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A. Tlepbergenova, M. Yesenamanova, Zh. Yesenamanova, 2024.
Kh.Dosmukhamedov Atyrau University, Atyrau, Kazakhstan.
E-mail: mansiya.73@mail.ru

DEVELOPMENT OF HYDROPONICS FOR THE FORMATION OF PRACTICAL SKILLS OF THE STEM EDUCATION SUBJECTS

Tlepbergenova Anar – Candidate of Pedagogical Sciences, Associate Professor of the Department of "Ecology", Kh. Dosmukhamedov Atyrau University, Atyrau, Kazakhstan, E-mail: anar_2808@mail.ru, http://orcid.org/0000-0001-7373-8944;
Yessenamanova Mansiya – Candidate of Technical Sciences, Professor of the Department of "Ecology", Kh. Dosmukhamedov Atyrau University, Atyrau, Kazakhstan, mansiya.73@mail.ru, https://orcid.org/0000-0002-5423-2857;
Yessenamanova Zhanar – PhD, Associate Professor of the Department of "Ecology", Kh. Dosmukhamedov Atyrau University, Atyrau, Kazakhstan, zhanyessen@mail.ru, http://orcid.org/0000-0003-3868-4092.

Abstract. The article analyzes the use of a hydroponic device as a STEM education tool. STEM education is the basis of practical interest and a high level of motivation of schoolchildren for research activities and obtaining all the necessary competencies. The use of STEM technology will allow you to transfer the educational process to another basis: from observation to hypothesis and experiment, from studying individual subjects to studying phenomena, from obtaining abstract knowledge to solving real life problems. The hydroponic system as a teaching technology can be used in the study of a number of school subjects: computer science, biology, chemistry, physics and natural sciences. First of all, in order to build the design of a hydroponic installation, creative data is needed on the selection of necessary products, the ability to work with tools for connecting plastic pipes, connecting to a pump, etc. In the manufacture of the structure, it is necessary to calculate the length, height of the structure, the number of holes for pots, when connected to the pump, etc. In addition, it is necessary to calculate the amount of nutrients necessary for the growth of plants, which are controlled by changes in the acid-base environment and total salinity. The hydroponic plant can monitor the growth and development of vegetable and green crops and monitor the transport of nutrients. In all courses of such subjects as "Natural Science", "Biology", "Chemistry" and "Physics", students will have the opportunity to gain practical skills when working with hydroponic devices.

Key words: STEM-education, school subject “Natural Science”, school subject “Biology”, school subject “Chemistry”, school subject “Physics”.

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Х.Досмұхамедов атындағы Атырау университеті, Атырау, Қазақстан.
E-mail: mansiya.73@mail.ru

STEM-БІЛІМ БЕРУ КАБИНЕТІНІҢ ПРАКТИКАЛЫҚ ДАҒДЫЛАРЫН ҚАЛЫПТАСТЫРУ ҮШІН ГИДРОПОНИКАНЫ ӘЗІРЛЕУ

Тлепбергенова Анар Ерсаиновна – педагогика ғылымдарының кандидаты, «Экология» кафедрасының қауымдастырылған профессоры, Х. Досмұхамедов атындағы Атырау Университеті, Атырау, Қазақстан, E-mail: anar_2808@mail.ru, http://orcid.org/0000-0001-7373-8944;
Есенаманова Мансия Санаковна – техника ғылымдарының кандидаты, «Экология» кафедрасының профессоры, Х.Досмұхамедов атындағы Атырау Университеті, Атырау, Қазақстан, mansiya.73@mail.ru, https://orcid.org/0000-0002-5423-2857;
Есенаманова Жанар Санаковна – PhD, «Экология» кафедрасының қауымдастырылған профессоры, Х. Досмұхамедов атындағы Атырау Университеті, Атырау, Қазақстан, zhanyessen@mail.ru, http://orcid.org/0000-0003-3868-4092.

