МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

КРЕМЕНЧУЦЬКИЙ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ
ІМЕНІ МИХАЙЛА ОСТРОГРАДСЬКОГО

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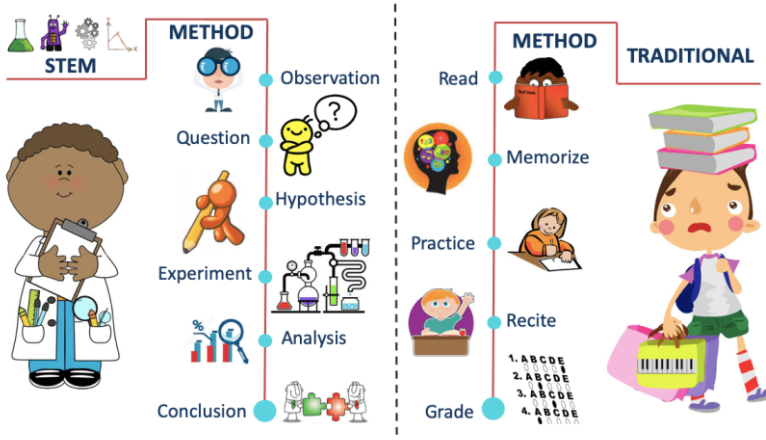
Basics of STEM education

Навчальний посібник



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Навчальний посібник «Basics of STEM education» («Основи STEM-освіти») висвітлює питання імплементації STEM-освіти в українську шкільну освіту, зокрема, в аспекті розбудови Нової Української школи, для якої концепція STEM є фунтаментальною. Посбіник розкриває особливості STEM підходів на уроках математики та інформатики. Окремі підрозділи присвячено методичній підтримці вчителів, які упроваджують STEM-освіту, шляхам реалізації STEM-освіти у школі, а також організації інтегрованого навчання, яке є базою STEM-освіти. У посібнику висвітлюється досвід упровадження STEM-освіти у Кременчуці та на Полтавщині. Контрольні запитання і практичні завдання, які додаються до кожного підрозділу, допомагають здобувачам освіти перевірити рівень засвоєння теоретичного матеріалу. Посібник написано англійською мовою, оскільки відповідна навчальна дисципліна («Основи STEM-освіти») викладається у КрНУ англійською.

Посібник призначений для здобувачів вищої освіти зі спеціальності 014.09 «Середня освіта (інформатика)». Також він буде корисним вчителям-практикам і всім, хто цікавиться STEM-освітою.

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Minister of Education and Science
of Ukraine
Oksen Lisovyy

Mathematics, science, engineering, technology are the basic components of STEM, but the concept is much broader, it is a systemic process and, as a rule, it touches/covers almost all educational fields. The areas of STEM education are robotics and programming, as well as chemical-biological and agro-ecological technologies, construction, the basics of video technologies, digital art, etc.

CONTENT

INTRODUCTION

One of the most important tasks facing Ukrainian education today is modernization with the aim of joining the world education system, which involves the active involvement of advanced pedagogical experience, innovative learning technologies, etc. Reforming the education system is one of the most important components of the European integration process of Ukraine. The need to approach European standards is a priority task of education. European and world trends to integration and globalization in education, changing the educational paradigm, modern social demand for quality education determines the importance of optimizing it work are construction of the educational process in the context of implementation innovative pedagogical technologies, improvement of methodological and pedagogical the principles of activity of educational institutions for the formation of children's and young people's ability to learn and use knowledge in practice.

In education, approaches are divided into traditional and innovative. In context traditional approaches (knowledge, activity, etc.) with the main purpose and content learning is the acquisition of knowledge, the formation of skills and the ability to use it in practical activities. In particular, the cognitive approach is focused on acquisition students of the knowledge defined by the curriculum. Active approach aimed at the formation of students' abilities and skills of educational performance task. Recently, the number of approaches is constantly increasing. Special differentiated, person-oriented, gender, competence, cultural approach, which in its content is innovative.

In the "National strategy for the development of education in Ukraine for 2012–2021" it is emphasized that the key directions of the state policy in the field of education should be the updating of the legislative and regulatory framework of education, adequate to the requirements of

the time, with the aim of bringing the structure and content of education into compliance with European standards, as well as modernization of the structure, content and organization of education on the basis of the competence approach, reorientation of the content of education for the purposes of sustainable development; understanding that the modern labor market requires from a person with a higher education not only deep theoretical knowledge, but the ability to independently apply it in non-standard, constantly changing production and life situations, the transition from a society of knowledge to a society of vitally and professionally competent citizens.

In the field of school education, STEM education (abbreviated as ***S****cience*, ***T****echnology*, ***E****ngineering*, ***M****athematics*), which is an educational system that combines science, technology, engineering and mathematics, is currently the most common in the developed countries of the world. It is this complex that makes it possible to form a qualified specialist capable of successfully competing in the conditions of accelerated scientific and technical progress and rapid changes in the economy. Conceptual approaches and methods of STEM education are thoroughly covered in this guide.

One of the basic characteristics of STEM education is that it is based on an integrated, interdisciplinary approach: rigorous academic concepts are combined with problem-based classes that reflect all the complexity of the real world and are aimed at creating a specific product or result.

An interdisciplinary approach to learning that creates connections between school, community, work and the global enterprise enables the development of STEM literacy and, with it, the ability to compete in the new economy.

In Ukraine during reform has been underway for the past few years of secondary education, and secondary schools are implementing updated educational standards. Educational programs of the updated content of education ensure the implementation of the principle of the unity of education and education based on the interrelationship and

interdependence of educational values and results at the "exit" from school with a system of learning objectives specific subject.

An excellent feature of educational programs is their focus on the formation of not only subject knowledge and skills, but also a wide range of skills.

The built system of learning goals is the basis for the development of the following skills of a wide range: functional and creative application of knowledge, critical thinking, conducting research works, use of information and communication technologies, the use of various methods of communication, the ability to work in a group and individually, problem solving and decision making.

It is important to note that the education system using STEM pedagogical technology has not yet been formed, therefore it is ahead of educational technology the society faced the task of improvement educational process, introduction of new technologies.

To modernize and improve education it is necessary to study and implement STEM education in the everyday educational process.

STEM education is gradually spreading in Ukraine, in particular, scientific conferences, seminars and forums are being held, and STEM centers are being created. At the moment, STEM technologies are most actively implemented in the secondary education sector. This determines the importance of scientific understanding and substantiation of the experience of implementing elements of STEM education. In the process of training, future teachers must not only master the system of theoretical knowledge, but also acquire the practical skills and abilities necessary for future activities in the specialty, which involve a creative approach to professional tasks.

STEM technologies in education are very important, so the world is starting to depend on these skills. Any branch of our life (economy, medicine, industry) reinforced science, technology, engineering and mathematics.

Training of future innovators and inventors should begin with STEM curricula. It is necessary to master traditional education and focus on the priority of practical experience real world.

Understanding the experience of implementing STEM education in Ukraine, in particular, at the regional level, is also an important task.

Module 1

Implementation of STEM education at school

DIRECTIONS OF STEM EDUCATION DEVELOPMENT

The abbreviation STEM is deciphered as:
S – science
T – technology (technologies)
E – engineering
M – mathematics

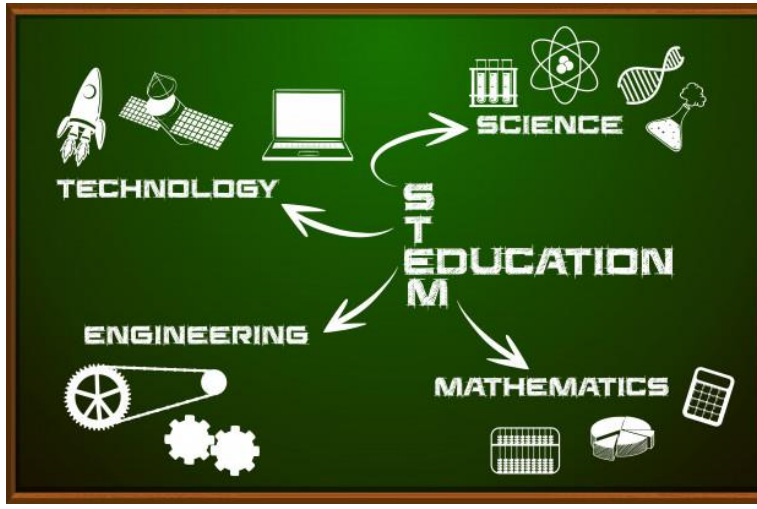

Figure 1.1 – STEM education

The acronym STEM defines the characteristic features of the appropriate didactics, the essence of which is a combination of interdisciplinary practices of oriented approaches to the study of natural

and mathematical disciplines. At the same time, STEM actively includes a set of creative, artistic disciplines united by the general term Arts (the designation of the corresponding approach is STEM and Arts). Current areas of STEM and Arts are industrial design, architecture, industrial aesthetics, etc. Recently, the European scientific debate emphasizes the importance of all disciplines, the use of interdisciplinary STEAM approaches (the letter A – All – all) and the combination of natural sciences with other educational disciplines studied at school.

Critics of the STEM Approach Raise Concerns About Enthusiasm practical and particular tasks and poor development of fundamental knowledge, general concepts, the ability to operate complex abstract ideas and models. There are several suggestions for STEM responses to such criticism. For example, revision of the minimum level of knowledge required for everyone, limiting this level to simple and practical questions.

The deepening and development of more fundamental knowledge is proposed to be transferred to an individual trajectory. Another suggestion lies in the fact that practice-oriented tasks and projects serve only an entry point and motivation for mastering fundamental knowledge.

The third proposal can be called the installation that all specific tasks to be solved must necessarily lead to the development of general solutions, theories and ideas.

STEM education is a specialized field, the main emphasis of which is on the study of exact and natural sciences, with the addition of powerful innovative and technological components. They rightly claim that STEM is the best educational solution for training modern specialists in the field of engineering and technology.

STEM education is a series of programs and experiments that combine natural science components and innovative technologies. By the way, technologies can even be used in creative or artistic disciplines (for example, children can create music with the help of computer programs).

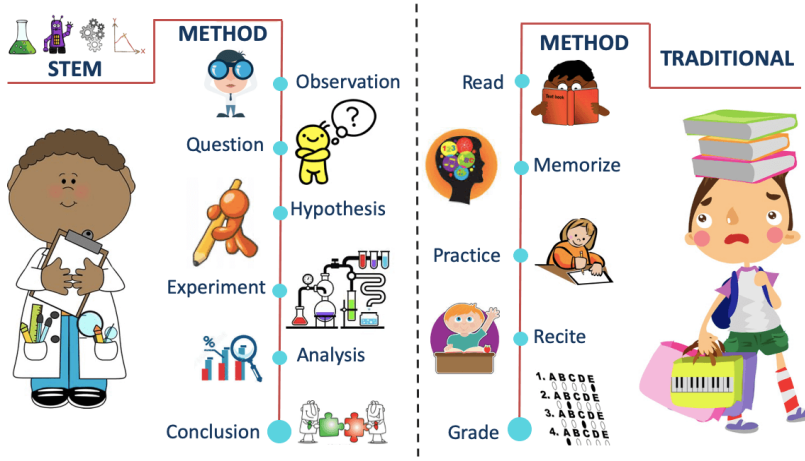

Figure 1.2 – Comparison of traditional education and STEM education

STEM education should cover all levels: from preschool to higher and postgraduated education.

STEM education is designed to increase interest in the exact and natural sciences, to research activities, to the motivation for choosing engineering professions in conditions of rapid development of “smart” technologies.

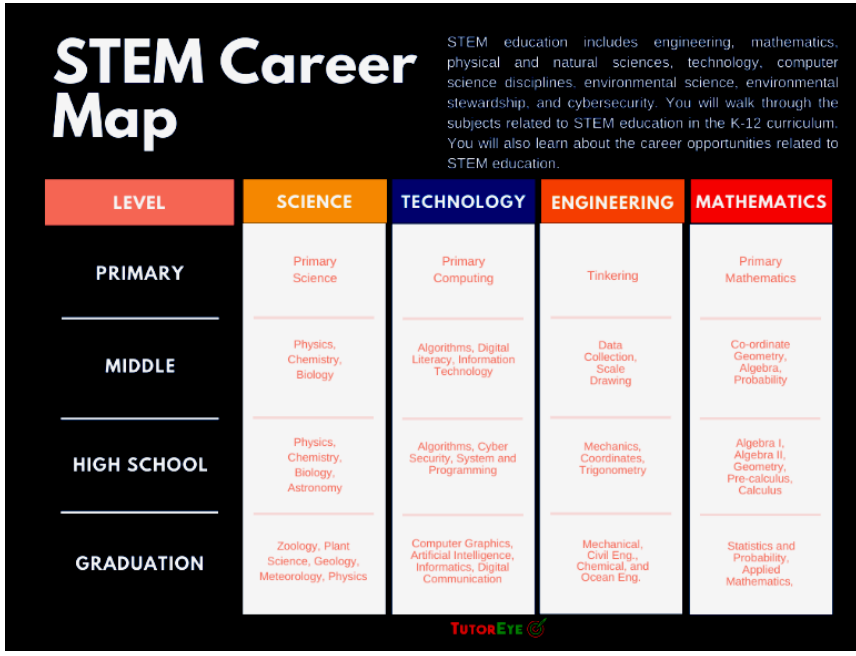

Figure 1.3 – STEM education at the different levels

D. Carlisle and G. Weaver are of the opinion that **STEM education centers (Science Education Center, SEC)** are of great importance for improving the training of engineers. According to the researchers, they inform students about the benefits of STEM education and unify the efforts of higher education institutions, increasing their significance and importance both inside and outside. The centers provide funding for STEM programs, provide additional resources and incentives for the implementation of STEM education through an increase in the number of hours of educational practices (Evidence-Based Instructional Practices, EBIPs) and STEM research projects. STEM centers complement these activities with learning outcome assessments and learning innovations. Today, a common fact is the opening of STEM education centers (SEC). Consequently, the increased focus on STEM education at the national

level is increasing the involvement of universities and colleges in education reform towards STEM. We believe that the development of existing and the creation of new centers of STEM education as a result of the interaction of various participants interested in training new types of specialists is an urgent task of education in Ukraine.

The essence of STEM education is that it is “learning in reverse”, “inverted education”, because the path “from theory to practice” in STEM is usually the opposite: first, practice (inventing and designing devices and mechanisms), and only then, in the process of this activity, mastering theory and new knowledge.

Flipped class is a learning strategy that "reverses" the distribution time resources: the main activities that were traditionally carried out in the classroom, performed outside of it through the independent work of students.

In the case of a flipped classroom, class hours are mostly reserved for activities for consulting and consolidating the subjects studied by students in the process self-learning.

The flipped class method is most effective when students are highly motivated, and as well as their skills in self-study, planning and critical analysis of their educational activities.

The main prerequisites for the "flipped class" are:

1. Modern technology opens up new opportunities for students to independent learning.

2. Multimedia learning materials thoughtfully designed and linked with the age characteristics of the student, can largely create favorable environment for self-learning.

3. The transition from the initial stages of learning, traditionally held in the classroom, to independent learning makes it possible to use class hours and time teachers for cognitive activity of a higher level (understanding, application, analysis, synthesis, evaluation).

The special features of STEM education, which distinguish it from traditional education, are the active application of the principles of integration and the project approach in the educational process. The actualization of the content is possible under the condition of studying

fundamental scientific disciplines based on modern practically significant examples and tasks.

STEM educational technologies are emerging in all regions to keep Ukraine as one of the leading countries in technological breakthroughs and scientific research. However, as with many important contemporary programs, state funding for STEM education is often insufficient or incomplete. Instead of public programs, private investors are raising enough money to advance the STEM education agenda because they understand that investing in our nation's education is one of the most important strategies for maintaining a strong, sustainable economy in the future.

The ultimate goal of STEM education is to encourage students to show an interest in STEM subjects early in their studies. This should benefit them when they enter the labor market, and in turn, it should benefit the country's economy.

STEM education is a priority due to the demand for IT specialists, programmers, engineers, and technological production specialists. STEM education is an integrated approach to learning in which academic scientific and technical concepts are studied in a real-life context that requires different and more technically complex skills.

Technological STEM education is usually supported by the humanities, which are "responsible" for the creative development of the individual. For example, **STEAM** (when art skills are developed in parallel with mathematics or physics), **STREAM** (together with reading) and **STEMM** (supplemented by music lessons). Since STEM is not only an education, but also a professional field, there is a significant shortage of specialists in the latter today.

The main reasons that led to the development and widespread use of STEM teaching methods in the developed countries of the world are as follows:

1. In the near future, out of the 10 professions with the highest growth, 9 will require STEM knowledge.

2. Despite the fact that in the technological sector of the economy of developed countries, about a quarter of the Gross Domestic Product of

the respective countries, the total number research workers in mathematics, natural and technical sciences becomes insufficient.

3. A small number and relatively low skill level of engineering and technical of the workforce leads to the immunity of the economy to technological innovations.

4. The slowness of the educational system in fulfilling social orders and satisfaction of the requests and requirements of the state, family and society related to the level of training of graduates who intend to work in high-tech sectors of the economy.

5. Most school graduates do not have sufficient knowledge and skills in the field of exact and natural sciences, while society is in dire need in highly qualified specialists, inventors, innovators and entrepreneurs.

STEM education is the basis of training workers in the field of high technologies. Therefore, many countries, such as Australia, China, Great Britain, Israel, Korea, Singapore, and the United States, have government programs in the field of STEM education.

Singapore has achieved significant economic success. Singapore's education system remains promising. With the introduction of bilingualism with English (in addition to the mother tongue), a focus on science, technology, engineering and mathematics (STEM), Singapore anticipated many of the key education strategies adopted by today's policymakers. Back in 2002, the "Transforming Singapore" initiative was launched, aimed at transforming this city-state into a world center of creativity, innovation and design. The government of Singapore is reforming the education system in order to stimulate the creative qualities of young people. One of the ways to do this is to attract young, talented people who think in a new way to various government structures responsible for economic policy.

The organization "Change the Education" conducted a study: in the United States, there are an average of 1.7 open STEM jobs per potential employee. For comparison, in other industries, the competition is approximately 4.1 unemployed per vacancy. Demand for STEM professionals was high in 2018. In particular, the demand for computer

technologies was 71 %, traditional engineering – 16 %, natural sciences – 7 %, biological – 4 %, mathematics – 2 %. Even in developed countries, such a trend is observed, specialists in the above-mentioned technologies are not enough either in Great Britain or in Germany. STEM education is quite common in the United States - American schools have shifted the emphasis in the curricula to those areas that have traditionally received insufficient attention. The educational process was simply brought closer to the realities of the modern economy, even talking about the same skills to quickly bring innovative products to the market.

There is even a specialized scientific journal on STEM education.

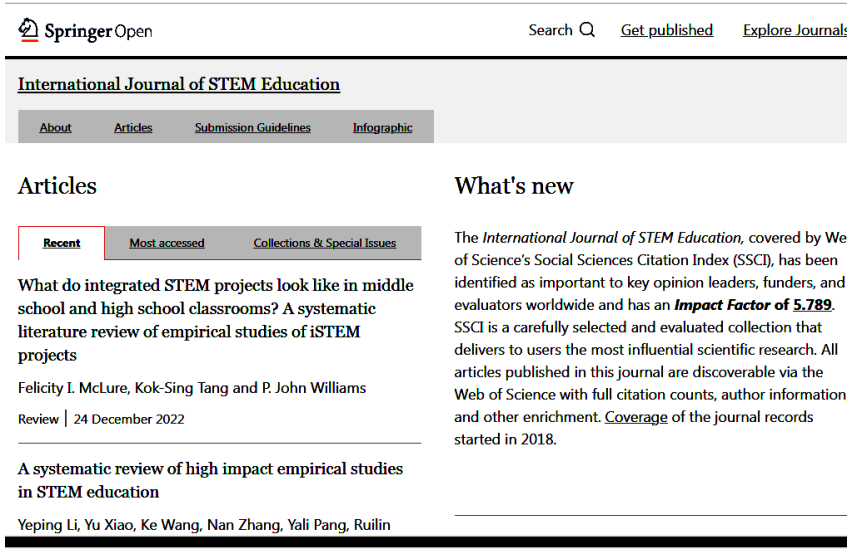

Figure 1.4 – International Journal of STEM education

The leading countries of the world are active in involving schools, universities and enterprises in the integration of STEM in education and

science and, subsequently, the employment of STEM specialists in all areas of the labor market.

