study related subjects". The indicators of achieving these goals are formed by graduates of the 2nd grade. They can convert information into charts, tables, schematic drawings. The students are able to choose a sequence of actions, to solve the problem situation, to define the action to solve the problem situation.

The content "Critical data assessment and own mathematics activity" involves the development of critical and logical thinking. In second graders it reveals the ability to determine the adequacy of data for solving problem situations; to find out the possibility of using another way of solving the problem situation; to check the result of arithmetic tasks; to find mistakes and correct them.

The implementation of the main content "The world investigation by means of mathematics" – creating the conditions for the development of mathematics abilities of students – requires the solution of interrelated tasks set by the state standard of primary education: the formation of children's ability to determine the essential, common and different features of the objects of the world; to compare them and merge them into a group on a mutually agreed basis; to count objects; to compare numbers and organize them; to construct plane and volumetric figures from hand-made material, to create layouts of real and imaginary objects; to measure values with the help of tools and measuring instruments.

These contents are implemented through the specific subject "Mathematics" and the integrated course "I Study the World".

Natural Sciences education sector

Following the state standard of primary education, the purpose of Natural Sciences education in the elementary school via the scientific and educational project "The Intellect of Ukraine" is the formation of competencies in natural sciences, engineering and technology, environmental and other key competencies. These are based on knowledge mastery and development of skills that ensure successful interaction with nature; forming the basis of scientific philosophy and critical thinking; becoming responsible, safe and environmentally responsible student behavior in the environment, by

understanding the principles of sustainable development. Overall results determined the following abilities of elementary school graduates:

1) to discover the natural world, gain experience of research; to wonder, observe, experiment and simulate; to get pleasure from knowledge of nature;
2) to process and systematize information of natural sciences content obtained from available sources and reproduce it in various forms;
3) to realize the diversity of nature, the relationship of objects and phenomena that explain the role of science and technology in human life, the importance of a responsible attitude to nature;
4) to evaluate facts, to combine new experience with experience gained in the past and use it creatively to solve problems in the natural science sector.

Following the purpose and objectives of the Natural Sciences educational sector we identify the following content lines: "I am a researcher", "I am in the world", "I am an inventor. "

The content lines "I am a researcher" and "I am an inventor" are aimed to implement one of the main objectives of STEM-education – development of students' research competence in science, engineering and technology.

Formation of students' research and inventive competencies begins in grade 1. It is about ensuring the ability of candidates to formulate the questions of scientific nature and engineering problems; to create and use models; to plan and conduct research; to analyze and interpret data; to use mathematical tools; to construct scientific explanations and design engineering solutions; to build arguments based on facts; to receive, evaluate and interpret information properly.

All content lines are implemented in an integrated school subject "I Study the World".

Technological part of the experimental work covers innovative educational technologies which, in terms of the educational environment of scientific and educational project "The Intellect of Ukraine", can realize the objective content of STEM-education in elementary schools.

Folowing the principle of unity of content and procedural-activity (methods, forms, means of educational process) in components of education, and in accordance with the basic provisions of the Concept "New Ukrainian School", the Law of Ukraine "On Education", State standard of primary education in the educational process of 1-2- project's grades are implemented:

interdisciplinary technology of integration, based on building integrated disciplines created by synthesis of scientific knowledge on the basis of the fundamental laws of science and the resulting didactic reflection of extensive natural connections and relations among the various topics and sections of discipline and across disciplines in general;

technology of the educational process enrichment is based on Schoolwide Enrichment Triad Model by J. Renzulli. According to this model the Project aims to have a system of rules for students to do the research of all its components, creating conditions for the development of students' personal qualities (creativity, commitment, perseverance, self-confidence, etc.), cognitive processes and account ability for effective teaching and learning activities, students master the theoretical and practical levels;

technology of complete learning units is based on methodology of complete mastery in cognitive, sensory and psychomotor areas by J. Carroll and B. Bloom, theory of stage formation of mental actions by P. Halperin, repetition interval method by H. Ebbinghauz;