Аннотация. Мақалада гидропоникалық құрылғыны STEM-білім беру құралы ретінде қолдану бойынша талдау жасалды. STEM-оқыту студенттердің ғылыми-зерттеу жұмыстарына және барлық қажетті құзыреттерді алуға ынталандырудың практикалық қызығушылығы мен жоғары деңгейінің негізі болып табылады. STEM технологиясын қолдану білім беру процесін басқа негізге аударуға мүмкіндік береді: бақылаудан гипотеза мен экспериментке, жеке пәндерді зерттеуден құбылыстарды зерттеуге, дерексіз білім алудан нақты өмірлік мәселелерді шешуге дейін. Гидропоникалық жүйені оқыту технологиясын бірқатар мектеп пәндерін: информатика, биология, химия, физика және жаратылыстану пәндерін оқуда қолдануға болады. Ең алдымен, гидропоникалық қондырғының құрылымын құру үшін қажетті өнімдерді таңдау бойынша шығармашылық мәліметтер, пластикалық құбырларды қосу, сорғыға қосылу және т.б. құралдармен жұмыс істеу мүмкіндігі қажет. Сонымен қатар, өсімдіктердің өсуіне қажетті қоректік заттардың мөлшерін есептеу керек, оларды бақылау қышқыл-негіз ортасының өзгеруімен және жалпы тұздылықпен жүзеге асырылады. Гидропоникалық қондырғыда көкөністер мен жасыл дақылдардың өсуі мен дамуын және қоректік заттардың тасымалдануын бақылауға болады. «Жаратылыстану», «Биология», «Химия» және «Физика» сияқты пәндерді оқытудың барлық курстарында оқушылар гидропоникалық құрылғылармен жұмыс істеу кезінде практикалық дағдыларды меңгеруге мүмкіндік алады.

Түйін сөздер: STEM-білім беру, «Жаратылыстану» мектеп пәні, «Биология» мектеп пәні, «Химия» мектеп пәні, «Физика»мектеп пәні.

А.Е. Тлепбергенова, М.С. Есенаманова, Ж.С. Есенаманова, 2024.
Атырауский университет имени Х. Досмухамедова, Атырау, Казахстан.
E-mail: mansiya.73@mail.ru

РАЗРАБОТКА ГИДРОПОНИКИ ДЛЯ ФОРМИРОВАНИЯ ПРАКТИЧЕСКИХ НАВЫКОВ КАБИНЕТА STEM-ОБРАЗОВАНИЯ

Тлепбергенова Анар Ерсаиновна – кандидат педагогических наук, ассоциированный профессор кафедры «Экология», Атырауский университет им. Х. Досмухамедова, Атырау, Казахстан, E-mail: anar_2808@mail.ru, http://orcid.org/0000-0001-7373-8944;
Есенаманова Мансия Санаковна – кандидат технических наук, профессор кафедры «Экология», Атырауский университет им. Х. Досмухамедова, Атырау, Казахстан, E-mail: mansiya.73@mail.ru, https://orcid.org/0000-0002-5423-2857;
Есенаманова Жанар Санаковна – PhD, ассоциированный профессор кафедры «Экология», Атырауский университет им. Х. Досмухамедова, Атырау, Казахстан, E-mail: zhanyessen@mail.ru, http://orcid.org/0000-0003-3868-4092.

Аннотация. В статье проведен анализ по применению гидропонного устройства как инструмента STEM-образования. STEM-обучение является основой практической заинтересованности и высокого уровня мотивации школьников к научно-исследовательской деятельности и получения всех необходимых компетенций. Использование STEM-технологии позволит перевести образовательный процесс на другую основу: от наблюдения к гипотезе и эксперименту, от изучения отдельных предметов к изучению явлений, от получения абстрактных знаний к решению реальных жизненных проблем. Гидропонную систему как обучающую технологию можно использовать при изучении ряда школьных предметов: информатики, биологии, химии, физики и естествознания. В первую очередь для того, чтобы построить конструкцию гидропонной установки необходимы творческие данные по выбору необходимых изделий, умения работать с инструментами по соединению пластиковых труб, подключения к насосу и т.д. При изготовлении конструкции необходимо произвести подсчет по длине, высоте конструкции, количестве отверстий для горшков, при подключении к насосу и др. Кроме этого, необходимо рассчитать количество питательных веществ необходимых для роста растений, контроль которых осуществляется изменением кислотно-щелочной среды и общей соленостью. На гидропонной установке можно контролировать рост и развитие овощных и зеленых культур и наблюдать за транспортированием питательных веществ. На всех курсах обучения таких предметов как «Естествознание», «Биология», «Химия» и «Физика» школьники будут иметь возможностьи по получению практических навыков при работе с гидропонными устройствами.