The rapid evolution of technologies means that soon the most popular and promising specialists in the world will be engineers, IT specialists, programmers, professionals in the field of high technologies, etc. In the distant future, there will be professions that are hard to imagine now, all of them will be related to technology and high-tech production on the border with natural sciences. Specialists in the IT industry and specialists in bio- and nanotechnology will be especially in demand.

This is also confirmed by the American ranking of STEM vacancies Best Technology Jobs, which is formed based on a combination of various factors of the labor market.

If STEM is identified as a real national priority of the country in the field of education, the government and institutions of higher education should consider using a serious integrated approach to promote STEM education as an effective means of further employment of students, first of all, with the help of teachers who cooperate on the Internet and social networks at the same time as students and colleagues, and are the authors of new STEM practices (cases), spreading them through exchange, publications.

Recently, it has become obvious that the classical approach to Ukrainian education no longer meets the needs of a rapidly developing society. A traditional university may well produce excellent teachers of philosophy or history, but for mechanics, engineers, inventors, a different style of receiving and applying new information is needed, which should be available from childhood. Such an approach can not only help to reveal the talents and abilities of young innovators in time, but also give an opportunity to get closer to natural sciences and stop being afraid of "complex matters". Every year, the need for specialists in technical professions will grow, and we are already experiencing their shortage.

STEM combines a project-based and interdisciplinary approach that is currently recognized as the best by teachers around the world. It is based on the integration of natural sciences, technology, mathematics and

engineering creativity. All these fields are closely related in practice, therefore, their study in a common plane is very important.

One of the shortcomings of our education is that children simply do not understand how exactly they can apply their knowledge of exact and natural sciences in the future, so interest is not too high. STEM corrects this mistake and shows how children can use the information they receive in life. Students will not just study abstract data, they will explore a specific project and then implement the creation of their own project of a specific product. By conducting entertaining experiments, children easily begin to understand complex formulas and memorize terms.

STEM is inextricably linked to and aimed at developing critical thinking. Schoolchildren should learn to navigate independently even in difficult situations and solve problems without outside help, based on acquired experience, analogies and generalizations.

By creating interesting projects that really work, children not only learn, but also increase their self-esteem. Working in a team develops cooperative actions, the ability to determine the strategy of project implementation.

One of the main tasks of STEM is the promotion of technical and natural sciences. Being an engineer or a mathematician is not boring at all, on the contrary, it is fun and interesting. Even more so, because among the common teaching aids are constructors, robotic systems, 3D models, measuring complexes, laboratory devices, projection tables, overhead projectors, etc.

Therefore, the implementation of STEM education in Ukraine is connected with the employment problems of students of engineering specialties, which requires the dissemination of quality information about STEM among students, their parents, applicants, and students. Information about the quality of STEM education among employers is of particular importance for employment.

Scientific methods, mathematical modeling, engineering design and innovative thinking are the basis for STEM education. From this description, it may seem that STEM is an education intended exclusively

for training future IT specialists, and this is partly true. However, STEM education is broader, because it combines exact sciences with a creative approach and promotes the development of both directed at the personality of students.

In particular, musicians, artists, and philologists are trained in STEM methods in European countries. And all because specialists who understand technology are increasingly in demand on the labor market: already today, musicians create hits with the help of special software, and linguists study language thanks to artificial intelligence and big data.

Developed countries such as Singapore, the USA, Israel and Australia have been training schoolchildren in STEM fields for decades. STEM education has been officially introduced in Ukraine since 2015.

Cabinet approval of the Ministers of Ukraine "Concepts for the Development of Science and Mathematics Education (STEM Education)" (2020) confirms the importance of STEM education for Ukraine and at the same time raises the issue of new requirements for quality training of STEM personnel (science and mathematics), who in the future should form the country's own scientific and technical elite.

In Ukraine, the introduction of STEM education, in accordance with the mentioned Concept, is carried out taking into account the following principles: personal approach, permanent updating the content, continuity, patriotism and social orientation, productive motivation, integration, developmental and problem-based learning.

STEM education is implemented through all types of education, namely: formal, informal, informal (on online platforms, in STEM laboratories), by conducting excursions, competitions, Olympiads, festivals In addition, engagement is a must specialists to develop software and computer programs for everyone STEM subject.

Modern STEM education is aimed at technologies that are relevant not only at the moment, but also important for professions, the importance of which is still being formed. In other words, STEM education is focused on both the modern labor market and the predicted one.

Control Questions

1. How is the acronym STEM deciphered?
2. Who are the stakeholders in the development of STEM education?
3. Which countries were the first to develop Stem education and why?
4. When did Ukraine join the introduction of STEM practices?
5. Why is STEM education considered a priority?
6. What is the purpose of the activity of STEM centers?
7. What is "inverted education"?

Tasks

1. Prepare a presentation on the topic "Development of STEM education in the world".
2. Monitor the implementation of STEM practices in schools of the Poltava region.

STEM EDUCATION AS A PART OF THE NEW UKRAINIAN SCHOOL CONCEPT

STEM education is an integral part of the **New Ukrainian School (NUS)** concept, because it is aimed not only at acquiring knowledge but also at developing competencies.

The New Ukrainian School, this concept and its basic concepts are that at schoolchildren need to be given not only theory, but also taught to find the necessary knowledge, apply it, and be able to think critically.

The new Ukrainian school is based on the competence approach. Key competences are those that everyone needs for personal fulfillment, development, active citizenship, social inclusion and employment and which are able to ensure personal fulfillment and life success throughout life.

10 key competencies of the New Ukrainian School (NUS):

1. Communication in the state (and native in case of difference) languages.
2. Communication in foreign languages.
3. Mathematical competence.
4. Basic competences in natural sciences and technologies.
5. Information and digital competence.
6. The ability to learn throughout life.
7. Initiative and entrepreneurship.
8. Social and civic competence.
9. Awareness and self-expression in the field of culture.
10. Environmental literacy and healthy life.

Such skills are common to all competencies:

- ability to read and understand what is read (#to read);
- ability to express an opinion orally and in writing (#express);
- critical thinking (#think #medialiteracy);
- ability to logically justify a position (#logic);
- show initiative (#initiative);
- create (#create);

- ability to solve problems, assess risks and make decisions (#make decisions);
- ability to constructively manage emotions (#emotions);
- applying emotional intelligence (#emotions);
- ability to cooperate in a team (#teamwork).

In fact, this is all at the heart of STEM education:

- formation of professional and social competences (competence is a combination of knowledge, abilities, skills, values that is the result of training);
- formation of scientific perception of the world;
- development of individuality.

The New Ukrainian School has three levels of education: primary level, basic level, and specialized level.

The task of primary education is to encourage the child to desire to gain knowledge, to independent research, to create the simplest projects.

The task of the basic level is to interest students in natural and mathematical sciences, to teach them to apply them in practice to solve problems in technologies.

The task of the profile level is to promote the right choice of further education: research activities, competitions, projects, development of startups.

Among the **competencies of NUS** that intersect with STEM goals:

1. Developing logical and mathematical thinking.
2. Understanding nature and technologies from the position of exact sciences.
3. Education with information and communication technologies, ability to use them.
4. Forming the ability to think creatively and express creative abilities.

It is for the implementation of STEM education that education will continue until the age of 12. With this approach, it will not be a strengthening of the curriculum, but an improved transition from a "theoretical approach to learning" to a "scientific-practical one".

Therefore, you should not be afraid of 12 years of education, you need to inform parents and teachers sufficiently.

Combining subjects into educational fields is not a simplification of the program, but a desire for a competency-based approach to education. The same applies to the expansion of educational subjects, this is not planned, it is better to integrate relevant topics into already existing ones. This particularly applies to philosophy.

For the profile level of education, students and parents will be able to make their own choices in favor of subjects that they will need in the future when receiving an education. This approach has proven itself well in many countries whose education is based on the STEM approach. For example, natural sciences are combined in the "Science" course, this allows you to acquire holistic knowledge, such as when studying the circulatory system, the student studies it in terms of biology, chemistry, and physics (chemical composition, structure, speed).

With such an approach, already at the end of their studies, children will have comprehensive knowledge that will help them with the further choice of the desired profession.

The New Ukrainian School includes inclusive education. That is, children with special needs will be integrated into regular schools, they will study on the same level as everyone else, this is an important step both at the pedagogical and social level.

But STEM education is not only written curricula, it is also an educational space in which schoolchildren will be. It should be remembered that classrooms should be comfortable, meet sanitary standards, and be technologically equipped. Only such a space will make it possible to implement the new reform.

Without which there can be no Ukrainian school or STEM education, this is perhaps the most important link of this process are teachers. Now the realities are such that many teachers do not meet the standards of the new Ukrainian school. The Ministry of Education and Science of Ukraine is making a lot of efforts to eliminate this problem: online courses, seminars, trainings, webinars, we hope that over the years the

teaching profession will gain prestige and competitiveness. Therefore, NUS with a STEM approach is the training of the teachers themselves, raising their professional level.

From the experience of other countries, it is clear that STEM specialists are more valued in the labor market, and the need for them is growing year by year.

One of the main tasks of STEM education is the development of systemic thinking in schoolchildren. That is why you can often find multidisciplinary among STEM students, for example, designing a greenhouse or working traffic lights at an intersection. Combining various sciences and views of reality, STEM education teaches children to live in a rapidly developing world; easily and quickly adapt to new technologies and trends.

The potential of STEM education for **schoolchildren** is:

- more effective assimilation of educational material;
- complex understanding of subjects and processes;
- interesting educational process and motivation to learn;
- originality of thinking;
- the ability to formulate research questions and comprehensively search for solutions;
- the opportunity to get a prestigious higher technical education in the best universities and find a high-paying job in any country in the world.

STEM education allows **teachers** to:

- visually convey knowledge and skills, promote students' independence;
- use extraordinary approaches in training;
- they teach more motivated and interested students.

STEM principles can be introduced both in computer science or mathematics lessons, and in Ukrainian language lessons; both in elementary school and in high school. Wherever you use STEM tools, they diversify the learning process and make knowledge more visible,

which means that it will be easier to understand and remember new information.

It is not difficult to introduce STEM education methods into the general educational process; all that is needed is the motivation of the teacher and a creative approach to explaining the educational material.

The STEM approach involves teamwork. Therefore, students cannot do without interaction during work and searching for joint solutions. After all, it is obvious that communication skills are in demand in the modern world no less than professional knowledge. Each student of the team gets his role at all stages of creating the project.

High-quality equipment for busy STEM makes it easier for the teacher to organize the lesson, because most of the teaching sets contain ready-made methodical materials in which the roles of children during group work are prescribed.

Practical project work focuses children's attention on solving the problems of humanity or everyday complexities. For this, children get to know and use knowledge of engineering as a practical and accurate field of activity. The more various parts, elements, and spare parts students will use, the more large-scale and thoughtful projects they will be able to implement.

Schoolchildren explore both a task or a problem that needs to be solved, and a ready-made module or program. STEM equipment for schools is a relatively new and interesting activity, so the desire to explore arises in children on their own initiative.

STEM equipment contains technological elements, electronics, structural and decorative details. Thanks to such equipment, students can assemble almost any mechanism, device or system, or improve already ready projects (Fig. 1.5).

Figure 1.5 – STEM classes

The task must be completed during the lesson (or for a certain time), using only the available equipment, taking into account the number of students in the team and their skills. This develops both leadership skills and the ability to plan and be responsible for one's own decisions.

Bright, mobile, complex constructions and technological equipment arouse interest in learning, focus attention more easily, and make it more pleasant for students to explore ready-made projects and engage in them.

STEM classes and robotics, in addition to studying basic STEM disciplines, are easily combined with other subjects. The methods and equipment can be used in the lessons of geography, physics, mathematics, visual arts, and others. The interdisciplinary approach strengthens all subjects that are studied in parallel, and also shows the interrelationship and practicality of knowledge.

And this is one of the most important advantages of STEM, because technologies are developing at an incredible pace, at which children must

keep up. Therefore, teachers should already think about how to educate the best specialists of the future who will be able to combine science and art in a qualitative way.

STEM schools form a special style of thinking. The child becomes more consistent and at the same time is not afraid to look for alternatives. During classes, students themselves look for ways to solve the problem – change the design, rewrite the program or choose another approach to the problem. Such independence trains the ability to plan work and divide tasks into parts.

The obtained results of experiments often do not coincide when students choose different approaches. This is how a child learns to analyze information and defend his point of view with arguments, because everyone has facts based on his measurements.

Control Questions

1. How is the concept of the New Ukrainian School related to STEM education?
2. What is the difference between competences and knowledge?
3. On which approach the New Ukrainian School is based?
4. How do New Ukrainian School competencies correlate with STEM education?
5. How does STEM education affect the formation of a holistic worldview of students?
6. What is the special style of thinking, which forms STEM schools?
7. What makes STEM education attractive to schoolchildren?
8. Does STEM education contribute to the development of soft skills?

Tasks

1. Find signs of applying the principles of STEM education in the NUS Concept.
2. Analyze the school computer science program for the 5th grade in terms of implementation of STEM education.

3. Analyze the school computer science program for the 6th grade in terms of implementation of STEM education.
4. Analyze the school computer science program for the 7th grade in terms of implementation of STEM education.

STEM EDUCATION IN MATHEMATICS LESSONS

Schoolchildren rarely call mathematics their favorite subject. It requires maximum concentration, as well as the ability to think abstractly, which is not easy for many children. In this case, STEM methods can help children understand and love mathematics.

In modern Ukrainian secondary education institutions, the situation has developed such that the vast majority of students, even winners of chemistry, biology, computer science olympiads, do not really like mathematics, considering it a subject that is a tool for other, more interesting sciences. Instead, mathematics can be interesting if it allows you to solve complex applied problems. Mathematics becomes really interesting for students only when they are involved in solving non-standard, creative problems.

The professional orientation of topics in mathematics is designed to form students' persistent interest in the subject, develop their mathematical abilities, and contribute to their preparation for participation in olympiads and competitions of various levels in mathematics.

Mathematics is a unique means of formation not only educational, but also developmental and intellectual potential personality A clear logical scheme of reasoning, accuracy, brevity of language, systematic consistent argumentation: all this contributes to the education of the mental culture of students, influences for the successful study of all subjects, including humanitarian Implementation of STEM education is an innovative way in studying mathematics.

Elements of STEM education can be used on in mathematics lessons while solving problems, in the project room work and extracurricular activities. These can be tasks about architectural buildings and sights of the native city, the world; tasks biological, chemical, physical and geographical content.

The effectiveness of mathematical problems and exercises that activate the mind the activity of students in class depends on the degree of creative activity of students. In the process of solving such problems, students consider all possible options given situation. Solving

mathematical problems and exercises aimed at memory and attention leads to new ideas. Completion of tasks and proof exercises promotes the development of logical thinking. Schoolchildren create their own algorithm solving problems, there is a need to substantiate mathematical facts and concept.

Mathematical problems, depending on their role in the educational process, are divided by didactic goals: tasks of a cognitive nature, control, training and development.

In the process of learning mathematical disciplines, it is important to use educational programs for interactive content of lessons. Usually they are act as a means of visualizing the studied mathematical objects, expressions, illustrations of construction methods; as an environment for simulation and empirical research of properties of objects; as instrumental and measuring a complex that provides the user with a set of specialized tools for creating and transforming an object, as well as measuring its specifications parameters. Involvement of students in completing tasks using such programs contributes to the expansion of the range of educational tasks, including in it non-standard tasks of a research nature, optimization tasks.

Applied orientation is important in the school mathematics course, that is orientation of goals, content and means of learning in the direction of students' acquisition of the process of mathematical modeling of knowledge, abilities and skills that will be used by them in various spheres of activity. Solving problems applied direction involves the use of functional components related to motivation and setting goals for studying the course, students clarifying the importance of the applied component and applied potential of the abstract component of the course. Educational activities related to introducing into the training components characteristic of applied activity:

– use of heuristic reasoning, application of mathematical modeling as a basis for studying the course of mathematics and the solution method applied problems, development of mathematical abilities and skills necessary for solving applied problems; professional and educational

activities (skills planning and adjusting activities, independent work, creative activities, work with computer programs);

- activities related to modeling geometric situations.

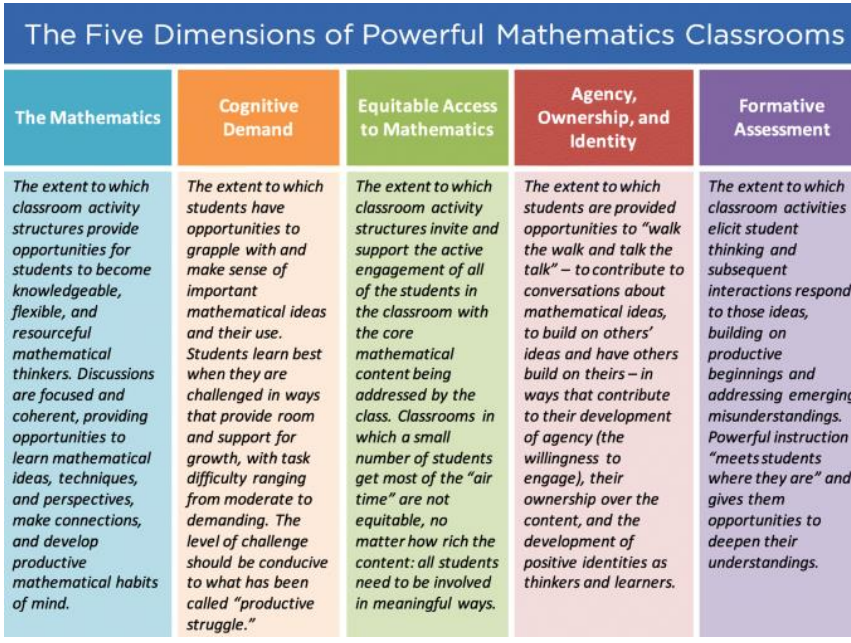

Figure 1.5 – The Dimensions of Powerful mathematics Classroom

In the process of solving applied problems, it is advisable to involve work in pairs, a person-oriented approach, which includes the method of projects, training incooperation, contextual learning, intensive learning and multi-level learning. Working in pairs or groups, students freely express their own opinion, defend it, learn to formulate and present their work correctly.

Let's consider the project method in more detail. In the basis of the method of projects as synthesis of methodical methods is assigned to the comprehensive teaching method exploratory nature. This way of

organizing the pedagogical process, based on the interaction of the teacher and the student between themselves and the environment in the process of implementing the project – step-by-step practical activities related to achievement of the educational goal.

Implementation of educational projects involves integrated research, creative activity of students aimed at obtaining independent results under the guidance of the teacher. During the study of school material, students will develop educational projects under the clear guidance of the teacher. At the same time, the teacher is only helps in determining the purpose, tasks, methods and techniques of research, searching for information, and research work is carried out directly by students.

In the process of implementing educational projects, different levels are implemented didactic, educational and developmental tasks: students acquire new knowledge and skills they will need in life; develop motivation and cognitive skills; form the ability to independently navigate information spacious, express their own judgments.

Adhering to STEM approaches in the educational process, the teacher forms students, the most important characteristics that define a competent specialist:

- the ability to identify a problem;
- the ability to identify as many sides of the problem as possible;
- the ability to find ways to solve a problem; the ability to be original, departure from the template;
- the ability to regroup ideas and connections;
- the ability to abstraction or analysis; the ability to concretize or synthesize.

This will allow to approximate the content of various spheres of human scientific and technical activity society to the educational process.

For secondary school students, Ukrainian teachers and methodologists recommend conducting a series of practical activities called "My Farm", in which they need to calculate how many pets need to be kept and how much different feed for them needs to be purchased or prepared during the year, so that a family of five people can ask eggs,

dairy products and meat. It is possible to complicate the task by adding to the task the calculation of the necessary fruits and vegetables, and, accordingly, the expenses for the maintenance of the garden and vegetable garden, as well as the area for pastures and cultivation.

In this assignment, students will work at the intersection of biology and mathematics. The clarity of the task will help them to concentrate more effectively and learn new material better.

The project "STEM: professions" was implemented in Ukraine of the future" for students of secondary schools.

The goal of the project is to familiarize students with STEM professions, namely to introduce them to the world of new concepts, in particular, such as innovation, engineering, reengineering, creative industry, mechatronics, nanotechnology, fundraising, scientific literacy, educational robotics (ORT), project activity, facilitation etc.

For the formation and development of STEM skills with early childhood use STEM toys, the development of which is aimed at an entire industry.