interactive educational technology and critical thinking, work in pairs or groups ("jigsaw", "alphabet", "brainstorming", "Brownian motion", "call", "tree assumptions", "dialogue", "round about", "synthesis of ideas", "small and large questions", "teacher", "six hats"); learning technologies in the game; discussion ("Karl Popper debate", "press method", "choose the position", "talk show"); project method; trainings (psychological training, personal development training). Their aims are to educate students in order that they have successful and happy lives, be proud citizens of Ukraine, active members of civil society who possess traditional and modern democratic values, ideas of positive thinking, as well as to think independently, critically, working in a team, interacting effectively with others;

rational reading technology which purpose is development of students' skills such as reading comprehension, the ability to express their opinion orally and in written form, critical thinking, the ability to justify a position, creativity and ability to handle a significant amount of scientific and educational information for a limited time. The main idea of this technology is systematic work on the formation of the students' skills: 1) the technical component of reading through a set of special exercises aimed at increasing speed of reading aloud and improvement of simultaneous perception of the pieces of text and storing process improvement; 2) the ability to understand, read, interpret and evaluate information through the exercise "Key words", "Questioner", "Technique of argumentation"; 3) the ability to retell the text, highlighting key information, and remembering it to express it orally and in writing; form their own opinion on what they read, justifying it through the complex of exercises, such as "Teacher", "Brownian motion", "Debates"; 4) the ability to create their own essays, narratives, stories.

Results of the research.

Analysis and synthesis of the results of experimental work made it possible to make some conclusions about the importance of STEM-education technology. Significant positive dynamics in the formation of mathematical, research and inventive, technological, informative competencies in comparison with the control diagnostics were revealed.

There was a significant increase in the number of students who, at the stage of the intermediate diagnosis, demonstrated a high level of STEM-competencies: conceptual (53,62%), strategic (39,3%), cognitive (68,2%), operating (54,15%), axiological (41,5%).

Conclusions and recommendations for further research. The study made it possible to conclude that STEM-education in Ukraine reflects trends of modernization of educational systems in leading countries, in accordance with the civilizational challenges caused by the third industrial revolution. Key changes include, for example, the fundamentalization of education, its pre-emptive and interdisciplinary character, the transition from a supportive learning model to an innovative learning technology, the integration of natural sciences and humanitarian knowledge, and so on.

The implementation of STEM-education into the national educational space is carried out in compliance with a series of normative documents at three levels (formal, non-formal and informal). The implementation of STEM-education technology in the elementary schools via the all-Ukrainian scientific and pedagogical project “The Intellect of Ukraine” is assured by grounded theoretical and methodological provisions and educational programs, developed on their basis, in mathematical, natural, technological and informative educational fields.

The results of the experiment to determine the level of formation of STEM-competencies of students (mathematical, research and inventive, technological, informative competencies) proved the scientific validity of the theoretical and methodological foundations of implementation of STEM-education in the practice of elementary school.

Looking forward to further research, we see teachers’ professional preparation for STEM-education, their professional development and support through the creation of professional STEM-collaborations to disseminate innovative pedagogical experience in teaching STEM-subjects, to form STEM-competencies, to motivate students to STEM-careers.

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Information about the authors:
Gavrysh Irina Volodymyrivna
irina.gavrysh@gmail.com
H. S. Skovoroda Kharkiv
National Pedagogical University,
Alchevsky St., 29
Kharkiv, 61000, Ukraine

Ushmarova Victoria Volodymyrivna
victoria.uschmarova@gmail.com
H. S. Skovoroda Kharkiv
National Pedagogical University,
Alchevsky St., 29
Kharkiv, 61000, Ukraine

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Відомості про авторів:
Гавриш Ірина Володимирівна
irina.gavrysh@gmail.com
Харківський національний педагогічний
університет імені Г. С. Сковороди,
вул. Алчевських, 29
м. Харків, 61000, Україна

Ушмарова Вікторія Володимирівна
victoria.uschmarova@gmail.com
Харківський національний педагогічний
університет імені Г. С. Сковороди,
вул. Алчевських, 29
м. Харків, 61000, Україна

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