Ключевые слова: STEM-образование, школьный предмет «Естествознание», школьный предмет «Биология», школьный предмет «Химия», школьный предмет «Физика».

Introduction. There are many abstract theoretical disciplines in school today, the knowledge of which the child does not have the opportunity to apply in real life (Yessenamanova, 2020): knowledge is often given in a ready-made form, requiring memorization, and unconscious work. It is extremely important for a practical teacher to stimulate in children their personal interest in the acquired knowledge, which can and should be useful to them in life. Leontiev (1975) emphasized "activity is not a reaction and not a set of reactions, but a system, having a structure, its internal transitions and transformations, its development". Lack of practical interest and a low level of motivation hinder the acquisition of all necessary competencies. The methods of pragmatic pedagogy, especially the project method, which is gaining popularity again, can help to correct the situation with some formalism of education, isolation from life, authoritarianism of traditional pedagogy.

STEM, formerly known as SMET, is an abbreviation derived from the timely rearrangement of the letters by American biologist Judith Ramaley in 2001, who is the assistant director of the NSF Department of Education and Human Resources.

In fact, STEM is a kind of hybrid learning. This is the integration of the 4 different disciplines that are most useful to today's industry, namely:

-Science

-Technology

-Equipment

-Mathematics.

In the most general form, the abbreviation STEM (Science, Technology, Engineering, and Mathematics) refers to a complex of academic and professional disciplines in natural, technological, engineering sciences and mathematics aimed at training specialists with a new type of thinking, without which the development of an innovative economy is impossible.

At all levels of education, teaching staff and the administration of educational institutions strive to implement engineering education as much as possible and strengthen the technological training of graduates. To this end, the use of the STEM approach in teaching is very effective (Sinelnikov, 2020), since it is a very wide range of tools, including a set of actions, approaches, practices and techniques that are focused on ensuring that society and the individual are ready for the future. International studies reveal problems with the natural science literacy of students, which is understood as the ability to apply the acquired knowledge in real life situations. In-depth STEM training of motivated students to give them the opportunity to succeed in science and technology, enter the technology sector and succeed:

-Motivation for engineering and technical specialties and a career in science and technology

-Access to laboratories where experiments are conducted and industrial tasks are solved for experience and practice

-Absence of barriers limiting career and professional growth

-In-depth knowledge in the field of science, engineering, technology.

The study of STEM subjects is based on the analysis of the problems and challenges

of the modern world. Work with problems is carried out within the framework of the creation of project groups and teams.

Materials and methods.

The study of the problem is based on the involvement of a wide range of sources in scientific circulation. Data on the creation and organization of hydroponic devices, textbooks of school courses of subjects "Natural Science" for grades 1-6, "Biology" for grades 7-11, "Chemistry" for grades 7-11 and "Physics" for grades 7-11 allow us to comprehensively, fully and comprehensively investigate the most important aspects of the possibility of using hydroponic systems in school project activities in STEM- education. In the method of school projects, more emphasis is placed on the development of the student's general capabilities than on the ability to solve practical problems. Specialized school research projects on hydroponic installations will form a professional view of agronomy, robotics and automation, modern biotechnologies and much more, develop practical skills in programming, modeling, maintenance of agricultural complexes.

Results and discussion

The use of STEM technology will allow you to transfer the educational process to another basis (Salahub, 2020): from observation to hypothesis and experiment, from studying individual subjects to studying phenomena, from acquiring abstract knowledge to solving real-life problems. STEM is defined as an educational method based on the natural connection of four disciplines, and identifies the three key principles of this method: applying nature to real-world problems; learning through problem-solving and critical thinking; when studying individual subjects such as computer science, biology, ecology, and technology, students do not form an overall picture of the world: the same phenomenon is studied in different subjects as different. The use of STEM technology allows you to integrate disciplines and research phenomena in a complex.