These are robot toys, lotto, dominoes, puzzles, moving cars, etc. For example, a high-tech ball robot (Sphero Mini), which can control using a smartphone or tablet through a mobile application. Built into the toy gyroscope and accelerometer. This toy develops the motor skills of the child's hands and logical thinking.

Certain STEM equipment has been developed for each educational field. For mathematical education industries with the help of LEGO constructors is possible to create an exciting practice-oriented educational process aimed at forming students STEM competencies. LEGO pieces and robotic platforms help in math lessons awaken children's natural curiosity and develop the most important communication and creative skills thinking, joint activity and critical thinking. With LEGO, you can learn parts and fractions, arithmetic operations, the laws of addition and multiplication etc.

Sets for modeling 2D and 3D objects, 3D printers, 3D glasses, mobile applications for learning are used from geometric material spatial figures,

cards with augmented reality, etc. For example, to study volume figures use Google VR services. Based on the Cardboard application allows you to create and customize your own 3D glasses, which are used to watch videos with elements of augmented reality.

To study units of measurement, models of mechanical clocks, stopwatches, various scales, measuring tools length, width (ruler, caliper, tape measure, compass, protractor).

In order to improve the quality of professional training for the educational process, such a type of educational work as solving problems using mathematical modeling methods with the use of information and communication technologies can also be introduced. Modeling involves the process of studying a real system, which includes building a model, studying it, and transferring the obtained results to the system being studied. Designing technical objects is impossible without modeling.

Mathematical modeling should be inextricably linked with technical experiment data. For example, applying an algorithm to solve a technical problem without understanding the fundamental physical phenomena or limitations of the algorithm is evidence of insufficient professional training. This should become the main motivation for learning mathematics. Also, the connection between mathematical modeling and the solution of an engineering and technical problem should be explained to the students.

Today, Ukraine is already taking the first steps to implement the STEM education system. Interdisciplinary programs of study are being introduced in high school, increasing student awareness of STEM subjects and professions, as well as academic requirements in STEM fields and professions. The high school provides a complex curriculum with an emphasis on the application of STEM subjects, offers courses and pathways to training in STEM fields and professions, and prepares students for successful post-secondary employment and education. At the same time, at any stage, this system "builds bridges" and connects school and extracurricular opportunities and forms of education.

As practice shows, the effective implementation of the components of STEM education in the process of teaching mathematics to 5th-6th grade

students possible through the use of practice-oriented educational projects that can be combined in the system case studies. A case study is an educational technology based on an integrated approach, which involves studying one a certain object or phenomenon from the standpoint of various academic disciplines during an organized independent research project activity.

The transition to the competence model of STEM education during the teaching of mathematics, first of all, involves adjusting the content of individual topics with an emphasis on personal development tasks; introduction innovative, game-based learning technologies, interactive methods of group learning; creating favorable conditions for the organization of successful project activities. Thanks to project-based learning, students are able to receive a holistic a picture of scientific knowledge from various educational disciplines, to form a culture of designing one's own educational activities to solve a real problem, analyze, predict and control all processes of cognition and develop entrepreneurial skills from an early age.

Control Questions

1. Why mathematics is considered the basis of STEM education?
2. How can STEM principles be implemented in mathematics lessons?
3. How does the introduction of STEM affect students' interest in mathematics?
4. What equipment can be used in mathematics lessons?
5. Is mathematical modeling related to STEM?

Tasks

1. Develop a math lesson plan using the constructor.
2. Suggest an experiment for a geometry lesson.
3. Complete the table on the didactic effects of certain STEM learning tools in mathematics classes.

STEM learning tool	Grade	Didactic effects
LEGO constructor		
Puzzles		
Lotto		
Robot toys		
3D printer		
3D glasses		
Mobile applications for learning		
Measuring tools		
Cards with augmented reality		

STEM EDUCATION IN COMPUTER SCIENCE CLASSES

Modern rates of informatization, widespread digitization of the education system and transformation of its paradigm lead to inherent changes in the approaches to education. Rapidly changing trends in education and the active development of new information and communication technologies actualize complex approaches to training. The predicted fourth industrial revolution, which represents the introduction of artificial intelligence and cyber-physical systems into the life of mankind, requires the transformation of the education system already today. In the report of the World Economic Forum for 2019, a possible increase in the main risks with the introduction of artificial intelligence and machine learning is noted. At the time of entering the labor market, the majority of secondary school students will perform jobs that do not yet exist, most of the printed products on information and communication technologies become irrelevant even before they are printed. In such conditions, the skills of students' functional literacy, critical thinking, optimization of time and mechanisms for obtaining new knowledge, and the formation of a complete picture of the world become vital.

The rapid development and popularization of the IT sector gives rise to a special interest in programming and robotics. This raises concerns those who are concerned about a more harmonious and comprehensive development of various areas, including sciences and technologies that are not directly related to IT. Their development requires great effort, resource base and time (medicine, instrumentation, etc.). A serious contribution is also required in the development of science (fundamental) and the preparation of relevant specialists. This discussion overlaps somewhat with the one above. since it appeals not only to the question of which branch of the economy more important, but also to assessing the prospects for the labor market and employment in the future.

We are talking about importance of "**four C's" (or 4C) 21st-Century competencies** (*critical thinking, creativity*, *collaboration,* and

communication), which set significantly broader educational requirements beyond mastering the digital literacy, programming and robotics.

IT and high-tech manufacturing are today the most prestigious areas. They are associated with both high incomes and with rising social status. Therefore, despite the fact that STEM education is designed to overcome social inequality, access to a prestigious area is still associated with social and cultural barriers, stereotypes, as well as infrastructure limitations.

Thus, the issue of STEM education for girls remains relevant, especially if it is taken out of the scope of the compulsory school curriculum.

According to experts, additional and special work that will allow girls to overcome the existing psychological, social and cultural barriers in order to be included on an equal footing in the development of STEM subjects, the work of projects, etc.

Another issue of social inequality is the impossibility for a motivated and talented teenager from a small town or villages to gain access to laboratories, teachers, technology, etc.

Online education partially solves this problem, but still questions remain about accessibility to the environment and the community where they could students develop.

Informatics lessons are a fruitful field for the application of STEM education methods, because technologies and programming make up its basis. Educators advise teachers not only to teach children programming, but also to use 3D modeling tools, for example, studying the human body on the Zygote Body site or modeling geometric figures independently on the Geogebra site.

Using a variety of sensors, motors, and programmable devices in the classroom, children will be able to learn by experience how it all works, learn to practically use the equipment to create projects with various capabilities, practical products and smart systems.

Using the example of robots and programmable structures, students clearly understand and learn the principles of programming. The written

code of the sequence of movements and rotations is perceived much easier when the actions are performed by a material object. Students understand that programming is not only manipulation of numbers, but a practical tool.

Webinars as a form of training have proven to be highly effective, because online seminars and conferences allow you to discuss problematic issues, identify weaknesses, or, on the contrary, identify achievements. In the conditions of a significant reduction in academic hours, webinars significantly increase the ability of the teacher to ensure a solid assimilation of the educational material, to encourage students to work independently.

Virtual computerized laboratory complexes allow conducting computer experiments that cannot be conducted in real time (Fig. 1.6).

Getting to know the principles of virtual laboratories and interactive virtual experiments allows students to organize and conduct their own online research.

Figure 1.6 – Virtual computerized laboratory

Virtual experiments are interactive computer programs that mimic real life experiments. As a rule, the corresponding computer programs are based on mathematical models of the studied objects or phenomena of the real world.

For example, in biology, mathematical models of colony growth are widely used bacteria or the spread of diseases, in physics used models of oscillatory systems, in chemistry used models of fast reactions, etc. With the help of appropriate computer interactive programs, students have the opportunity to change the conditions under which the studied phenomena occur (concentration, temperature, pressure, deflecting force etc.) and observe the effects of corresponding changes, take readings from sensors, systematize and analyze the obtained data.

Ideally, a virtual experiment provides students with a fun, interactive experience. 3D simulation of a realistic laboratory, improving their understanding and knowledge with using a virtual practice test of what they have learned.

As a rule, the interface part of computer programs for virtual experiments, implemented using interactive multimedia extensions (static, audio and video) and various controls.

In addition, some mathematical models of the studied objects and phenomena impose increased requirements on the computing power and the amount of RAM used to train computers.

An electronic lesson is a holistic educational process carried out in certain time frames.

As in the case of traditional lessons, in the **digital lesson** all the constituent stages of the process understanding and assimilation of knowledge – learning objectives, methods for achieving them, the content of the training programs, organization of educational practice are interconnected, and also are in continuous interaction. Obviously, the digital lesson, like the traditional one, is not able to ensure the achievement of all the goals of the educational process, being only one of the most important links in the multifaceted learning process.

In addition to the requirements of traditional lessons, the digital lesson must also meet certain specific requirements arising from the way it is carried out (synchronous, asynchronous or mixed) and from the ways content delivery (through a learning management system or as a separate educational resource).

Most learning management systems offer teachers a set of numerous computer tools that allow you to develop electronic lessons, including a wide variety of digital learning objects such as texts, images, audio and video clips, electronic tests, etc. The specifics of these tools are different from one system to another, which requires the use of unified approaches to design electronic lessons both at the level of each educational institution and at the level of the entire educational system.

The rapid development of computer games and the widespread introduction of digital media in the educational process led to the so-called **gamification of learning**.

In a modern school, computer games are used in the following cases:

– as self-contained digital learning objects for the classroom or extracurricular activities;

– as a constituent element of a more complex digital learning object, for example, an electronic lesson, an online course or an electronic textbook.

At the same time, computer educational games are used to achieve the following educational goals:

1. Consolidation of certain knowledge that the student already possesses.
2. Acquisition of new knowledge.
3. Improving certain skills and abilities that the student already possesses.
4. Formation of new skills and abilities.
5. Development of attention and cognitive interest in the subject.
6. Development of attention, memory, speech, thinking.
7. Formation of the student's personal qualities (physical, intellectual, creative, strong-willed, competitive).

When choosing computer games, educational goals always remain a priority.

Game goals are intended only to support the internal motivation of students to fulfillment of educational tasks.

As you know, the essential features of computer games are:

1. The presence of an entertaining plot.

2. Presentation of information using hypermedia technology: for presentation game model used images, sound, text, animation effects.

3. The existence of a reactive environment that provides interaction with game model. The response can be presented in the form of sound signals, encouraging statements, scoring, switching to another game level.

4. Simulation of real situations and activities. Game scenarios are models various real situations in which the player needs to find ways actions that will be most successful.

5. The situation of competition, which ensures the interest of the student in the course games.

In addition to the merits, some researchers and practicing teachers also point to some of the shortcomings inherent in computer games (excessive enthusiasm for students, turning into addiction; the presence of information that distracts students from the initially set educational tasks; violation of socialization, etc.).

These shortcomings can be eliminated by choosing for training only those computer games that fully correspond to the psychological, pedagogical, methodological and organizational requirements.

Currently, there are a large number of computer educational games on the Internet.

They are classified according to the levels of general education (primary, gymnasium, lyceum), and in school subjects (languages, mathematics, physics, chemistry, etc.).

Although some of them are proprietary (commercial), most computer educational games are freely available.

List of common Internet sources containing the most popular computer educational games, is given in Application A.

It is also advisable for students to develop their own engineering and technical startup projects. We consider the applied nature of the research and the possibility of implementation into real production to be the main criterion for project evaluation. Projects have a diverse nature: they can be equipment (devices), information products, etc.

The main thing that unites them is the ability to modernize and optimize production processes. Implementation of applied projects by students allows revealing the origins of theoretical concepts and methods, visualize the connection between theory and practice, and, in general, contribute to the development and maintenance of students' interest in science and education. This provides an opportunity to assess effectiveness of learning and student's readiness for independent activity.

Non-standard approaches to conducting computer science lessons provide an opportunity not only to increase students' interest in the studied topics, but also to improve their independence, creative activity, and teach them how to work with different, unusual sources of knowledge. The organization of this kind of lesson leads students to the need for creative evaluation of the studied phenomena and processes, activity results. In the process of carrying out such lessons, favorable conditions are formed for the development of skills and abilities of quick thinking, the implementation of logical operations, and the organization of cooperation.

Control Questions

1. Why informatics lessons are a fruitful field for the application of STEM education methods?
2. For what purpose are 3D modeling tools used in lessons?
3. What affects the development of digital competence?
4. Is STEM education possible without digital competence?
5. How can elements of robotics be introduced into the computer science lesson?

Tasks

1. Analyze the NUS computer science program in terms of STEM education.
2. Suggest an idea for a 5th grade programming lesson.
3. Suggest an idea for a 6th grade programming lesson.

INCLUSIVE STEM TEACHING

Implementation of inclusive education is one of the most important tasks of modern education, not only because it is a mandatory condition for implementation in the European educational space, but also, first of all, for the development of a society of equal opportunities in Ukraine. And the mission of preschool education as the first educational link is to create prerequisites for the development of the further individual educational trajectory of each schoolchild, taking into account his special needs.

The implementation of inclusion is important not only from the point of view of creating an accessible educational environment for children with special educational needs: inclusive education in a broad sense involves creating equal opportunities for all categories of children in Ukraine who are in a situation of possible exclusion or segregation. Every child should feel like a full-fledged and active participant in the educational process, and this is the main task of inclusion.

The organization of effective inclusive activities requires three main conditions:

– human resources, that is, the presence of pedagogical workers who have special knowledge (of psychology, correctional pedagogy, speech therapy, etc.) and possess competencies related to the socialization and adaptation of children with special needs;

– material base and infrastructure prepared for inclusive education and training;

– a small number of children in groups, which ensures an individual approach.

The transition to an inclusive-competency model of STEM education and the application of new ones methodical approaches, first of all, involves:

– fundamentally new goal-setting in the pedagogical process, shift of emphasis in educational activities from narrowly focused to general didactic;

– updating the structure and content of educational subjects, special courses, etc.;
– definition and assessment of learning outcomes through key and subject competencies of the student;
– introduction of end-to-end STEM education, competently oriented forms and methods of training, system-activity approach;
– introduction of innovative, game-based learning technologies, case-study technologies, interactive methods of group training, problematic methods for the development of critical and systemic thinking, etc.;
– adjustment of the content of individual topics of educational subjects with an emphasis on personal development, game methods of learning, value attitude to the researched question;
– creation of pedagogical conditions for obtaining effective individual experience of project activity.

The introduction of an inclusive model in Ukraine at all educational levels involves the creative use of the experience of developed countries based on their own traditions and heritage, because classical Ukrainian pedagogy has developed a significant number of methods and technologies for teaching children with special needs, in particular at the level of preschool education. An important practical task of modern early childhood pedagogy is the development of such a model of inclusion that would simultaneously take into account innovative foreign trends and Ukrainian practices and realities.

During the educational process in an inclusive environment effective pedagogical approaches are use for a diverse contingent of students. In particular, there are three: traditional intensive training, cognitive formation strategies, learning in cooperation/cooperative learning.

In differentiated teaching, the methods of all three approaches are applied flexibly and consistently. Each of them covers a number of methods that determine the teaching strategy.

To solve specific strategic learning tasks (for the class as a whole, a group of students, an individual student) the methods most suitable for such a case are chosen.

Learning strategies are techniques that they teach to think, and their main goal is the formation of abilities students to expand the scope of application of these tools in order to learn to think. Methods of formation of educational strategies make it possible to facilitate learning for students who face difficulties in the learning process.

A special form of end-to-end STEM education is integrated lessons/classes that aim to establish cross-curricular connections and contribute to the formation of a holistic, systematic worldview in students, actualization of personal attitude to the issues considered at lessons/classes.

Integrated lessons/classes can be conducted by combining similar subjects of several educational subjects or training integrated courses or separate special courses by combining educational ones programs of such courses/subjects. The basis of data efficiency lessons/classes have a clear definition of the goal and their planning to ensure multifaceted consideration by students of a certain object, concept, phenomenon, that are studied in various subjects.

The peculiarity of planning and conducting integrated, binary lessons is that they can be conducted as one teacher who teaches integrated subjects as well as several. Because of the complexity coordination of teachers' activities in the second case of such lessons is done unreasonably little, so it is necessary to plan them in advance to all parallel teachers or the teaching staff.

In cases where the program material of different educational subjects allows to integrate it within one educational day, they can to organize "thematic days", "thematic decades", in the process of which lessons and extracurricular activities lead to implementation of a single educational goal.

The teacher's use of the leading principle of STEM education integration (interdisciplinary, transdisciplinary) allows to carry out modernization of methodological principles, content, volume of educational material, use modern technologies during training for the

purpose of formation competencies of a qualitatively new level, which will ensure effective work institutions of inclusive education.

For effective equal access to all directions quality education of children with special educational needs, formation early professional self-determination and conscious professional selection, dissemination of innovative pedagogical experience and educational technologies, wide promotion of the results of children's science and technology creativity requires the development of a methodological basis implementation of STEM education. Methodological foundations of the development of STEM education consist of such structural components as: regulatory framework, organizational and educational and methodical work, material and technical and information provision, participation of children and youth in events all-Ukrainian and regional levels, professional skills of teacher.

At the same time, the successful development of STEM education is facilitated by involvement resources and cooperation between pedagogical teams and external participants: educational institutions, academic research institutions, research laboratories, scientific museums, natural sciences centers, enterprises, business structures, public organizations Special attention is paid to the cooperation of specialists of various profiles in the development of a special educational environment with using ICT.

If we look at the structure of even the simplest STEM lessons that do not require a fully equipped laboratory, we will see that they are ideal for students with special educational needs:

1. Activity is result-oriented. STEM classes are based on solving real problems. In addition, at each stage of the lesson, students solve a specific problem or perform a specific task with clear conditions and expectations regarding the result. This is easier for most students with special educational needs than working with abstract concepts.

2. Constant change of work format. In addition to the fact that the engineering design process consists of various stages of activity, each stage is also a collection of different forms of activities. Therefore,

students at each stage can both choose the most comfortable work format and alternate between them.

3. Shorter class time. Working on a STEM project often takes even longer than a regular lesson, but because all activities are divided into stages, the breaks between them allow students to realize what was done in the previous stage and what needs to be done in the next.

4. Work in small groups. A team of 4-6 children is the norm for well-designed STEM lessons. So, even in a large class, students will work in small comfortable groups, where it is easier to establish contact with each other. In this case, it is important that schoolchildren with special educational needs do not complete tasks separately from the class with a teacher or assistant, but is part of such mini-groups. After all, it creates an opportunity for the socialization of some students and the development of empathy for other students - it teaches them to work together and establish connections.

5. Lack of pressure. The majority of students, not only those with special educational needs, perceive mistakes as defeats and confirmation of their own incapacity. But for engineers, a mistake is just one of the steps in finding, testing and evaluating a solution, or redesigning it. It is important to explain this to all students in advance. For example, to talk about how real engineers and inventors created the things we know. Then it is necessary to trace whether this is exactly how students will perceive failures in the work process.

6. Flexible format of training and testing of acquired knowledge and skills. STEM lessons give both teachers and students a lot of freedom in choosing how they want to share knowledge.

Specialists in engaging students with special educational needs in STEM activities advise:

1. Assume competence. Believe that students with special educational needs can do more than what is normally expected of them. Especially if you create an environment that will facilitate this.

The expectancy effect leads to a decrease in performance during learning, a decrease in interest in learning science and math disciplines, and a decrease in effort to achieve counter stereotypic skills.

For the most part, research on the expectancy effect has focused on racial and ethnic minorities or women in STEM fields, but it is logical to assume the same detrimental effect on students with special educational needs.

2. Build on students' strengths and interests. Students will be more interested in completing tasks if they feel they have the appropriate knowledge and skills to do so. But remember, as with students without special educational needs, you need to raise the bar from time to time to ensure development and improvement of skills.

3. Help students achieve a "flow" state. To do this, clearly define the goal of the task in general and each of the stages. Set the level at which your students with special educational needs should complete the tasks. Provide accurate and prompt feedback so students can adjust their actions as needed.

The state of flow (flow) is full concentration on what you are doing, accompanied by a feeling of lightness and pleasure.

4. Use assistive technologies as needed. This can make it easier to absorb information and understand tasks, especially for students who are visually or hearing impaired. Provide materials in digital format, duplicate information with information cards, print assignments on yellow sheets, and more. Information boards for people with visual impairments are made yellow, because this color is bright enough. It's the same here: when there are a lot of things on the table, it's easier for students to find a worksheet if it attracts attention.

Ideally, text materials for students with visual impairments should be adapted to be voiced by screen readers (NVDA, Jaws for Windows, etc.). And the texts for students with dyslexia are typed in the Inclusion UKR font.

5. Pay attention to safety. Many tasks involve working with a variety of tools, from scissors and utility knives to drills, soldering irons, and more.

Be with the students when working with these tools, but at the same time, if possible, entrust them with the work by guiding and prompting. This will contribute to their gaining greater independence and confidence in their own capabilities.

6. Show an example of hard work and how team members can communicate and cooperate with each other. This is important not only for those students who need help in acquiring and developing social skills, but also for everyone - for the development of soft skills and empathy.

2022 on the basis of Poltava Academy of Continuing Education named after M.V. Ostrogradskyi Regional scientific and methodological project "STEM-inclusion" was started.

The goal of the project is development of inclusive competence of pedagogical workers of educational institutions of the Poltava region through the development and use of electronic educational and methodical cases regarding the implementation of STEAM education technologies for various categories of special educational needs of children.

Task of the project are:

– reveal the theoretical foundations of teaching children with special needs using STEAM education technologies to ensure equal access to quality education;

– implementation of methodical, analytical and personnel support for the activities of general secondary education institutions, regarding the application of STEAM education technologies in the Poltava region;

– methodical provision of training and professional development of pedagogical workers of inclusive resource centers, educational institutions regarding the education of children with special educational needs using STEAM education technologies;

– spreading the practice of organizing the educational process using STEAM education technologies with children with special educational needs, methods and technologies of inclusive education, joining the efforts of pedagogical and scientific-pedagogical workers of educational

institutions and IRCs, parents and the public for the development of the system of inclusive education in the Poltava region.

The project states that educational institutions of the Poltava region are equipped with offices and STEM laboratories with appropriate equipment:

– general purpose multimedia equipment in the amount of 2196 pcs.;

– additional equipment (TVs, audio systems, video cameras, cameras, etc.) – 1181 pcs.

STEM laboratories are equipped with 3D printers (34 pcs.), 3D scanners (48 pcs.), 3D pens (42 pcs.), programmable electronic modules (121 pcs.), educational works (364 pcs.), photo and video studios (335 sets), mechatronic systems (39 pcs.), kits/sets for modeling/design (353 pcs.).

It is extremely useful for children with special educational needs involvement in STEM lessons that:

– are based on solving specific tasks and performing specific tasks with clear conditions and expectations regarding the result;

– constant change of work format at each stage;

– the ability to work in small groups and a flexible learning format and testing of acquired knowledge and skills.

STEAM creates new and exciting opportunities for students with disabilities educational needs. The main goal of teachers' activities is to ensure success his students, teaching them necessary life skills, at the same time developing their natural talents. The current view of inclusive education concentrates more on weaknesses than strengths. STEAM technologies offer a better approach, encouraging teachers to focus on the abilities of students with special needs, not their difficulties.

The realism of the project is determined by organizational and personnel factors resources aimed at achieving specified goals. Its integrity is compliance with the goal, tasks, action plan and expected results.

Controllability is provided by suitable tracking system intermediate and final results of project activities.

Project organizer: Department of Pedagogical Mastery and Inclusion education of the Poltava Academy of Continuing Education named after M. V. Ostrogradskyi, Poltava University of Economics and Trade, Communal Institution “Inclusive Resource Center of the Poltava City Council”, Communal Institution “Poltava Interschool Resource Center of the Poltava City Council”.

Figure 1.7 – Educational classes in Poltava Inclusive Resource Center

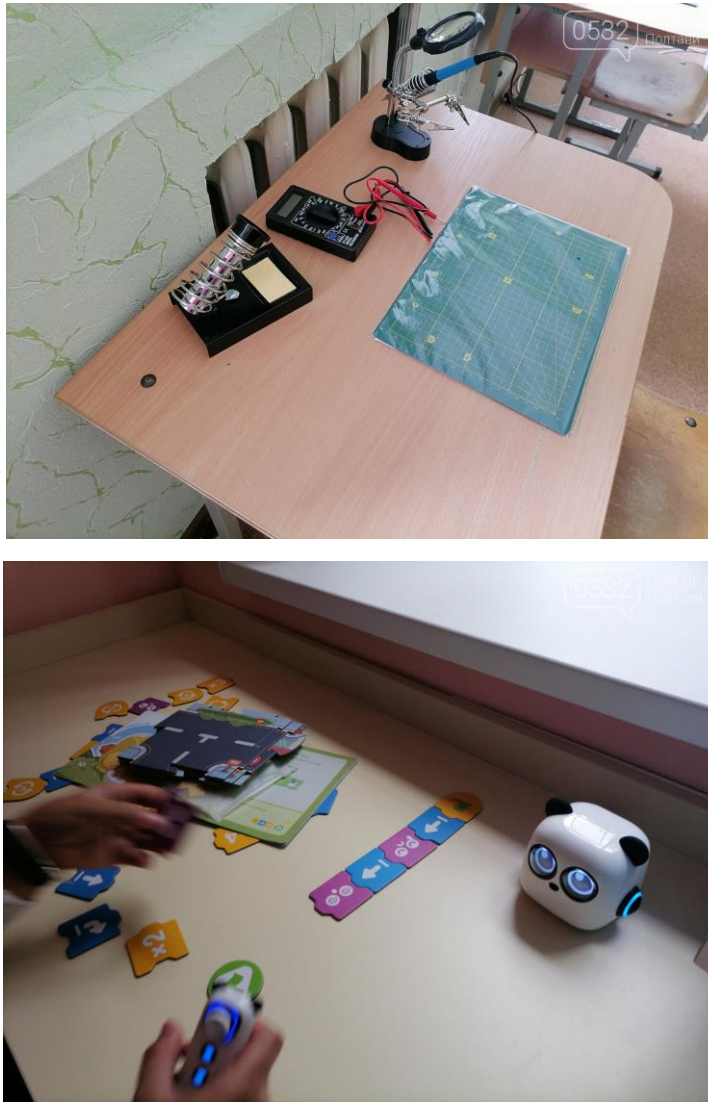

Figure 1.8 – STEM equipment in Poltava Inclusive Resource Center

Figure 1.9 – Augmented reality device in Poltava Inclusive Resource Center

Figure 1.10 – Computer class in Poltava Inclusive Resource Center

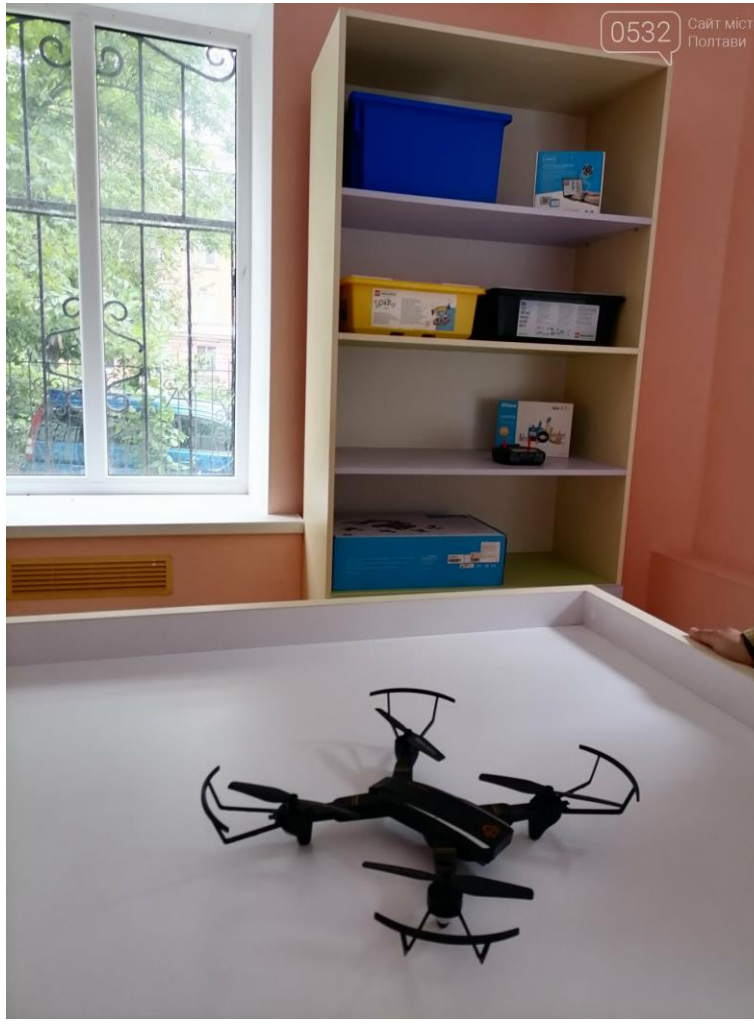

Figure 1.11 – Mechatronic system in Poltava Inclusive Resource Center

Control Questions

1. Why should inclusion extend to STEM education?

2. How does STEM education affect the cognitive sphere and intellectual development of a child?
3. From what age should children be involved in STEM education?
4. What competencies does STEM education form? How can elements of robotics be introduced into the computer science lesson?

Tasks

1. Analyze the Regional scientific and methodological project "STEM-inclusion".
2. Justify the feasibility of creating and implementing the project in Kremenchuk.
3. Make a list of the necessary equipment to create an inclusive STEM center.

STEAM EDUCATION

Recently, the trend of STEAM education has been gaining momentum in the educational space of Ukraine.

It covers natural sciences (***S**cience*), technology (***T**echnology*), technical creativity (***E**ngineering*), art (***A**rt*) and mathematics (***M**athematics*). Though initially, this approach was simply called STEM, without the creative component. But art is very important for all-round development, so it was decided add the letter A (Art) to the abbreviation.

It is important to understand that STEAM is not just a technical education. It encompasses a much broader concept, namely a successful combination of creativity and technical knowledge.

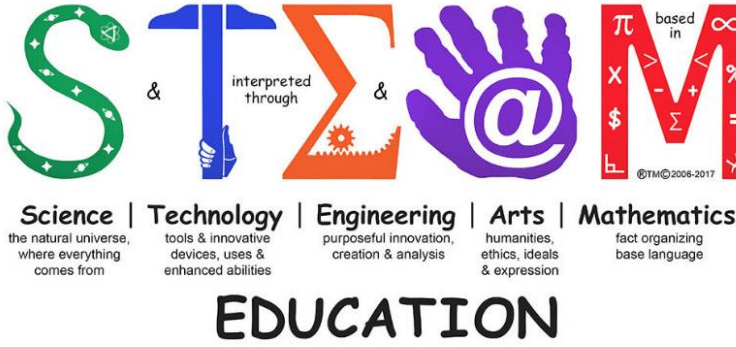

Figure 1.12 – STEAM education

The main difference between the STEM approach and STEAM is that STEM focuses on scientific concepts. STEAM, on the other hand, explores the same concepts, but does so through research and learning methods that are applied as part of the creative process.

STEM and STEAM are not new learning methods, they are a way of applying an integrated form of learning that is very close to real life.

Instead of teaching the sciences separately, they can be taught together in a way that shows how knowledge from different fields complements and reinforces each other.

Adding different types of arts to the STEM approach helps us build critical thinking in students as well as solve real-world problems through a creative approach. Art is not just drawing in a studio. Art is the search for original ways of solving problems, integrating principles from different fields or ways of presenting information.

STEAM is one of the trends in global education that provides blended learning environment, and shows the child how to apply science and art together in everyday life.

The term STEAM originates from the USA and was introduced into the school curriculum for to strongly develop and strengthen their own competencies students in the scientific and technical direction.

Integrating concepts, themes, standards, and assessments is a great way to help change the way schools learn for the sake of children and their future.

First of all, the student becomes not a consumer, but a customer of knowledge.

The teacher is a kind of mentor, a person who helps to explain how to use the potential of each technology for one's own benefit and the benefit of society. During STEAM lessons, the focus is not on the teacher, but on the practical task to be solved.

For the full implementation of such an approach, the presence of STEAM laboratories is mandatory. They include the availability of 3D printers, sets of educational electronics, a photo-video studio and other modern technical means.

STEAM education allows teachers to explain the necessary material more clearly, because next to the theory, children immediately see how it looks in real life.

The STEAM approach allows children to be educated in flexibility and critical, practically oriented thinking.

The ability to learn and accept changes comes to the fore, not the knowledge itself, which is now becoming obsolete at an incredible rate.

This gives parent's confidence in the future of their children, because after applying STEAM teaching, children will have a deep understanding of how to live in today's dynamic world.

Implementation of STEAM education is an innovative way in studying mathematics. Elements of STEAM education can be used on in mathematics lessons while solving problems, in the project room work and extracurricular activities. These can be tasks about architectural buildings and sights of the native city, the world; tasks biological, chemical, physical and geographical content.

For the implementation of STEAM education in schools, an appropriate environment must be created. For this, STEAM laboratories must function with available technological equipment in the form of 3D printers, sets of educational electronics, a holographic photo-video studio and other modern technical means. Professionals from various fields can be invited to lessons, who will be able to share their own real-life experiences with children for a better understanding of the discipline.

The implementation of STEAM education in Ukrainian schools was planned for 2022, when students of 5th grade study STEAM in addition to the main subjects, which contribute to the development of personality through the formation of competencies, worldview positions and life values.

STEAM education is a creative worldview space child, where he fully realizes his needs. Therefore, all activities related to the implementation of STEAM education are structured in such a way as to contribute to the formation of an individual as a creator and project work in these perspectives is one of the most promising.

The project as a means of implementing STEAM education at school allows organic integration of children's knowledge from various disciplines during the solution of real problems, conditions them practical use, while generating new ideas, forms all the necessary life skills, in particular, multicultural, speech, informational, social etc.

Unlike a traditional organization of the educational process, STEAM projects are approaching students to the realities, eliminating the gap between the theoretical solution to the problem and its practical implementation in the life of acquired knowledge. The perceived need to use knowledge from various disciplines while working on the project contributes to the solid assimilation of new ones of knowledge.

Technology is the subject that best demonstrates integration knowledge and skills of students in various subjects. Carrying out work on each educational project students need to independently design the future product, while using knowledge from mathematics, physics, chemistry, information technology, art, biology for creation functional, interesting and new product. In this case, students see an effective connection theory with the practice in life.

STEAM projects can be both educational and experimental-research nature. There are certain requirements for the implementation of such projects:

– topic of the project must be relevant and specific, aimed at solving a specific problem;

– teacher acts as a manager, organizer, consultant, project tutor, that is, it directs the students' work in the right direction, but does not interfere in the process itself research;

– it is necessary to create the necessary conditions for conducting the apprenticeship experiment, of course, it is best to have a specially equipped STEM laboratory, although you can limit yourself to providing researchers with the necessary equipment;

– fourthly, in the process of working on the project, students must independently apply and be able to integrate knowledge from various scientific fields or educational subjects, analyze the received information, draw your own conclusions,

– conclusion of any STEAM project there must be a practical result, a product aimed at solving the chosen problem.

For example, during the tasks of comprehensively designing a "Smart house" in addition to technical aspects, schoolchildren must engage their imagination and design the house so that it looks attractive and is comfortable for life.

2019 the best schoolchildren-inventors from all over Ukraine presented their innovative projects of "smart devices" at STEAM House 2019 and will be able to manufacture them. The purpose of creating the competition is precisely the great desire to help the state in implementing such necessary educational reform. At the same time, many schools are not yet equipped with the necessary STEAM laboratories, so STEAM House gives children from all over Ukraine the opportunity to try themselves as inventors-innovators right now. The competition is a chance for children, parents and their teachers to show themselves.

Ukrainian students invented a smart snowplow, a mobile mini-agro complex, "smart seasonal tires" and many other projects.

The finalists of the national smart device modeling competition were awarded certificates for components for their gadgets. Now students will be able to put their projects into practice. In Kyiv, unique master classes were held for schoolchildren and awards were presented. In total, the organizers recognized the ideas of 17 Ukrainian schoolchildren and their 10 projects among 150 applications.

In the final, the jury determined the winners in three nominations — Internet of Things (IoT), Smart gadgets and Smart City.

Experts and educators talked about how important it is to create and develop STEAM centers — technology circles and laboratories — in educational institutions.

Figure 1.13 – STEAM House 2019

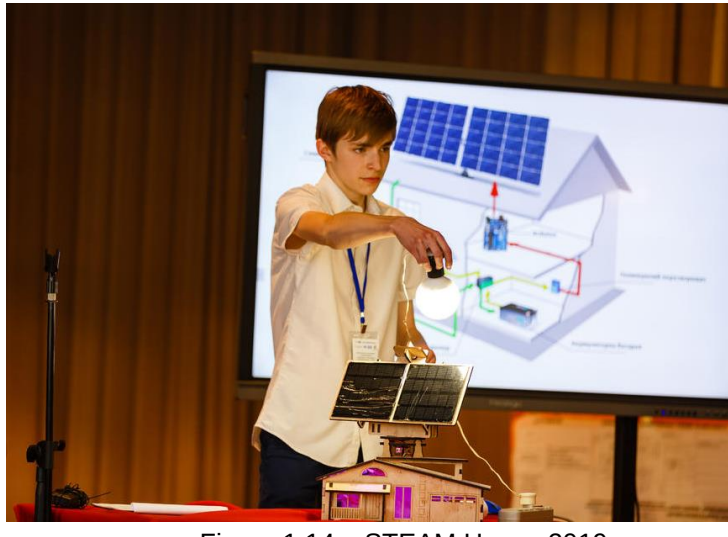

Figure 1.14 – STEAM House 2019

Today, the huge attention of the state, entrepreneurs, and patrons is focused on identifying and support of talented scientific youth. Accordingly, wide opportunities are opened for senior students' opportunities: participation in competitions and scientific and technical exhibitions, implementation of research programs, competitions for obtaining grants.

One of the main tasks of a modern school is to create conditions for versatile development of the younger generation, to ensure activation and development of intelligence, intuition, and light productivity, creative thinking, reflection, analytical and synthetic abilities and skills taking into account the capabilities of each child. Modern teaching methods provide active interaction of students and the teacher in the educational process. Implementation of STEAM projects contributes development of scientific and research activity of students, in particular, during study technologies. The introduction of STEAM education is an important vector for the development of New Ukrainian schools and the future younger generation as a whole.

An example of STEAM education is teaching children the technique of origami. Origami (translated from Japanese as "folded paper") is an ancient art of folding various shapes from paper without using scissors and glue. There are many versions of where the origami technique originated. Presumably in ancient China, where paper was invented, but we can definitely say that it developed and became a whole art form in Japan.

Figure 1.15 – Kremenchuk schoolchildren's origami works

Figure 1.16 – Kremenchuk schoolchildren's origami works

At the heart of STEAM education is a competency-based approach. Competency approach assumes that the student does not learn individual one from knowledge and skills, and mastering them in a complex. In this regard changes, or rather, the system of teaching methods is defined differently. In the basis of the selection and construction of teaching methods is the structure relevant competencies and the functions they perform in education. Let's consider grounds for selection and construction of teaching methods based on competence approach.

Society now needs individuals who are ready to be involved in the future life activity Therefore, the competence approach makes it possible to find out and determine the level mastering the graduate's competencies, what he can do, what by way of activity he mastered what he was ready for. Competency approach means reorientation of the dominant educational paradigm with a predominant broadcast knowledge, formation of skills to create conditions for mastering the complex key competencies characterizing the potential of an individual.

This approach also shows the graduate's ability to survive and sustain life activities in the conditions of modern multifactorial socio-political, market-economic, information and communication saturated space.

Methodical implementation of the competence approach is connected with using such pedagogical tools that would provide in a timely manner the educational process of creating appropriate situations in which the acquired are synthesized educational knowledge and skills and methods of practical activity.

Social demand for education, which is characterized by a practical orientation and wide opportunities for creativity self-realization of the individual, needs optimization of educational work in general education, extracurricular, professional and technical, higher education institutions Implementation of such a task is possible provided that the requirements are met the quality of education determined by modern integration processes; buildings educational process based on the principles of socialization and humanization; improvement of methodological and

pedagogical principles of their activity; unity educational, educational, developmental goals and tasks.

Control Questions

1. What is the difference between STEM education and STEAM education?
2. What competencies does STEAM education develop?
3. Does STEAM education contribute to interdisciplinary integration?
4. How can mathematics be related to architecture, painting, embroidery, and landscape design?
5. What is the meaning of the adjective Smart in such phrases as smart home, smart city, smart watch?
6. How are STEAM education methods used in extracurricular education?
7. 1. Why did the subject "Labor training" get the name "Design and technologies" in the New Ukrainian School?