One of the basic attitudes of STEM learning, which is still the most methodical, complex and important today, is the development of student practice and research methods. Experts point out that mastering the research method itself and gaining such experience may be more important than the specific knowledge gained as a result. The second important setting is to master the project, that is, to create a new response task. Within the framework of this installation, students learn to find solutions to specific problems and create prototypes for new mechanisms, technologies, and procedures. Science and STEM subjects are related to real-life problems or situations. The basis of training is a project where students observe, identify problems and find solutions independently and with their peers. The structure of school children's projects and research activities includes a large number of different processes, from raising questions, comprehensive data retrieval to finally presenting results. At the same time, a prerequisite is the teamwork of students.

The technique of growing plants without soil provides a huge opportunity to acquire practical skills. One of the technologies is hydroponics. In turn, hydroponics and unfounded planting can be a panacea for the problems of the modern world-

global warming, malnutrition, new diseases, rising food prices, the use of genetically modified products, lack of clean drinking water, soil depletion.

The active hydroponic device is equipped with a mechanical device (pump) to ensure a constant necessary circulation of nutrient solution (Mohd Salim Mir, 2022). There is also a forced aeration system, that is, the root system is saturated with oxygen. An illustrative example of an active hydroponic device is a structure operated based on pneumatic principles.

In a passive hydroponic device, the nutrient solution is supplied to the roots and surface parts of the plant only due to the capillary force of the culture itself, in this case it is not subject to any mechanical action. A good example of a passive hydroponic device can be considered a system that operates on the principle of periodic flooding of matrix crops.

The nutrient solution contains all the chemical elements needed by plants. Because the roots are easy to contact with all substances, it spends less life energy looking for water and nutrients, which has a positive impact on the development and growth rate of its above-ground parts. This allows gardeners to get a rich harvest in a shorter period of time. The absence of soil also allows you to strictly control the amount of nutrients obtained by plants, and in case of excess, quickly change the solution. Such an environment is completely sterile, which eliminates the appearance of fungi and pests.

Hydroponic methods allow you to grow plants without fertilization, fertilization, watering and soil filling. The fact is that land is rapidly depleting, leading to soil diseases and therefore having a negative impact on plant development.

The hydroponic system consists of a container of porous material with a solid consistency (*Nguyen*, 2016). It can be gravel or expanded clay. Then put the container in a pot with the nutrient mixture. Thanks to this solution, bean sprouts receive all vitamins from water, which previously absorbed the necessary elements from the mixture. This technology provides appropriate levels of carbon dioxide, oxygen, humidity and temperature. The system is a connection of plastic pipes, with automatic watering and built-in lighting, allowing you to observe how plants grow from seeds. The irrigation system has automatic control, can work continuously, and is not limited by weather events. The system also has fans required for pollination. This will promote air circulation and air temperature balance, helping plants grow perfectly. Automation systems are used to control the water environment for acid-base environment and salinity.

The hydroponic system as a teaching technology can be used in the study of a number of school subjects: computer science, biology, chemistry, physics, natural science, mathematics, and art work.

First of all, in order to build the design of a hydroponic installation, creative data is needed on the selection of necessary products, the ability to work with tools for connecting plastic pipes, connecting to a pump, etc.

In the manufacture of the structure, it is necessary to calculate the length, height of the structure, the number of holes for pots, when connected to the pump, etc.

Therefore, knowledge of mathematics is essential when working with a hydroponic structure.

The research strategy is to identify the dominant plants that can grow under hydroponic conditions, analyze and compare soil and unfounded vegetation planting methods.

As for the results, they can be determined by the difference in the size of the leaves, the weight of the plant, or the total height of the plant. In addition, it is possible to analyze quantitative aspects, which may include the taste, smell or appearance of experimental plants.

Such experiments can provide students with many learning opportunities. Among them:

-Develop scientific research skills

-Improve the writing of scientific reports

-Cultivate team spirit and spirit of cooperation

-The impact on all stages of the plant life cycle.

Another experiment may require sensory evaluation of plants under various growth conditions, which will increase students' ability to use their senses for successful scientific research.

If you think about it carefully, a completely new world of experiments with smart hydroponic equipment opens up, which gives timely promotion of STEM education.

The following are school subjects and topics on which knowledge of the use of a hydroponic device can be used as a STEM of education. As the first subject, consider the subject "Natural Science" (Kucherbaeva, 2021; Boltushenko, 2017; Kucherbaeva, 2018; Bigazina, 2019; Verkhovtseva, 2019). Most of the topics in all courses of the study of "Natural Science" from 1st to 6th grades (Table 1) related to the growth and development of plants, plant parts such as leaves, stem and roots, flowers and seeds, as well as methods of water purification can be considered on the example of a hydroponic installation, where all plant organs can be seen in full and to investigate as they study their growth in the care of plants sprouting on this installation. This will be the basis for conducting research work in the 5th and 6th grade.

Table 1. List of topics in the course of studying the school course "Natural Science", which can be studied as STEM-learning using a hydroponic device

№	Topic	Class
	What are the plants	1
	Plant Parts	1
	Conditions necessary for plants to live	1
	Wild and cultivated plants. Care of indoor and cultivated plants	1
	What are the secrets of plants?	2
	How plants live	2
	What we know about water	2

	How Plant leaves work	3
	How plants are adapted to living conditions	3
	Methods of water purification	3
	What stages of development do plants have	4
	Why does a plant need flowers	4
	How seeds are formed	4
	How plants develop	4
	What water dissolves	4
	How is water polluted	4
	How to formulate a research question and make a plan	5
	What helps to conduct research	5
	How to analyze the information obtained during the research correctly	5
	What are solutions for?	5
	Objects of natural sciences research	6
	How to classify all substances into organic and inorganic	6
	How to identify a particular type of plant or animal	6

In the course of studying Biology in grades 7-11 (Ochkur, 2017; Solovyova, 2018; Asanov, 2019; Abylaykhanova, 2018) with the help of a hydroponic installation (Table 2), students will gain knowledge and skills on the biological significance of the necessary substances and chemical elements for the growth, development and physiological processes of plants, as well as changes in plant structure under growing conditions on hydroponic devices with the study of the role of water and water potential for the transportation of essential nutrients of plant communities. In the course of studying biology, students will be able to conduct research on a scientific basis on the role of various types of macro and microelements for the growth of various types of green and vegetable crops.

Table 2. List of topics in the course of studying the school course “Biology”, which can be studied as STEM-learning using a hydroponic device

№	Topic	Class
	The importance of water for living organisms	7
	The role of micro- and macroelements in the vital activity of organisms	7
	Deficiency of macronutrients — nitrogen, potassium and phosphorus in mineral fertilizers	7
	The importance of nutrient transport in living organisms	7
	Organs involved in the transport of substances in plants	7
	The internal structure of the stem and root	7
	The relationship of the structure of the root and stem with their functions	7
	Structure and functions of the sheet	7

	Necessary conditions for the photosynthesis process	7
	Plant respiration	7
	Features of isolation in the plant	7
	Photoperiodism in plants	7
	Biological significance of sexual and asexual reproduction of plants	
	Methods of vegetative reproduction in plants	7
	Processes of elongation and thickening of plants	7
	Distinctive features of plant departments	8
	Bisexual and dicotyledonous plants	8
	Comparison of aquatic and terrestrial ecosystems	8
	Adaptation of living organisms to environmental conditions	8
	Regulators of plant growth and development	9
	The importance of water for life on Earth	10
	The effect of the ratio of surface area to volume on the diffusion rate	10
	Mechanism of passive and active transport	10
	Modern technologies in agriculture	10
	Water potential	11
	Cultivating substances	11
	The effect of producing substances on plants	11

Most of the topics in all Chemistry courses from grades 7 to 11 (Usmanova, 2018; Usmanova, 2019; Ospanova, 2019) include the study of substances and their properties, natural acids and alkalis that change the acidity and alkalinity of the aquatic environment, as well as their interactions with various elements to form salts, as well as minerals, including basic nutrients like nitrogen, phosphorus and potassium related to the growth and development of plants can be easily demonstrated on a hydroponic installation (Table 3).