Tasks

1. Develop an integrated lesson plan for computer science and technology for 6th grade students.
2. Develop an integrated math and music lesson plan for 7th grade students.
3. Propose a project using STEAM education methods.
4. Using the lexical minimum (Application D), write a report about the essence of STEAM education.

Module 2

Methodical support for STEM education

METHODICAL SUPPORT FOR TEACHERS

More and more Ukrainian schools are equipping their own STEM laboratories and preparing for the school year. It should be noted here that educational tools for STEM students are not the simplest. And teachers have practically no experience working with new equipment and technologies, so it is not surprising that they often treat the new approach with mistrust or even fear.

STEM is not just a combination of various subjects in one project, it is an attempt to develop the effect of synergy when learning the laws of the surrounding world. Some researchers consider STEM as a separate philosophy of understanding the laws of the universe through the prism of specific subjects. Others as a way to prevent the separation of science from the real world. Therefore, in the process of introducing STEM technologies, there may be problems of determining priorities and taking into account all the goals of the subjects included in a certain project. Different variations of accents of this educational technology such as phenomenon, context, research, project, problem can only confuse students in achieving the set goals.

Analyzing the experience of countries working in the STEM approach, it is possible to conclude that this technology is very interesting and useful from the point of view of developing schoolchildren's future **4C skills** (*critical thinking, creativity*, *collaboration,* and *communication*) they need today. At the same time, when implementing this technology, do not forget about the goals of education and the importance of each subject in the process of training children.

Originating as a way of more effective and optimal education of migrant children, STEM educational technology attracts more and more teachers in different countries of the world every year. The content and methods of this approach allow students to form a holistic picture of the world, teach them to see inextricable relationships in the surrounding reality, and show the value of scientific knowledge for life.

According to a survey conducted in 2021 by the Institute of Education Content Modernization, more than 150 STEM centers and laboratories worked in Ukraine in the 2020/21 academic year. Implementation of the science and mathematics branch will continue according to the plan until 2027. In this organization, there is a special Department of STEM Education (Fig. 2.1).

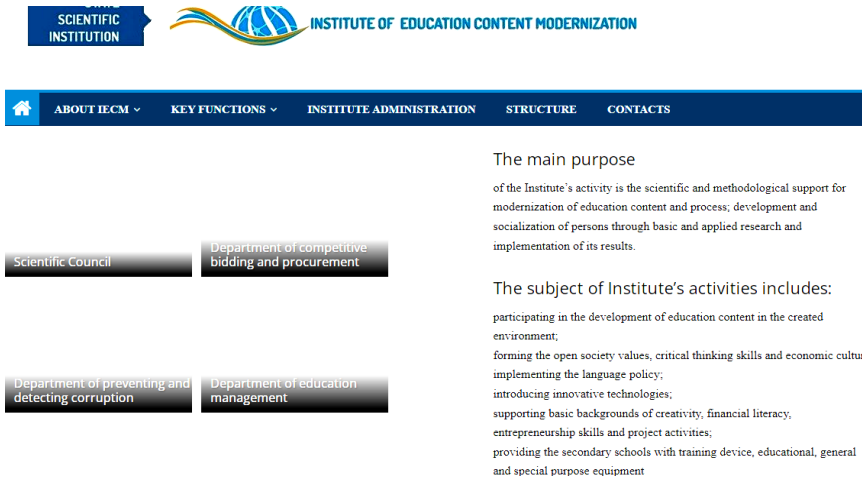

Figure 2.1 – Homepage of Department of STEM Education

The main tasks of the department:

– implementation of a general strategy for the development and advocacy of STEM education;

– development of conceptual, legal, scientific and methodological foundations of STEM education;

– provision of scientific and methodological support for experimental innovation activities based on educational institutions introducing STEM fields;

– analysis of the development process and dynamics of the development of STEM education, identification of problems and forecasting of further trends in the implementation of STEM education;

– provision of scientific and methodological, practical assistance to educational institutions, organizations that contribute to the implementation of STEM education;

– coordination of work groups of scientists, teachers and specialists in STEM education;

– establishment of communication links with services and structures of the educational sector, stakeholders, other institutions implementing STEM education in the regions;

– initiation, fundraising and coordination of innovative educational projects;

– organizing and conducting educational events aimed at popularizing STEM education, career guidance work among students;

– conducting scientific and practical seminars and other events for training and upgrading the qualifications of teaching staff on innovative educational activities in the field of STEM education;

– remote and face-to-face professional methodical assistance to teaching staff in the organization of STEM education within the framework of a STEM school;

– dissemination of experience and achievements of STEM education through publications, presentations during educational events of various levels: international, all-Ukrainian, regional scientific and practical conferences, seminars, webinars, round tables, trainings, competitions, etc.;

– coordination and methodical support for innovative pedagogical ideas within the framework of the activities of regional post-graduate pedagogical education institutions, regional STEM centers, etc.

Creating an educational STEM environment in any educational institution type and form of ownership is one of the main tasks of the modern stage of development STEM education. The concept of an educational STEM environment of an educational institution is possible interpreted as a set of intellectual and material conditions of implementation results of scientific research, technologies, engineering, integrated knowledge that ensures the self-development of a free and active personality, realization of the creative potential of education seekers.

The directions of STEM education can be:

– programming, artificial intelligence, electronics, mechatronics, bionics, additive technologies, numerical software control, computer modeling;

– milling and laser technologies, climatic, astronomical, biological observations and processing of their results;

– robotics, engineering, rocket modeling, aerospace technologies, radio electronics, car, aircraft, ship modeling, three-dimensional modeling;

– chemical-biological and agroecological technologies;

– designing;

– web design, basics of video technology, digital art, etc.

A common area of STEM education is robotics. Robotics is a science that studies the processes of creating and programming special complex technological devices to achieve a certain result. Process creation of a robot is an object of robotics, and the robot itself is a subject robotics.

The study of robotics allows you to apply practically theoretical ones knowledge obtained through the integration of subjects of natural mathematical cycle and informatics. In the process of creating the output as a result, students get acquainted with various types of modeling, mathematical methods, physical principles, programming, design and other components of scientific research. When designing robots, students have to solve tasks that go beyond the content of the school course and

belong to the engineering disciplines: mechanics, theory of automatic control, resistance of materials, etc.

In today's conditions, it is recommended to use specially prepared platforms for scientific research with a large number modular, ready-made components and software for them easy programming. Examples of such platforms are Arduino, Lego education, JIMU Robot.

The process of creating a robot includes a certain number of stages, the main of which are:

- modeling;
- selection of materials;
- creating an intercomponent interface;
- designing;
- design;
- programming;
- testing;
- diagnosis.

Programming as one of the main sections of robotics is not only a universal tool for computer modeling of objects and processes, but also a powerful tool for the development of schoolchildren's thinking. Necessity describe non-standard processes occurring in the programming language real world, form the ability to determine the goals of their activities independently build educational tasks, determine the ways and methods of solving them, and in this way, to achieve the set goal. Construction and design work allows students to independently check the level of theoretical knowledge and learning skills.

Construction sets are an integral part of the STEM environment of different manufacturers, constituting a coordinated chain of sets, each of which corresponds to a certain age group and allows solving educational problems.

A project approach using such sets gives students the opportunity to independently analyze the "field" of creative activity; independently set goals and objectives for future work; develop plans independently gradual achievement of the set goal; exercise self-control; coordinate their

activities with the activities of others. Work with the constructor aimed at the development of independent, flexible, creative thinking.

Methodological recommendations contain such functional requirements to schoolchildren:

1. Schoolchildren must understand the needs of the technical toys they will create (e.g. tasks, functions, styles). They can look at samples made by the teacher as suggestions.

2. Schoolchildren discuss in a group to find a solution: what they like more and what is better. They design the model with graphics. In order to have a good design, students actively collaborate, applying the knowledge gained, imagining themselves, or looking for any suggested information from others, such as textbooks, the Internet, or teacher recommendations.

3. Schoolchildren choose materials for making technical toys. They choose suitable materials for the production of technical toys and tools.

4. Schoolchildren create technical toys with design and materials. They test and modify the product if it meets the requirements or not. At this stage, students take practical classes, have the opportunity to practice and perform. They can apply knowledge gained from previous lessons and their social experience. The teacher should encourage students to devote themselves to any idea that excites them.

5. Schoolchildren present developed products in class. They can be proud of their products and be interested in STEM education.

Experience designing with robotic devices makes it possible education seekers to try themselves as a researcher, inventor, programmer and forms an initial interest in STEM professions, which are needed in the modern labor market.

Also, modern education can adopt the experience of foreign colleagues and others use STEM in work with children with special needs, which is so relevant now in education.

Teachers can apply engineering in various contexts for children with disabilities opportunities, creating an attractive learning environment and encouraging children to identify and solving various problems.

Also this process can be used for long periods of time so that schoolchildren can immerse themselves in the educational environment. For example, teachers can conduct STEM research where children participate in problem-based learning, which includes teamwork to solve a local problem. This type of in-depth investigation allows schoolchildren see the relationship between STEM research and implementation of solutions.

Institutions of general secondary and out-of-school education are desirable to take participation in the activities of the All-Ukrainian scientific and methodological virtual of the STEM center, which offers remote and face-to-face professional methodical and technological assistance in the organization of STEM training for education seekers.

Didactic design of project-based STEM learning is largely degree depends on the type of study project, i.e. from the duration of the project activity students, the profile of the studied knowledge, the dominant type of project activity students, the number of participants, the way the project results are presented, etc.

According to the number of participants, training projects are divided into:

- individual;
- paired;
- group.

According to the duration of project activities, training projects are divided into:

- short-term (up to 5 days);
- medium-term (up to 1 month);
- long-term (from 2–3 months to the academic year).

According to the profile of knowledge, projects are divided into:

- monosubject;
- interdisciplinary;
- transsubject;
- oversubject (going beyond the content of school disciplines).

According to the dominant type of project activity, the following types of projects are distinguished:

- information;
- research;
- creative;
- practice-oriented projects.

According to the type of school products created by students, projects are distinguished that end creation:

- electronic text documents (essays, abstracts, reports, reports);
- electronic presentations;
- digital graphic documents (drawings, diagrams, images, photo albums, posters, etc.);
- multimedia school products (audio and video clips, sound recordings and videos);
- full-scale layouts and models;
- computer models, programs, databases, websites, etc.

According to the form of presentation of the results of project activities, students are distinguished:

- reports to the class;
- reports at school conferences;
- exhibitions;
- school, regional, national and international competitions and olympiads.

The key point in project-based learning is the choice of topics, offered to students. The choice of topics for project-based learning should be based on learners' preferences. By offering them lists of recommended topics, encourage them to offer new, interesting topics for them. Requirements to topics of STEM projects are:

1. Contribute to the achievement of the set educational goals.
2. Be relevant and meaningful to learners.
3. To be feasible for students (correspond to the level of their training).

4. Be oriented towards the practical application of existing knowledge and skills.

5. Be provided with the necessary resources (literature, digital resources, material resources, etc.).

6. Be concise and understandable.

The essence of the STEM approach to education can be considered as an "engineering approach to invention". For the result to meet the goal, the task must correspond to it and contain a share effective solution. That is, the engineer produces study of the goal and all available means, puts task, designs and receives a prototype. But that's more not the end, because we need to present the final finished product. Here the young engineer and it is necessary to use your knowledge of several areas to improve your project, which would carry has a practical benefit in itself.

As noted, for deployment of STEM programs requires retraining of teachers and managers. Research training is of particular importance. practices, and even better – the inclusion of teachers in real research and engineering practices. This means that retraining should not take place in a closed educational system, but in cooperation with research institutes, universities and real companies, industry. The second part of this direction is involvement in educational processes of those who can include in their practice actions and show how to do it.

The STEM approach allows immerse the student in understanding the essence of specific things, as well as their application in practice. The main principle of STEM education is learning through action. At the center of the educational process are practical tasks that students must complete. For this, it is important to teach them to work with information, and to apply the acquired knowledge in practice. This approach allows students to develop an understanding of the interrelationship of various sciences. In the future, they will deal with the challenges of the adult world: they will develop energy-saving technologies, ensure environmental protection, build smart cities – all this requires a wide range of knowledge and teamwork experience.

Control Questions

1. What are the main directions of STEM education?
2. Why do some researchers consider STEM as a separate philosophy of understanding the laws of the universe?
3. How many STEM centers and laboratories worked in Ukraine?
4. What are the areas of activity of the special Department of STEM Education of Institute of Education Content Modernization?
5. How does the special Department of STEM Education help educational institutions?
6. What are specially prepared platforms for scientific research?
7. What is the key point in project-based learning?

Tasks

1. Analyze the activities that are covered on the site of the special Department of STEM Education of Institute of Education Content Modernization.
2. Read the Text **«10 Essential STEM Teaching Practices»** (Application B) and prove their feasibility.
3. Make recommendations for a teacher who is starting to implement elements of STEM education.
4. Suggest multiple topics for STEM projects.

WAYS OF IMPLEMENTING STEM EDUCATION AT SCHOOL

Despite the efforts of some countries for nationwide programs to promote the STEM approach, while the key object (and often the subject) of change is a separate school, whose staff strives for innovation. For schools, on the one hand, there are no generally accepted and binding decisions that would dictate required set of actions. On the other hand, every school has its unique context and operating conditions. However, it is possible highlight some fundamental principles, the implementation of which characterizes STEM education at the level of an individual school. These principles relate to the organization of the program, the construction of the educational process, the organization of the interaction of all its participants.

The study of STEM subjects takes place on based on the analysis of the problems and challenges of the modern world. Dealing with Problems goes as part of the creation of project teams and commands. Problems become the starting point and center around which the learning and development of STEM subjects is built. The solution to the problem includes all the skills and abilities of students (data analysis, forecasts, etc.)

The problems that students work with should be related to real life and everyday life. They should be close and understandable. These are not standard or typical projects and problems. Teachers involved in the formulation of projects and their implementation. The results of the implementation of projects should show visible practical value and make life a little better.

There must be an atmosphere of respect and trust that allows students and teachers to work together. It provides a comfortable introduction of new members' community (schoolchildren) in the group learning process. Good practices here are work in small groups; organization of extra-curricular, club or other activities; help and support project teams (groups) on the part of teachers, as well as the creation of

the School Code with fixed elements of ethnicity and the attention of the entire school staff.

The school is collaborating on ideas and plans, a reflection of this work is organized. General planning time and individual planning time are specially allocated. “Risk support” is provided, that is, the possibility of searching and experimenting, autonomy in content solutions. The constant participation of employees (teachers, administration, technical staff) in relevant professional development activities is encouraged. School staff shares the general meaning and values of the work of the school.

For the development of a STEM school, it is necessary consideration of environmental factors, in including the existence of common programs and infrastructure for approach development, relationships with local businesses, universities and government institutions. It is also important to take into account current social questions. For example, the need introduce all social layers and groups or focus on involvement of certain groups.

The most basic level implementation of the STEM approach is a separate lesson or curriculum.

For the Ukrainian situation, this level is still remains the key and most accessible. Here main efforts and there is a search for methods and approaches to work. Therefore, such platforms and resources are becoming especially important, which collect and systematize various experiences.

One of the basic settings of the STEM lesson, which today remains the most methodologically complex and at the same time the most important is the development of practice and research methods by schoolchildren. Experts point out that mastering the research approach itself and gaining such experience may be more important than a specific the resulting knowledge. The second important setting is the development of engineering, that is, the creation of a new one in response to a task. Within this setting, the student learns to find solutions

to specific problems and create prototypes for new mechanisms, techniques, programs.

In general, we see that for new approaches in education, it becomes extremely important to master the methods of thinking and searching, which take the place of knowledge of facts. In this direction, it is no less important to understand the differences between not only natural science and engineering approaches, but also approach to humanitarian and social phenomena.

To promote and implement the STEM approach in education different entities are involved. These are government agencies and structures, local communities and self-government bodies, business and corporations, individual educational institutions and networks, public associations, associations and professional communities, individual educators. Each of them chooses his own strategy of action, based on the general situation, his interests and opportunities. To help you navigate the variety of activities, we offer a typology of different practices, among which each subject of action can find his way.

The development of the STEM approach in education is determined not only by activity different actors, but also the problems that need to be addressed. We are talking about the difficulties of growing or transforming the old system, as well as and conceptual challenges. Let us outline a number of issues that today are the subject of heated discussions and do not yet have unambiguous solutions.

Among the priority tasks regarding the implementation of the educational direction.

STEM is worth highlighting the following:

- regulatory and legal provision of STEM education;
- study of the available national and international practical experience of development of gifted education and implementation of the STEM educational direction;

– creation of new models of integration of formal and informal education at the level of content, educational environment, relevant educational processes and their results;

– development of new integrated educational programs, technologies for creating individual educational trajectories;

– creation of educational and methodical complexes: STEM learning tools, electronic training manuals, STEM projects, STEM cases, etc., which provide personal and developmental content of education, use, in addition to traditional, resources of global and local computer networks, multimedia tools, network educational systems, etc.;

– pooling of resources of formal and informal education, involvement of specialists and resources of educational, scientific, industrial institutions, business, etc.;

– proper preparation of teachers to work in new integrated conditions, their uniting in creative professional network communities, partnership both domestically and internationally.

To develop STEM education, each school can take the following first steps:

– analyze what equipment the institution has. What it should be like is stated in the Standard list of teaching aids and equipment for classrooms and STEM laboratories;

– if your school has an interesting idea related to STEM, you can try to collect the necessary funds for its implementation on crowdfunding platforms, ask for the assistance of an IT company, tell the world about your idea thanks to public figures, and be sure to participate in student hackathons, competitions and olympiads;

– implementation of STEM in an educational institution requires the training scientific and pedagogical workers, in particular, teachers can undergo training on the basis of the Institute of Education Content Modernization, which, starting in 2017, held 9 sessions for more than 21 thousand educators;

– using remote educational opportunities, for example, to form modern competencies in schoolchildren, you can visit the virtual STEM center of the Minor Academy of Sciences of Ukraine with them.

In the case of an emphasis on STEM literacy for all, an urgent task there is a revision of the content and principles of organization of school education, introducing new foundations into it. Emphasis on preparation highly qualified personnel pays attention to the organization channels of access to the necessary knowledge, the elimination of barriers, the creation of additional conditions and a common interest in scientific and technically oriented sector of the economy.

For further deep study of STEM education models at the level of the entire system it is important to distinguish between such sub-processes as preparation, functional literacy, training, upbringing and education proper in a narrow meaning.

One of the main problems of organizing work with students who take part in the Minor Academy of Sciences of Ukraine work competition is, along with involving them in search and research activities, preparation for a conscious choice of a profession thanks to the choice of research topics that have a professional orientation, because professional training is one of the important tasks of secondary education institutions.

Usually, student-members of the Minor Academy of Sciences of Ukraine reach the stage of choosing and substantiating research topics with a defined range of their professional interests. Under these conditions, topics in mathematics, in our opinion, must necessarily be applied, aimed at solving the problems of one or another professional field.

Unlike olympiads, where mathematical problems are "imposed" on students by the organizers, student-members of the Minor Academy of Sciences of Ukraine during preparation for research work have the opportunity to choose not only topics for in-depth study, but also to substantiate those that interest them in terms of professional orientation.

The methods, forms and means used during the training of students using the STEM approach should be associated with new scientific and

practical developments, which allows in practice to show the effectiveness of STEM technologies and increase the professional orientation of education and the motivation of students to choose professions in STEM industry.

Consideration of the main approaches to education and development of gifted children in the process of implementing STEM education and improving programs based on them educational subjects, optional and elective courses, etc. provides the opportunity for the pedagogical staff, teachers, lecturers, specialists to join the all-Ukrainian and international partnership for the development of the STEM educational direction through the development of original educational programs, creation of didactic materials for STEM education, practical transfer experience etc.

We will consider the introduction of STEM education and examples of schools in Poltava Region. Poltava Region is one of the seven regions of Ukraine that was selected for the second stage of the EU4Skills Program. Currently, three institutions (from Reshetylivka, Kremenchuk and Hadiach) continue to compete in the open competition. One of them will receive a million-dollar investment from the European Union to create an educational center of practical excellence.

In 2019, more than UAH 31 million was allocated from the regional budget to finance STEM education. With these funds, 63 modern sets for vocational training were purchased: innovative classrooms for science and mathematics training with interactive teaching aids, equipment for the automotive training program, for the training of specialists in the production of fabric products. The first to receive them were two institutions in Kremenchuk: the Reshetylivka Vocational Agrarian Lyceum and the Hadiach Higher Vocational Agrarian School.

Reshetylivka Vocational Agrarian Lyceum named after I. H. Borovenskyi prepares professional personnel for the agricultural sector. During the last five years, the educational institution exceeded the plans of the state and regional order. The lyceum has been working in the direction of STEM education for over a year.

STEM education is actively being implemented at Higher Vocational School No. 7 in Kremenchuk. This institution trains specialists in mechanical engineering, electrical engineering, construction, and welding. Graduates of the institution work at the best enterprises of the Poltava Region.

In 2020, a STEM center was opened in Poltava (see Fig. 2.2). This center consists of stationary laboratories and includes:

- three extremely powerful multi-age robotics laboratories with a robot arena (tables for holding competitions);
- 3D graphics laboratory with a 3D printer and a 3D scanner for the production of elements of parts of robots and cyber-physical devices, 3D pens with hot and cold modes;
- virtual and augmented reality laboratory (it has enough glasses to use the resource in the classroom when studying a certain topic, and a helmet to immerse yourself in the virtual world as much as possible);
- Makerspace laboratory, which includes a laser jigsaw, a laser engraver, machines (wood lathe, metal lathe, drilling and milling, grinding), a sewing machine, etc. All these devices can work from given programs;
- photo and TV studio where a mobile film crew will work;
- recording studio, where, in addition to studying the basics of sound recording, it will be possible to provide musical accompaniment for events;
- Lego laboratory;
- 3D cinema;
- Arduino laboratory with the study of electronics (allows you to create complex projects for scientific works that require prototyping, tinkering and programming).

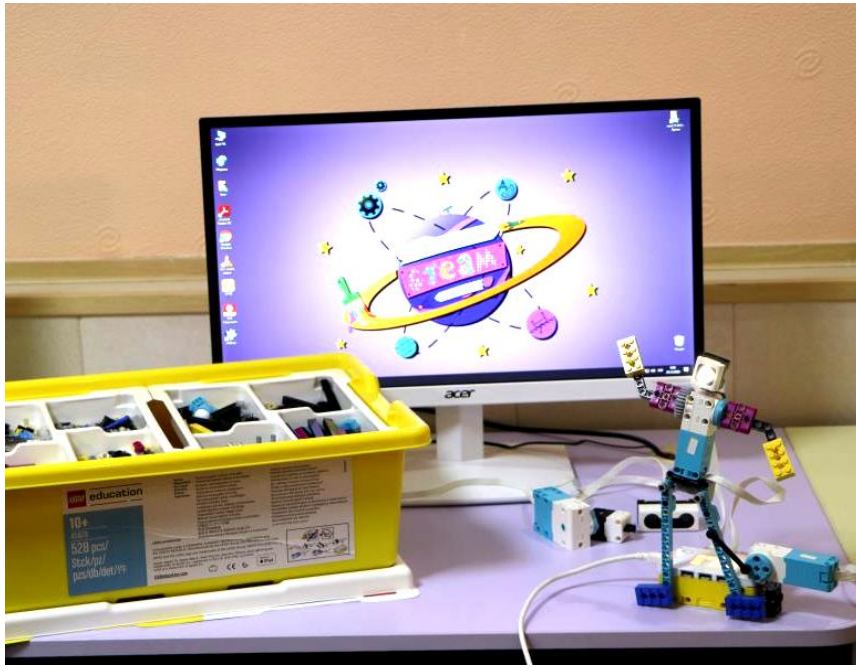

Figure 2.2 – Poltava STEM center

In 2021 three educational institutions in Kremenchuk received STEM laboratories.

In total, UAH 20.2 million from the regional budget were allocated for the purchase of 17 STEM laboratories in Poltava Region. 17 modern STEM laboratories were delivered to 15 educational institutions of Poltava Region (including three from Kremenchuk).

As reported in the Poltava Regional State Administration, they will help create a modern educational environment that will provide the necessary conditions, means and technologies for student training, development of competencies necessary for successful self-realization of the individual.

UAH 20.2 million from the regional budget were allocated to the purchase of STEM laboratories. In Kremenchuk, the following laboratories were awarded: Poltava Regional Scientific Lyceum Boarding II–III degrees at the Kremenchuk Pedagogical College named after A.S. Makarenko; Kremenchuk Specialized Boarding School of Sports Profile I–III Degrees named after I.M. Poddubny of Poltava Regional Council; Kremenchuk Lyceum with enhanced military physical training. The STEM laboratories are presented in the Fig. 2.3 and Fig. 2.4.

Figure 2.3 – STEAM Laboratory of Hadiach Lyceum I–III degrees No. 1 named after Olena Pchilka

Figure 2.4 – STEM laboratory in Kremenchuk Pedagogical College

In 2019, the STEM Education Department held a distance winter session "STEM School 2019", which was attended by teachers and students of Kremenchuk. Its purpose is to acquaint the pedagogical public with innovative educational technologies necessary for the implementation of the conceptual foundations of the New Ukrainian School, to create a platform for communication, search and support of promising scientific ideas regarding the development of STEM education in Ukraine.

Pedagogical workers (scientists, methodologists of postgraduate pedagogical education institutions, employees of district (city) methodical offices, managers and teachers/educators of educational institutions) had the opportunity to study remotely for five days.

The winter session "STEM School 2019" presents materials for all levels of education and for teaching different age categories of children in the following areas:

– scientific and theoretical aspects of STEM education: conceptual foundations of STEM education, models of STEM education, didactic principles and approaches of STEM education, etc.;

– scientific and methodological support for STEM teaching: curricula, teaching materials/resources for teachers, manuals, notebooks, etc.;

– material and technical support for the implementation of STEM training: measuring devices, digital laboratories, etc.;

– problems and prospects for the development of STEM/STREAM areas as education in preschool, primary and extra-curricular education: formation of STEM is an environment that educates researchers; resources, tools, methodological techniques, etc.;

– life hacks for STEM lessons/classes: resources, tools, methodological techniques, non-standard approaches, complex tasks/exercises, educational projects, etc.;

– innovative forms of extracurricular/extracurricular activities: hackathons, competitions, contests, forums, battles, festivals, scientific picnics, etc.;

- development of professional competence of teaching staff.

Every year in spring in Kremenchuk on the basis of Kremenchuk Mykhailo Ostrohradskyi National University the All-Ukrainian STEM week is traditionally held as part of the popularization of STEM education. Each year, educational institutions are offered a theme and schedule of the event. At the invitation of educational institutions of our city teachers of Kremenchuk educational institutions helped students understand what STEM is and why it is important.

The development of stem education involves:

– provision for each schoolchild's innovative thinking and experience of how use math, engineering and science to solve different professional tasks;
– developed logic and thinking;
– the ability to set and solve problems;
– scientific view of the world: skill explore, analyze, prove;
– teamwork, communication;
– creativity;
– digital literacy.

Advanced STEM learning motivated schoolchildren to give them the opportunity to succeed in science and technology, the technology sector and succeed:
– motivation for engineering and technical specialties and careers in the field of science and technology;
– access to laboratories where experiments are carried out and industrial tasks for experience and practices;
– lack of barriers limiting career and professional growth;
– in-depth knowledge in the field science, technology, engineering and mathematics.

Implementation of the transition to the competency model of training and the introduction of new methodological approaches, first of all, involves:
– fundamentally new goal-setting in the pedagogical process, shift of emphasis in educational activities from narrow subjects to general didactic;
– updating the structure and content of educational subjects, special courses etc;
– definition and assessment of learning outcomes through key and subject competencies of the student;
– introduction of end-to-end STEM education, competently oriented forms and methods of training, system-activity approach;
– introduction of innovative, game-based learning technologies, case-study technologies, interactive methods of group learning, problem-based

methods for the development of critical and systemic thinking, etc.;
– adjusting the content of individual topics of educational subjects with emphasis on personal development, game teaching methods, value attitude to research question;
– creating the pedagogical conditions for the acquisition of effective individual experience of project activity and development of startups.

School teachers and student projects are built into university educational and research programs. This makes it possible continuous professional development of teachers and the relevance of scientific problems that are solved in the course of educational program. Topics, problems and tasks training is often offered by the "City" – local government, communities, industry. Conjugacy with higher education, practice and industry of the city ensures the development of social responsibility, the involvement of school in solving problems of the local community provides flexible and practical career guidance.

The future belongs to technology, and the future of technology belongs to teachers of a new format, who are free from prejudice, do not accept a formal approach and can broaden the horizons of students with their knowledge.

Control Questions

1. What is the importance of the Minor Academy of Sciences of Ukraine for the introduction of STEM education?
2. Who can be a sponsor for the purchase of equipment for classrooms and STEM laboratories?
3. Why the implementation of STEM in an educational institution requires the training of scientific and pedagogical workers?
4. What laboratories are necessary for schools to implement STEM education?
5. Do teachers need professional retraining for the introduction of STEM education?

Tasks

1. Prepare an approximate list of equipment needed for a computer science room.
2. Name the software necessary for a school to successfully implement STEM education.
3. Read the Text «9 principles for teaching STEM effectively» (Application C) and give your own examples of implementation of the principles.

INTEGRATED LEARNING AS THE FOUNDATION OF STEM EDUCATION

STEM education represents a symbiotic relationship between the four interlaced fields to succeed in time. Learning experience in STEM is the need to be able to go beyond the scope of cognitive tasks (for example, recalling facts about separate) and get a basic understanding of the content, which allows you to think more broadly, on a large scale.

STEM education implies a mixed environment in which students begin to understand how scientific methods can be applied in practice. Students of this program, in addition to mathematics and physics, study robotics, on which they program and design their own robots. Special technological equipment is used in the classes.

One of the most important conditions for modernization modern education is to reveal the potential of each student to achieve which the principle of intersubject communications or process is applied integration of educational subjects.

The meta-subject educational minimum is developed on the basis of the goals of general education. In integrated learning various interdisciplinary problems are considered, necessary and appropriate for the development of students and in this approach harmoniously combines various teaching methods.

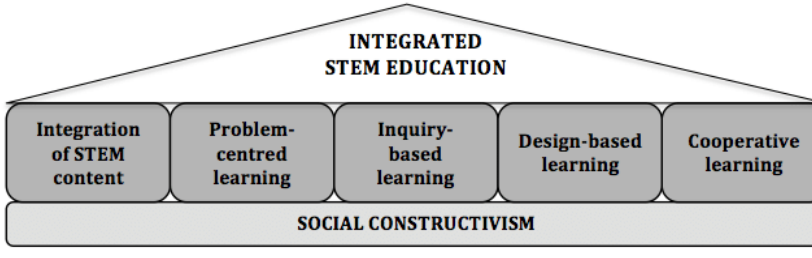

Figure 2.5 – Integrated STEM education

STEM education combines project-based and interdisciplinary approaches, the basis of which is the integration of natural sciences into technology, engineering creativity and mathematics.

It is very important to teach science, technology, engineering and mathematics in an integrated way, because these areas are closely interconnected in practice. Applying scientific and technical knowledge to the real world is important too.

With the help of practical classes, STEM education demonstrates to students the application of scientific and technical knowledge in real life. They study a specific project, as a result of which they create a prototype of a real product.

Integrated lessons are a special form of STEM education aimed at:

– establishing interdisciplinary connections that contribute to the formation of students holistic, systemic outlook;

– updating of personal attitude to the issues considered at lessons.

Teachers conduct integrated lessons in two ways:

– through combining similar subjects of several educational subjects;

– through forming integrated courses or separate special courses by unification of educational programs of such courses/subjects.

The introduction of the integration of subjects in the education system provides the ability to solve the problems currently set for the school and society as a whole. Integrated lessons can help the formation of a holistic picture of the world in children, understanding the connections between phenomena in nature, society and the world as a whole.

A special form of STEM education is integrated lessons/classes that are aimed at establishing interdisciplinary connections that contribute to the formation in students of a holistic, systematic worldview, actualization personal attitude to the issues discussed in the lesson.

Integrated lessons can be conducted in two ways:

– through combining similar subjects of several educational subjects;

– through the formation of integrated courses or individual special courses by combining the curricula of such courses/subjects.

The basis of the effectiveness of such lessons/classes is a clear definition of the goal and their appropriate planning to ensure versatile consideration by students a certain object, concept, phenomenon using different educational tools subjects. The peculiarity of planning and conducting integrated, binary lessons is that they can be conducted as one teacher who teaches integrated subjects as well as several. Because of the complexity coordination of teachers' activities in the second case such integrated lessons are carried out unreasonably rarely, so it is necessary to plan them in advance for everyone parallel teachers.

In cases where the program material of different educational subjects allows integrating it within one educational day, they can to organize «thematic days», when all lessons according to the schedule are directed to implementation of a single educational goal, achievement of a specific one result.

In order to involve students in practical activities, it is desirable to expand range of organizational forms, teaching methods, methods of educational interaction and give priority to the assimilation of educational material during excursions, quests, contests, festivals, hackathons, workshops, etc. At the same time, for the formation and verification of subject competences, the teacher should rely on a system of integrated tasks aimed at students' application of methods educational and cognitive activity, knowledge, abilities and skills for solving certain tasks in simulated life situations.

At the lessons of computer science and mathematics interdisciplinary communications informatics-mathematics are carried out.

Integrated learning helps to reveal in a student such qualities such as reproductive activity, patriotism, intellectual and physical development, learning ability, ability for self-development, creativity, and search activity. Consolidation of knowledge can contribute to improving the effectiveness of training in general and level of cognitive activity in particular.

The main task of the teacher in these classes is to form student's information competence and the ability to transform into practice mathematical objects using information tools technologies.

Integration of informatics and information technology with other subjects is an important practical necessity. Mathematics offers the researcher a number of mathematical methods that allow not only to obtain numerical characteristics of the object under study, but also to model his behavior is influenced by various factors. Informatics provides tools to improve accuracy and reduce the complexity of complex activities that are not available for "manual" technology.

The introduction of the integration of subjects contributes to the stimulation analytical and synthetic activities of students, the development of the need in a systematic approach to the object of knowledge, the formation of skills analyze and compare complex processes and phenomena.

Benefits of integrated lessons are:

1. Contribute to increasing motivation for learning, formation cognitive interest of students, a holistic scientific picture of the world and consideration of the phenomenon from several sides;

2. Contribute to the development of speech, the formation of students' skills compare, generalize, draw conclusions, intensify educational process, relieve overstrain and overload;

3. Not only deepen the understanding of the subject, expand horizons, but also contribute to the formation of a diversified, harmoniously and intellectually developed personality;

4. Integration is a source of finding new links between facts that confirm or deepen certain conclusions observations of students in various subjects.

Integrated lessons captivate young professionals with novelty, the possibility of including alternative ideas in the school curriculum and non-standard approaches. The principle of integrated learning with the use of ICT becomes an integral part of the educational process, which fully shows the methodological and didactic teacher's approach to the lesson.

Integration in learning is a procedure for discovering links between the structural components of the content within a clear concept of education

in order to form an integral concept of the world, focused on the development and self-development of the student.

The integration of subjects is one of the directions of dynamic selection of non-traditional pedagogical solutions, the creation of original products of the work of pedagogical teams for a fruitful and expedient impact on students.

Main integration approaches:

1. Integrative courses (unification of the essence of the education of subject disciplines).

2. Integration according to the method (the development of all disciplines exclusively in a creatively developing model).

3. Hermeneutics (the introduction of methods of communication agreed for all teachers with students during the lessons).

4. Integration by technology (building an educational process using ICT technologies).

5. An integrated lesson is a private model of a lesson that combines learning simultaneously in several disciplines while studying one concept, topic or phenomenon.

The concept of integrated lessons is the beginning of integrated learning, they combine a variety of teaching and learning methods used on the verge of academic subjects.

Integrated lessons provide a chance for the student to more accurately represent the surrounding reality, as well as to establish the relationship of phenomena and objects.

The principles of integrated lessons should fully affect the result of learning – the development of students' thinking.

1. Relevance of the problem or its practical significance. An integral part is the implementation of this problem in some practical situation, which enhances the practical orientation of training and develops thinking, contributes to the comparison of theory with practice.

2. Generalization of knowledge. A holistic understanding of the issues under study contributes to the formation of a breadth of thinking. Finding a problem creates a trend and dynamic thinking.

3. Deep study. The most complete understanding of the topic under study helps to develop the depth of thinking.

4. Alternative solution. New approaches to a given situation, original methods of posing a problem and the probability of choosing a solution to this problem are aimed at developing originality and flexibility of thinking. Comparison of solutions develops dynamism, criticality, organization of thinking.

An integrated lesson can be classified according to the following criteria:

– the presence of a basis for integration;

– an integrated approach to the choice of the content of education: knowledge, skills, orientations based on the configuration of the understanding of reality;

– selection of the correct form of the lesson, which guarantees the formation of various areas of the personality of schoolchildren.

When conducting research, mathematical experiments, as well as for complex calculations, it is advisable to use ICT technologies.

The connections of mathematics with computer science, physics and drawing help students improve their polytechnical knowledge and skills.

The implementation of intersubject communications can be carried out in various ways. One of the most effective ways to achieve this goal is to solve applied problems from related disciplines, which allow students to demonstrate the application of mathematical methods to solve problems from other subject areas.

From a psychological and pedagogical point of view, an integrated lesson contributes to the activation of the cognitive activity of schoolchildren, stimulates their cognitive activity, and is a condition for the successful assimilation of educational material.

The lesson should cover a large theoretical material of related courses. In this case, it is advisable to use such forms of organization of training that serve this purpose: lectures, conversations, conferences, seminars, combined lessons.

Lectures can be generalizing (for example, "Unified scientific picture of the world", "History of the development of technology", "Patterns of technical development"). At the same time, a significant didactic effect is provided by the participation of the students themselves in conducting such lessons in the form of a partial presentation of the elements of the educational material by them. In the process of developing forms and conducting integrated lessons, many teachers prefer conferences and seminars, which has changed the balance between informative and active teaching methods.

A modern **lesson of knowledge formation** in STEM framework based on a combination of various methods and teaching aids solves a set of problems. Both explanatory and illustrative, and partially search, research methods of teaching, discussion, various sources of knowledge, television programs, film fragments, tape recordings, multimedia courses, Internet technologies, other technical means of training and control. Various forms of work are also widely used: group, frontal, link, pair, individual.

At such lessons, more opportunities are created for solving cognitive problems, making proposals for the realization of creative potential, in a word, conditions are created for the full development of the student's personality.

Varieties of the lesson in the formation of new knowledge are also: lessons in the formation and improvement of knowledge, lessons in consolidating and improving knowledge, lessons in the formation of a new problem vision. Then, to the listed forms of the lesson, you can add a seminar, a final conference, a final excursion.

The **lesson of teaching skills and abilities** provides for the following forms:

- practical lesson;
- essay lesson;
- dialogue lesson;
- business lesson or role-playing game;
- combined lesson;
- travel;

– expedition, etc.

The structure of the lesson includes the following stages: organizational, goal setting, checking homework and updating knowledge, performing tasks of a standard type, then a reconstructive-variable type, creative type, monitoring the formation of skills and abilities, determining homework.

At the lesson of the formation of skills and abilities, textbooks, collections of tasks, sets of handouts and didactic materials, multimedia, Internet technologies are used as the main sources of knowledge. Managing the learning activities of students, the teacher widely uses the methods of stimulation, operational control.

Here, the corrective and control functions of the lesson are especially clearly implemented, which contribute to the organization of educational activities of schoolchildren with the highest productivity. This lesson allows for a wide differentiation of learning. Students complete assignments taking into account learning opportunities and, thanks to this, move towards the goal at an optimal pace.

The design of the lesson allows you to include students in various types of pair, group and individual work, which take up most of his time. It is possible to resort to individualized and individualized-group form of education.

In these lessons, mobilizing theoretical knowledge, students are involved in experimental, research, search and partially search activities. This is their high developmental role. Children develop scientific views, a holistic worldview.

It is also necessary to encourage schoolchildren to be inquisitive, to develop their natural curiosity, not in difficult situations to be afraid to make a mistake, to be open, to understand and value their personal perspectives and positions others, be able to grow through experience, be communicative, be able to think scientifically and express ideas and information in different modes of communication.

In the **lesson of repetition and systematization of knowledge**, students are included in various activities. Conversations, discussions,

laboratory work are held, tasks are practiced, and problem solving is practiced. In these lessons, along with the conversation, brief reports of children, speeches with oral reviews of individual articles, books devoted to the issue under consideration are included.

The effectiveness of the lesson depends on how widely various types of reproductive-search, partly search, creative activity of schoolchildren. It does not achieve its goal if the usual reproductive activity is preferred. The teacher prepares tasks of a creative nature, allowing you to take a fresh look at the previously studied. At the same time, the developing function is realized the more successfully, the more widely interdisciplinary connections are used, which allow transferring, collapsing and systematizing knowledge.

The next type is the **lesson of mastering skills and abilities, control and correction of children's knowledge**. In solving this problem, integrative learning processes play an important role, since in the educational field "Technology" most of the skills and abilities are developed on the basis of the synthesis of many knowledge of natural science disciplines.

These include polytechnic, creative design, measurement, graphic, computational and modeling skills.

Integrative lessons of control and correction of knowledge are best carried out in the process of completing a project task.

The structure of STEM lessons largely depends on the chosen methods of active learning. At the same time, such lessons have a number of common characteristics, the main of which are interdisciplinarity, emphasis on the practical activities of trainees, wide use of digital interactive learning objects.

The recommended structure of a STEM lesson is shown in the table 2.1.

Table 2.1

The structure of a STEM lesson

1. Name of the didactic project.
2. Teacher.
3. Grade.
4. Curriculum area.
5. Academic discipline.
6. Unit of competence.
7. Theme of the lesson.
8. Forms of education.
9. Type of lesson.
10. Purpose of the lesson.
11. Integratable academic disciplines (disciplines are indicated, the topics of which are integrated into this lesson).
12. Target specific competencies (competencies from integrable academic disciplines).
13. Operational goals.
14. Didactic strategies.
    - Teaching methods and procedures (emphasis on active learning methods).
    - Didactic tools (emphasis on digital didactic tools).
    - Organizational forms.
15. Bibliography.
16. Digital resources (links to relevant resources are indicated)
17. Lesson progress. It is formatted as a table:
    - Line by line lesson stages (according to the lesson model used).
    - By columns:
      1) Operational goals.
      2) Content units.
      3) The activities of the teacher and the activities of students in lesson (indicated references to the digital learning objects used).
      4) Methods and procedures (emphasis on active learning methods).
      5) Learning media (emphasis on digital learning tools).
      6) Organizational forms (emphasis on the widespread use of digital tools for collaboration and networking).
      7) Assessment (emphasis on computer tests, online questionnaires).

18. Applications (emphasis on digital learning objects hosted on the Internet, with Indicating.

When conducting STEM lessons with the physical presence of students in the classroom, at the points in time indicated in the didactic project, the teacher provides students online access to relevant digital learning objects. Together with students have the opportunity to perform practical tasks using real physical educational objects (measuring instruments, laboratory stands, layouts, natural models, materials, reagents, etc.).

At the same time, information and communication technology tools are used mainly for collecting and processing data, for organizing joint work of students (co-working), for reporting and presentation of the results of the work performed.

When conducting STEM lessons without the physical presence of students in the classroom, it is necessary to take into account the specifics of distance learning.

With distance STEM learning, in the absence of the required materials, tools and measuring devices, practical tasks should performed by trainees using digital tools (text editors, graphic editors, programs for electronic presentations, programs for spreadsheet, programs for processing multimedia files, virtual experiments, etc.).

In the case of synchronous learning, the course of a STEM lesson conducted using Internet conferencing tools follows the logic of a traditional, classroom lesson.

In the case of asynchronous learning, based on the didactic project of the STEM lesson, a corresponding electronic lesson is being developed. The developed lesson is loaded into learning management system or distributed to students as a separate digital educational resource.

In the absence of funds for the development of electronic lessons in an educational institution, the material lesson is provided to students in the form of an electronic document or electronic presentations with relevant links to digital learning objects.

When developing a system of integrated lessons focused on establishing interdisciplinary connections, the teacher needs to determine their goal, review the content of the studied material, choose methods, forms and means of organizing training that are adequate to the goal, predict the result.

Combining mathematics with art, and biology with robotics is exactly what reform of secondary education is all about. It is not just about the integration of subjects: there will be more group project work in schools, and the tasks in the lessons will become more applied. This will help children to leave school prepared for real life, and the country to get more specialists in the fields of engineering, IT or nanobiology.

When introducing STEM education, one should distinguish between:

1. STEM education in educational systems in which the natural sciences (physics, chemistry, biology, etc.) are taught as an integrated school discipline. Most often, this approach is found in Western countries, and the corresponding school discipline is called Science (Science).

2. STEM education in educational systems in which the natural sciences are taught as separate school disciplines.

Obviously, with the first approach, the school discipline Science (Science) provides integration of the relevant areas of knowledge, however, at the same time, systematicity suffers and the depth of study each of natural and exact sciences. With the second approach, you can provide more in-depth study of mathematics, physics, chemistry, biology, etc., however, at the same time, interdisciplinary connections are lost.

In order to develop and strengthen interdisciplinary links, Ukrainian education is based on an expanded interpretation of the concept of “STEM education”. According with this interpretation, although the exact and natural sciences are studied in our schools in within separate, non-integrated school subjects, STEM education should implemented through the use of interdisciplinary content and interdisciplinary educational tasks (exercises, tasks, educational projects, educational research, etc.).

STEM education in our country implies the widespread use of modern active learning methods, interdisciplinary digital content and such

interdisciplinary and applied learning tasks, the implementation of which involves use of information and communication technologies. STEM approach is applicable both in-class and out-of-class learning.

In STEM education, the didactic projects developed by the teacher should be based on the use of active learning methods, and the created training situations should be applied and interdisciplinary in nature, with a predominant using digital interactive learning objects.

Control Questions

1. What is interdisciplinary integration?
2. How are integrated lessons related to STEM education?
3. How does interdisciplinary integration affect the formation of students' skills and competencies?
4. With which subjects is it advisable to integrate informatics?
5. What types of integrated lessons do you know?
6. What is the structure of integrated lesson?
7. What is the difference between conducting STEM lessons with the physical presence of students and distance learning?
8. From what depends the effectiveness of the integrated lesson?
9. What are the varieties of the lesson in the formation of new knowledge?

Tasks

1. Make a plan-summary of an integrated computer science and mathematics lesson.
2. Fill in the table of the structure of the integrated STEM lesson for the lesson of informatics and mathematics.
3. Develop a set of tasks for an integrated lesson in design and computer science.

EQUIPMENT FOR STEM EDUCATION

On January 20, 2020, the Ministry of Education and Science of Ukraine proposed for public discussion the draft order "On approval of the Standard list of educational and methodological support, teaching aids and equipment for classrooms and STEM laboratories" with the aim of providing general secondary education institutions with modern equipment.

This project is a new step in the development of education and approaches to learning in schools. Students will be able to study science, technology, engineering and mathematics by interacting with gadgets and smart electronics and learning how they work directly during lessons. In STEM classes, the focus is not on the teacher, but on the practical task to be solved. The teacher becomes a mentor, explains how to use the potential of each technology in the project. Students solve practical tasks through trial and error, rather than studying "dry" theory.

For the full implementation of such an approach, STEM laboratories come to the rescue. They are equipped with 3D printers, educational electronics kits, robots and other technical means to give children everything they need to realize their potential.

The main confirmation of equipment compliance with the new order is the presence of a special certificate issued by the State Scientific Institution "Institute of Education Content Modernization". This certificate recognizes the compliance of all the equipment of this article with pedagogical requirements.

3D technologies are advanced technologies filling modern life a person 3D modeling is the basis of 3D technologies. Three-dimensional modeling has become an integral part of the engineering design of everything possible technical devices, architectural and landscape design, etc of course, the sphere of entertainment.

The relevance of the curriculum is related to wide penetration information technologies in almost all spheres of modern life and growth demand for IT specialists. Like all information technologies, 3D modeling

is based on the application of computer and software tools that are prone to rapid changes. Today, there is a need to master these technologies in at an earlier age.

A **3D printer**, together with consumables, is a printing device that makes products from plastic (in most cases) according to various physical principles of processing this substance. For institutions of general secondary education, the most useful are 3D printers that work on the technology of melting a plastic thread. Devices with this technology have a simple design, compact size, they are safe to use and affordable.

3D printers are gaining more and more popularity in education. For them pupils develop spatial, logical and creative thinking, learn IT technologies, get acquainted with various spheres of human activity : architecture, art, medicine, digital dentistry, technology, construction, etc.

In Ukraine, there is a wide selection of equipment for 3D printing, but most of the devices are offered in an open design. But there is a manufacturer of equipment that promotes devices in a protected closed version, with which ERC has been cooperating for three years — XYZprinting. The new order singles out 3D printers, the consumable for which is biodegradable plastic PLA (PLA). XYZprinting is the only equipment manufacturer operating in Ukraine that offers PLA plastic of its own production.

In addition, absolutely all models of XYZprinting 3D printers can work with this plastic.

An additional advantage of this manufacturer's equipment is a two-year warranty implemented by the ERC service center.

Figure 2.6 – 3D printer XYZprinting da Vinci 1.0 Professional Wi-Fi 3F1AWXEU01K

3D printers and design software inspire creativity and develop imagination students, the possibilities of what they can create with 3D printing are endless; they have the ability to transform their 3D designs into real physical objects.

Spatial intelligence involves analyzing and interpreting size, shape, movement, and relationships between objects; it is an opportunity to draw correct conclusions from observing three-dimensional objects environments.

Figure 2.7 – Working on a 3D printer

Computational thinking and skills such as decomposition, pattern recognition, logical thinking, reasoning and problem solving are becoming increasingly important. 3D printers (and others tools such as interactive whiteboard, touch panel, multimedia table) help make computational thinking a key part of the modern curriculum.

A **3D scanner** is a separate device for processing a finished product and converting its external forms into a digital format (for preparing an electronic 3D model of the product). Acquaintance of schoolchildren with 3D scanning technology will deepen their knowledge in the field of technologies of the 21st century. ERC offers one model of a portable 3D scanner, which, considering the cost, can be called the best choice for any Ukrainian school.

A 3D scanner is a device that examines an object, digitizing it with the help of sensors, and uses the received information to create a three-dimensional model. Basically, a 3D scanner creates a digital copy of a physical object of any configuration and degree of complexity. This

fundamentally distinguishes it from its predecessors, ordinary scanners that can only read information from documents and photos.

The scanning process itself can take place in different ways: depending on the type of 3D device and the technology used, as well as on what object needs to be processed with its help, moving or static.

Figure 2.8 – 3D scanning technology

Figure 2.9 – 3D scanner

There are several types of **3D pens**: low-temperature and conventional heating. They differ in the heating temperature during the melting of the consumable.

In particular, the low-temperature pen has a nozzle temperature of up to 60 °C and is safe to use. The risk of burns at this temperature is significantly reduced. To create 3D figures, it is necessary to use PCL threads that have a low melting point.

But in conventional heating pens, the temperature of the nozzle varies from 60 °C to 180 °C. Due to the fact that the temperature is higher, these pens must be handled with more care and attention.

The main advantage of conventional heating pens is the use of PLA plastic as a consumable.

PLA is a natural material that is made from corn starch, so it is completely safe for the environment. Plastic completely decomposes when it enters the ground, and also does not have any toxic effect on humans.

Figure 2.10 – 3D pens with consumables

Figure 2.11 – Working with 3D pen

Figure 2.12 – Work made with 3D pen

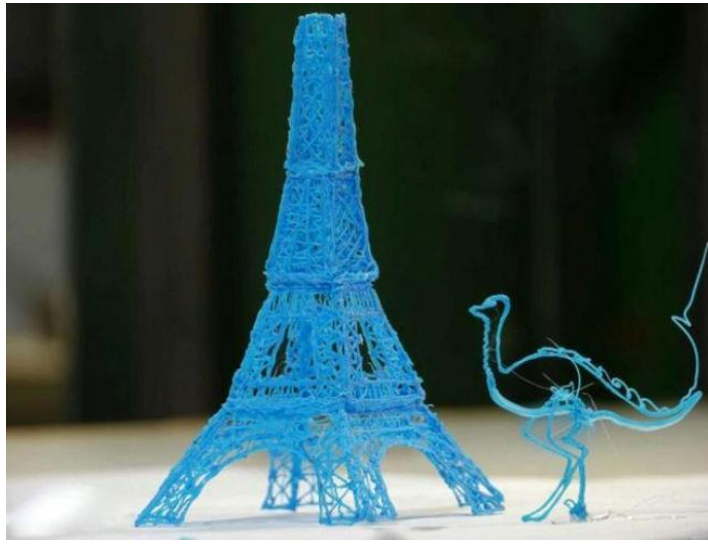

Figure 2.13 – Works made with 3D pen

A **digital laser machine** with numerical software control allows you to quickly manufacture structural parts, support elements, beams from various materials and cut complex shapes from ultra-thin materials. The

optimal solution for educational institutions will be Laserbox Pro Makeblock.

Specially designed for educational and crafting purposes, Laserbox reimagines and redefines laser functionality with an ultra-wide-angle, high-resolution camera with visual AI. The machine can automatically identify any material and adjust the engraving or cutting parameters accordingly. The closed body and automatic suspension system when opening the lid makes it completely safe for children. As a revolutionary laser, Laserbox recognizes hand-drawn images and makes the process of creating models easy and fun.

Figure 2.14 – Digital laser machine

Programmable electronics modules combine sensors and actuators with which students can build and program their first electronic devices. This is a set of boards, manipulators, resistors and other parts for studying robotics. In its finished form, it can look like a mobile mobile

platform with an integrated manipulator and a set of additional electronic components.

For a junior school, the Makeblock Neuron Creative Lab Kit is the optimal solution, the modules of which are reliably protected by a plastic case, and the magnetic connectors allow you to connect them together as quickly and conveniently as possible.

The set contains 30 different electronic modules, such as: LED display, camera, ultrasonic sensor, motors and more.

Figure 2.15 – Programmable electronic modules

The Polynom digital measuring computer complex in physics is a joint development of PJSC "Electrovymiruvach" (Zhytomyr) and the Institute of Applied Physics of the National Academy of Sciences of Ukraine (Sumy).

Polynom helps you measure, process, and visualize data from a lab or demonstration experiment. The complex consists of a set of sensors, special software, connecting wires and fasteners for installing sensors on experimental installations.

Digital laboratory Einstein™ Physics (by Einstein Digital Lab™) is a digital measuring complex includes a data logger LabMate+, a light, wireless data logger of a new type equipped with 6 built-in sensors (heart rate, humidity, illumination, UV radiation, pressure, temperature), which are most often used in training program, up to 4 external sensors can be connected to it at the same time. The complex allows you to conduct a large number of various school experiments, turning an ordinary computer, tablet or smartphone into a full-fledged digital natural science laboratory.

Figure 2.16 – Makeblock Neuron Creative Lab Kit **P1030021**

For middle and high school, Makeblock offers the latest **mBuild programmable modules**, the advantage of which is compactness, the possibility of programming in Scratch and Python, as well as support for

modern technologies, such as artificial intelligence and the Internet of Things.

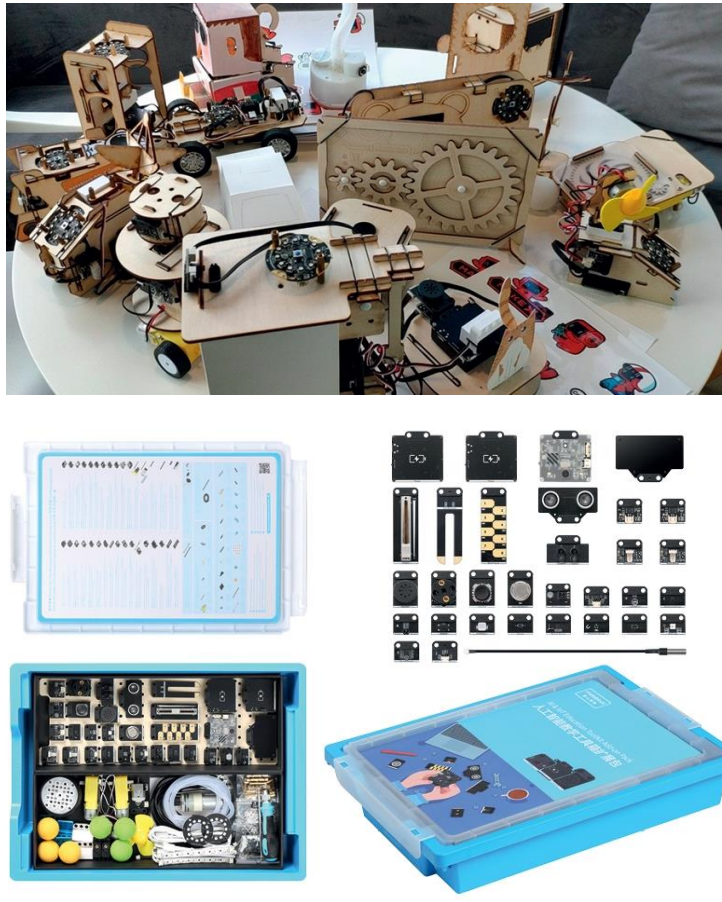

Figure 2.17 – mBuild programmable modules

One of the examples of effective implementation of STEM education is the use of research projects with the use of robotics. The rapidly growing need to create robotic systems used in various spheres of society activities, in production and in everyday life, suggests that even

ordinary users should have knowledge in the field of robotics. The educational process should be practice-oriented, motivate students to create their own projects and developments, with the aim of developing critical thinking, creativity, spreading the problem-based approach to learning and moving away from clip-based thinking.

The **mBot and mBot Ranger robots** successfully complement the line of robotics and are recommended for use in high school. Metal parts guarantee high accuracy and reliability of the design, and a variety of sensors allows you to create a project of any level of complexity.

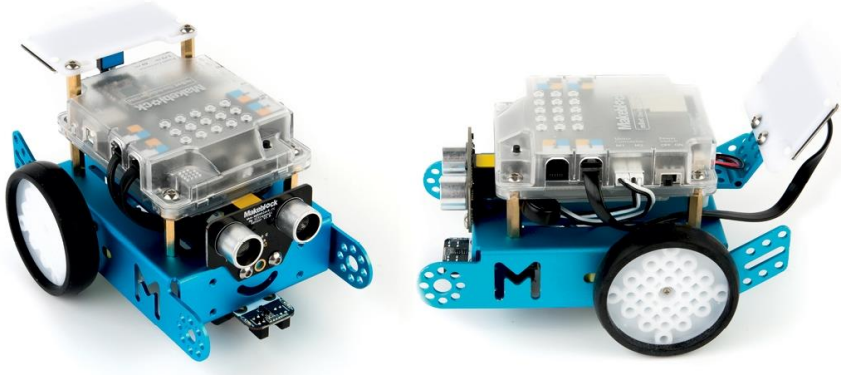

Figure 2.18 – The mBot and mBot Ranger robots

The electronic component of the mBot consists of a base board mCore created on the basis of an Arduino controller and two sensors - ultrasonic obstacle sensor and infrared line sensor.

You can program the mBot robot using the Arduino IDE, or by using the visual programming environment mBlock, which is built on the basis of Scratch 2.0 and is actually an extension of it that allows control motors, work with sensors, etc. Programming work is carried out via a USB cable or via Bluetooth. Manage the robot can be controlled via Bluetooth via the mBlock mobile application (available for iOS and Android) or with the included remote control set.

In the process of implementing STEM projects by means of robotics two levels of constructors must be distinguished:

– the first - projects aimed at mastering opportunities mBot and understanding of the principles of operation and capabilities of various technical devices, that is, mastering the designer as a tool for implementation complex tasks;

– the second is the direct use of the constructor for implementation of more complex projects, real problem situations.

Wonder Workshop's Dash and Dot robots have been actively used in the educational process by advanced schools in Ukraine for several years.

Figure 2.19 – Dash 1-DA01-05

They help to get acquainted with various physical phenomena, learn English, mathematics, master the principles of building algorithms and develop creative skills.

The mTiny robot is a unique development of Makeblock, because it does not require a tablet, phone or computer to interact with it. Its Tap

Pen controller, as a coding tool, facilitates the perception of the functions of commands and principles of operation of programming languages, and also protects the eyes from the harmful effects of device screens.

Physical blocks and different thematic story cards are used during exciting simulations, which give children quick feedback and promote the formation of creative ideas when solving tasks and problems. mTiny encourages children to learn by offering interesting games that pre-integrate knowledge from various fields, including math, music and art.

Figure 2.20 – mTiny P1030089

The mBlock programming training course is aimed at forming a practical understanding of algorithms and data structures, built on the development of interactive games that students can share and discuss. There is development of STEM education a promising direction that allows preparing students for successful self-realization in modern

society. Using the designer mBot allows you to implement such a direction of STEM education as robotics, increasing students' motivation to study natural and mathematical disciplines, understanding of connections and to promote while developing soft skills in demand on the labor market.

Robotics in education is an interdisciplinary, integrating course in itself science, technology, engineering, mathematics (STEM), founded on active learning of students. Developing skills and abilities:

– fine motor skills;
– knowledge of the basics of mechanics, mathematics and programming;
– ability to work in a team;
– development of logical and technical thinking;
– development of analytical abilities;
– understanding of exact sciences;
– modeling, designing, programming prototypes of robots that can find its application in such areas as logistics, automotive industry, construction;
– ability to analyze received data and make decisions.

Robotics lessons are, first of all, teamwork, where children work in pairs: assemble a robot, write a program. Work in pairs gives students have time to think, exchange ideas with a partner and only then implement them in life. Teamwork promotes the development of communication skills and abilities to express oneself, critical thinking, and the ability to persuade and lead discussion. Also, this form of work allows students to acquire skills cooperation, master the skills of speaking and active listening. These skills are very necessary in modern life.

Programming a real robot helps to visualize the laws mathematics not only on the pages of the textbook, but in the surrounding world.

Robot programming allows you to effortlessly organize interdisciplinary connections of informatics with subjects of the natural-mathematical cycle, etc.

Teaching robotics in the technological 21st Century helps development of communication skills of young people, develops interaction skills, independence in making decisions, reveals the creative potential of schoolchildren.

Programming a real robot helps to visualize the laws mathematics not only on the pages of the textbook, but also in the surrounding world.

Robot programming allows you to effortlessly organize interdisciplinary connections of informatics with subjects of the natural-mathematical cycle, etc.

Mathematics is significantly used in the teaching of robotics, in development and implementation of STEM education, while often required mathematical calculations that may go beyond the school curriculum.

Children understand the learning material better when they something independently create or invent, and it is used with taking into account numerous prospects for further development.

Mechatronic systems are specialized equipment that helps to combine mechanics and electronics in education. High school students study the principles of automated systems and acquire skills in programming production lines. This makes it possible to decide on a future profession and acquire basic knowledge for entering a university.

The model of solutions is the fisshertechnik Trainingsmodelle INDUSTRY 4.0, which is used for learning and applying machine programming skills, as well as for research and teaching at universities, companies and IT departments. The model simulates the processes of ordering raw materials, production and delivery of finished products and, ultimately, control of all these processes via the Internet. The designer's set includes: an automated multi-level warehouse, a vacuum manipulator, a multi-processing station with an oven, a sorting station with the detection of workpiece colors, an environmental sensor and a rotary camera. The camera sees the entire system, moving along the vertical and horizontal axes, and therefore can be used for remote web maintenance.

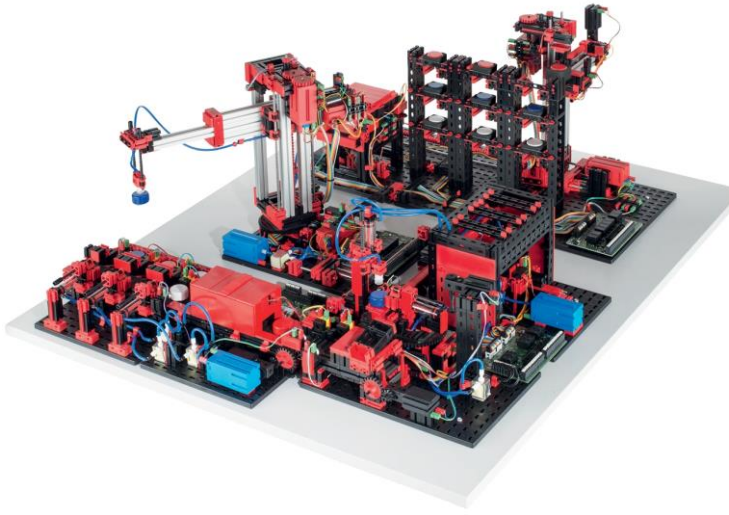

Figure 2.21 – Mechatronic system

Constructors/sets with different ways of connecting parts help schoolchildren develop construction skills and learn about the physical properties of materials.

Figure 2.22 – Constructors/sets with different ways of connecting parts

One of the most relevant set is all-in-one kits designed for educational institutions. They are delivered immediately in Gratnells branded containers, thanks to which you can conveniently and securely store the parts of the constructors.

Figure 2.23 – Constructor fischertechnik STEM-Laboratory FT-548904

Education with constructors/sets with different ways of connecting parts is one of the innovative technologies that helps to create new educational environment, increases motivation children to study, contributes to the formation of skills scientific activity and invention, helps implement the provisions of the New Ukrainian School.

The use of the constructor contributes to the achievement of the main learning goals:

– research, modeling and construction of solutions;

– involvement of students in studying subjects for using a practice-oriented approach;

– development of basic programming skills and algorithmic thinking;

– development of teamwork skills, communication and presentation competencies, skills present your point of view in an argumentative manner;
– development of critical thinking, skills in finding solutions to assigned tasks;
– using a scientific approach when studying natural phenomena and laws.

Due to active, exciting activities educational solutions for elementary schools build the skills necessary for successful lifelong development. Practice-oriented solutions awaken in children natural craving for research and discovery.

Control Questions

1. Which document regulates the list of school STEM cabinet equipment?
2. In which lessons is it appropriate to use a 3D printer?
3. What can be done with the help of 3D scanning technology? In what areas is it used?
4. What skills does working with a 3D pen develop?
5. What is a digital laser machine?
6. What is included in programmable electronics modules?
7. What sensors do the mBot and mBot Ranger robots have?
8. In which lessons is it advisable to use Dash and Dot robots?
9. What skills and abilities are formed in the process of working with robotics?
10. What are mechatronic systems?
11. What does working with constructors/sets with different ways of connecting parts develop?

Tasks

1. Make a presentation about the history of creation and scope of use of the 3D printer.

2. Develop an integrated lesson plan for computer science and drawing using a 3D pen.
3. Compile the costing of the equipment for the STEM cabinet.
4. Develop a lesson plan for 5th grade using constructors/sets with different ways of connecting parts.
5. Develop a lesson plan for 6th grade using programmable electronics modules.
6. Develop a lesson plan for 7th grade using mechatronic systems.

AFTERWORD

Today, STEM education is becoming for Ukraine one of the key areas of modernization of the educational industry, a component of state policy on strengthening the economy and developing human capital, one of the main factors of sustainable innovative development. STEM education is a series or sequence of courses or programs of study that which prepares students for successful employment, for post-school education or for both, requires different and more technically complex skills, in particular with application of mathematical knowledge and scientific concepts.

STEM education should start from preschool age and to be used as a student. In addition, involvement in STEM can undertake not only the development of creative thinking and formation the competence of the researcher, and to try to improve the socialization of the personality, therefore that encourages such skills as: cooperation, communication, creativity.

STEM education is one of the directions of anticipatory education for sustainable development, which in the forecast plan is designed to respond to the current and future requests of Industry 4.0. It is she who must provide high-tech production with the necessary personnel.

The purpose of implementing the interdisciplinary integrated course "STEM" in the system of basic general secondary education is an early professional orientation and the development of ideas about the role and importance of STEM education, STEM professions and careers in Ukraine; popularization and propaedeutics of natural, mathematical, informatics, and technological educational fields; the development of scientific and technical creativity, and the creation of conditions for the development of STEM which are defined competencies.

The concept of the development of science and mathematics (STEM education) through their involvement in research, making, development of new technologies and project activities.

Transformational processes in Ukrainian education, in particular, the formation of the New Ukrainian School is based precisely on the introduction of STEM education, it involves the development of informational and communicative competences, creativity, the ability to solve complex tasks, especially engineering and technical ones.

The transition to new educational standards and fundamental changes in the content and forms of education poses difficult tasks for the teaching community of Ukraine. One of these tasks is the prompt training of a cohort of teachers of a new format who are able to ensure the educational process at a new level, to make STEM education a system that actually works in Ukrainian schools.

One of the promising areas of STEM education is educational robotics, because it allows you to develop programming and design skills, being an integrator of all four STEM components. Region

The field of robotics is multidisciplinary and highly innovative, encompassing physics, mathematics, computer science and even industrial design as well social sciences. In addition, due to different areas of application, a team is required work, creativity and entrepreneurial skills for design, programming and innovative operation of robots and robotic services.

The analysis of the experience of educational institutions of the Poltava region showed that the concept of STEM education is being actively implemented. The administration of the region meets the initiatives and contributes to the provision of educational institutions with the necessary equipment and facilities.

Acquaintance with advanced global and regional experience in implementing STEM education is a condition for quality training of informatics teachers.

The main key competence concepts of the "New Ukrainian schools", a such as: communication in foreign and foreign languages, mathematical

literacy, competence in business sciences and technologies, information and digital citizenship, lifelong learning, social and civic competence, entrepreneurship, general cultural, ecological citizenship and future life, harmoniously enter into the system of STEM education, creating a new for the successful commercialization of the individual both as a specialist and as a citizen.

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APPLICATIONS

Application A

Навчально-розвивальні ігри та програми
(*джерело*: ресурс «TeachInf» https://teach-inf.com.ua/load/programi/rozvivajuchi_igri/35)

GCOMPRIS – ПАКЕТ НАВЧАЛЬНИХ ПРОГРАМ

GCompris являє собою пакет навчальних програм складається з різних вправ та ігор освітнього характеру. Нижче перераховані категорії вправ GCompris та приклади вправ:

- основи комп'ютерної грамотності: використання клавіатури і миші; падаючі букви;
- арифметика: основи рахунку; таблиця множення; додавання і віднімання;
- основи фізики: електрику; круговорот води; підводний човен;
- географія: розмісти країни на карті;
- ігри: шахи, розвиток пам'яті; з'єднай чотири точки; судоку;
- читання: практика читання;
- пазли; малювання, створення мультфільмів.

OMNITUX – ПАКЕТ НАВЧАЛЬНИХ ПРОГРАМ

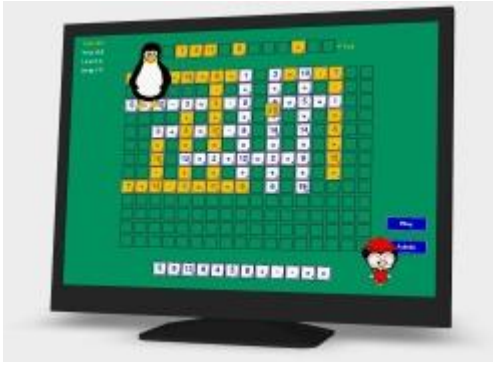
За допомогою **Omnitux** можна зробити яскравими та ефективними багато уроків з різних навчальних предметів. Пазли, аналітичні завдання і лічилки можна застосувати не тільки на уроках «Робота з розвивальними програмами», а й під час опанування інших тем, проведення уроків повторення, узагальнення і систематизація навчального матеріалу.

Види діяльності: асоціації, оформлення елементів на карті або схемі, підрахунок діяльності, головоломки.

TUXMATH

Це безкоштовна гра-аркада, мета якої навчити дітей арифметики. Гра TuxMath приємно оформлена, добре озвучена і має декілька рівнів складності. Найлегший рівень – ознайомлення з цифрами і арифметичними знаками. Найскладніший – розв'язування рівнянь, включаючи від'ємні числа. Починаючи з азів математики, дитина поступово вчиться додавати і віднімати, множити і ділити числа. TuxMath дозволить дитині грати як одиночний тип гри, так і мережний, так само є варіант гри з друзями, що дозволить влаштувати змагання на локальному комп'ютері між учасниками. Натиснувши в головному меню на кнопку допомоги, можна отримати прискорений курс навчання правил і тонкощів гри, знову ж таки в демонстраційній ігровій манері.

TUXMATHSCRABBLE



TuxMathScrabble — математична версія класичної словесної гри. Є чотири рівні кваліфікації для практики. У гру можна грати одному або удвох. Завдання виконуються перетяганням частин мозаїки. Неприпустимі приклади відкидаються назад у лоток користувача. Нещодавно було додано декілька нових опцій: можливість переставляти оперативні мозаїки програвача, створення безперервних мозаїк, прозорість мозаїки, що конфігурується, можливість використовувати фонове зображення.

ДИТЯЧА КОЛЕКЦІЯ. МІЙ КОМП'ЮТЕР

Епоха бурхливого розвитку комп'ютерних технологій відкриває багато перспектив, а також несе безліч небезпек. Тому дитині потрібно оволодіти комп'ютерною грамотою. Зокрема навчитися користуватися електронною скринькою та різноманітними програмами, знаходити потрібну інформацію в Інтернеті та багато іншого.

ІНТЕРАКТИВНА ГРА "ІНТЕРНЕТ-ШАХРАЙСТВА"

Інтерактивна гра "Інтернет-шахрайство" - це гра яка виконана засобами презентації з використанням тригерів. Дозволяє учням в режимі гри розібратися який контент можна вважати безпечним, а який ні.

КОМП'ЮТЕРНА АЗБУКА

Програма «Комп'ютерна азбука» розрахована на вивчення основ комп'ютерної грамотності та оволодіння дітьми на початковому рівні певною логікою роботи з комп'ютером в поєднанні з ознайомленням з навколишнім світом і місцем людини в ньому.

В процесі роботи діти знайомляться з можливостями використання обчислювальної техніки в науці, техніці, освіті, охороні здоров'я, побуті та повсякденному житті; набувають знання, уміння і навички володіння курсом інформатики і користуванням комп'ютера; формують елементи планетарного мислення і необхідність дбайливого ставлення до навколишнього світу.

Application B

10 Essential STEM Teaching Practices

Here are some aptitudes and proficiencies that seem to be valuable for the STEM teachers – or for any middle level teacher who wants to be cutting-edge.

1. Believe in your students. For your sake and the sake of your students, set high expectations for your students, challenge them to succeed, and believe that they will. Most students will perform at the level you expect, so trust them to make informed choices about their engineering challenges, come up with creative solutions, complete complex tasks, and work together smoothly to do so.

2. Transfer control of the learning process to the students. Develop new roles and rules that stress student responsibility.

3. Foster curiosity. Learn the art of asking open-ended questions with plenty of possible answers. Pose problems rather than answers and send students on a search for solutions. Use discrepant events to intrigue students and draw them into the problem.

4. Provide hands-on, experiential learning. Don't be the old-fashioned sage on the stage if you want to stimulate 21st century learning. Learning through reflection and doing is compelling. When your students have their imagination piqued, give them opportunities to actually investigate multiple possible solutions to a problem, or to solve a mystery. Provide materials that teams of students can explore and manipulate.

5. Increase collaboration among students. Get comfortable with teamwork. Actively teach teamwork skills and work with students to heighten awareness of their team behaviors and ways of interacting in the class. Here is a link to a student teamwork guide that you may find useful. Feel free to download and use it.

6. Accept failure – both yours and the students – as a necessary part of learning and growing. That is, accept failure that accompanies taking a risk and experimenting, knowing that they might not get it right. Everyone in the classroom should feel safe in taking risks. I tell students that we learn more from what we do wrong than from what we do right, and engineers learn from their mistakes. In fact, failure is a necessary part of learning. If you aren't comfortable with this idea, you might check out this online commentary.

7. Be an inspiring leader and role model for your students. Be positive and enthusiastic about what students are learning and how they are learning it. Be passionate in your teaching and your love of your subject area.

8. Accept some drawbacks. STEM education will improve student engagement, critical thinking skills, and workforce skills. But it may also play havoc with the lesson plan you wrote and make it more difficult to cover content benchmarks in a stepwise process. In the STEM classroom, you'll need to be flexible and ready to make some quick shifts in your thinking. You may also need to be willing to deviate from your lesson plan, depending on the direction the students' investigations and decisions take them.

9. Evolve and grow as a learner. One of the most important things you can do, as a STEM teacher, is to pay attention to the art of teaching. Develop your skills in facilitating (as opposed to dictating) so that students focus on learning how to think like engineers. Embrace digital tools and technology in the classroom with help from your students.

10. Learn in community. Work with your colleagues to study effective ways of teaching STEM lessons.

Application C

9 principles for teaching STEM effectively

To increase student engagement and achievement, STEM education in the classroom needs to reflect what's happening in STEM's exciting fields outside the classroom. Not every principle will be appropriate in every situation, but each will provide strong guidance. Many of the principles go well together, for example, equipping and empowering teachers to be confident in using inquiry-based learning.

Principle	What is it?	Why is this important?	Examples
Use inquiry-based learning	Inquiry-based learning is an education approach that focuses on investigation and problem-solving.	Students learn key STEM and life skills through inquiry-based learning: social interaction, exploration, argumentation, comfort with failure	Build active learning into teaching practices through problem-based scenarios to encourage students to think critically.
Solve real-world problems	Students tackle real-world STEM problems from industry and the community.	Demonstrates relevance of STEM; can enhance student motivation and interest and highlight career opportunities.	Partner with a local business and get students to work on a project that solves a real problem to see what they come up with.
Teach integrated STEM learning	Integrated STEM learning combines the subject matter of two or more STEM subjects into a joint learning experience.	Supports cross-disciplinary STEM skills; can enhance student interest.	You can teach Science using an Engineering process (design-based learning).
Equip and empower teachers	Equipping and empowering teachers means providing them with the right resources (e.g. high-quality professional	Teachers have the greatest influence on in-school achievement and engagement in STEM education.	Connect a STEM teacher with a STEM mentor from a local business.

Principle	What is it?	Why is this important?	Examples
	learning opportunities, up-to-date technology) and skills to teach best practice STEM education.		
Create partnerships between schools, industry and community	Schools, businesses and other organisations create STEM education initiatives to improve student outcomes.	Exposes students to the workplace, inspires enthusiasm about STEM and enhances and complements curriculum.	Choose some partners to work with on a STEM problem. Reach out to schools, industry, museums, local councils and government.
Engage parents and families	Encourage parents and guardians to be active in their children's education.	Improves aspiration, enrolment, achievement and belief in importance of STEM education.	Invite parents and families to a STEM exhibition day to show them all the exciting things students are working on.
Use technology as an enabler	Selective use of technology to support high-quality teaching and learning.	Accelerates student learning, increases confidence and ability in using technology.	Get students to program a technology instead of showing them what something does.
Differentiate for different levels	Learning is tailored to the needs and abilities of individual students.	Supports all students' needs, regardless of starting point.	Assess student capability formally and informally so lessons can be tailored.
Link STEM education to 21st century learning	STEM education is intentionally linked to the development of 21st century skills such as critical thinking, creativity and collaboration.	21st century skills are highly valuable for students' future careers.	Encourage teamwork and healthy debate. Let students 'play' with their STEM subject matter.

Application D

Lexical Minimum

applied orientation	прикладна орієнтація
augmented reality	доповнена реальність
collaboration	співпраця
competence approach	компетентнісний підхід
computer Science Classes	урок інформатики
contextual learning	контекстне навчання
creative ability	творча здібність
critical thinking	критичне мислення
digital competence	цифрова компетентність
digital lesson	цифровий урок
education	освіта
equipment	обладнання
emphasis	наголос
employment	зайнятість, праця
elimination of barriers	усунення бар'єрів
energy-saving technology	енергозбережувальна технологія
engineering design	інженерний дизайн
environment	середовище
environmental protection	захист навколишнього середовища
exact sciences	точні науки
flexible format	гнучкий формат
flipped class	перевернуте навчання
functional literacy	функціональна грамотність
gamification of learning	ігрове навчання
goal-setting	цілепокладання
implementation	упровадження
inclusive education	інклюзивне навчання
innovative technology	інноваційна технологія
Integrated lesson	інтегрований урок
interaction	взаємодія
interdisciplinary approach	міждисциплінарний підхід

learning technology	навчальна технологія
logical thinking	логічне мислення
mathematical modeling	математичне моделювання
measuring tool	вимірювальний пристрій
mobile application	мобільний додаток
multi-level learning	багаторівневе навчання
natural sciences	природничі науки
pedagogical staff	педагогічні працівники
practical skills	практичні навички
problem-based learning	проблемне навчання
professional competences	професійні компетентності
project-based learning	проєктне навчання
research activity	дослідницька діяльність
secondary education institution	заклад середньої освіти
scientific and technical progress	науково-технічний прогрес
scientific perception	наукове сприйняття
soft skills	гнучкі навички
sustainable development	сталий розвиток
systemic thinking	системне мислення
teamwork	командна робота

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