Table 3. List of topics in the course of studying the school course “Chemistry”, which can be studied as STEM-learning using a hydroponic device

№	Topic	Class
	The Subject Of Chemistry. Substances and their properties	7
	Natural acids and alkalis. Indicators	7
	The process of breathing	7
	Ion formation	1. 8
	The law of conservation of mass of substances	2. 8
	Chemical reactions in nature and vital activity of living organisms	3. 8
	Reactions of metals with oxygen and water	4. 8

	Interaction of metals with acids	5.	8
	Interaction of metals with salt solutions	6.	8
	The amount of substance. Mole. Avagadro Number	7.	8
	Oxygen	8.	8
	Solutions	9.	8
	Methods of expressing the concentration of solutions	10.	8
	Acids	11.	8
	Properties of acids and their application	12.	8
	Grounds	13.	8
	Properties of bases	14.	8
	Salts	15.	8
	Properties of salts	16.	8
	Water in nature	17.	8
	Water hardness. Causes of water pollution	18.	8
	Hydrolysis of salts	19.	9
	Qualitative reactions to cations	20.	9
	Qualitative reactions to anions	21.	9
	Elements of group 15 (VA). Nitrogen	22.	9
	Nitric acid	23.	9
	Specific properties of nitric acid and nitrates	24.	9
	Phosphorus	25.	9
	Orthophoric acid. Phosphoric acid salts	26.	9
	Mineral fertilizers	27.	9
	Biological role of metals and nonmetals in living organisms	28.	10
	Water hardness and methods of its removal	29.	10
	12 principles of green chemistry	30.	10
	Biologically important elements	31.	11
	The ionic product of water. The hydrogen index	32.	11
	Calculation models depending on the pH of the medium	33.	11

Unlike other subjects in the “Physics” course (Krongart, 2017; Krongart, 2018; Kazakhbaeva, 2019), the main topics that can be studied when using a hydroponic device are related to studies on communicating vessels, properties of liquid media and electric current (Table 4). In a hydroponic device, nutrients to the roots of plants come from a common tank through pumps, so the knowledge of electric current can be practically applied when creating the device itself. In addition, all cations and anions of nutrients can lead to an increase in the content of soluble solids or total salinity. The measurement of salinity is carried out with a TDS meter. The principle of operation of the TDS meter is based on the direct dependence of the electrical conductivity of the solution on the amount of substances dissolved in water. As a

result, knowledge of the potential and conductors of the electric field can be practiced in hydroponics.

Table 4. List of topics in the course of studying the school course "Physics", which can be studied as STEM-learning using a hydroponic device

№	Topic	Class	
	Scientific methods of studying nature	34.	7
	The movement of molecules. Diffusion. Brownian motion	35.	7
	Mass and mass measurement of bodies	36.	7
	Communicating vessels	37.	7
	Electric current, electric current sources	38.	8
	Electric heating devices, incandescent lamp, short circuit, fuses	39.	8
	Chemical action of electric current, Faraday's law	40.	8
	Saturated and unsaturated steam. Air humidity	41.	10
	Properties of the surface layer of the liquid	42.	10
	Wetting. Capillary phenomena	43.	10
	Electric field. The intensity of the electric field. Electric field lines of force	44.	10
	Electric field potential	45.	10
	Conductors in an electric field	46.	10

The use of hydroponic installations in school project activities allows you to explore a variety of subject areas. Therefore, hydroponics as an element of STEM education contributes to: overcome the isolation inherent in traditional education from solving practical problems and build connections between several disciplines that are understandable to students.

It will unite students into groups for joint solving of educational tasks. Working in a team on a project, they gain experience that is as close as possible to their future profession.

Key academic disciplines are selected to train a specialist in applied scientific research. These are modern technologies, engineering disciplines and subjects of the natural science cycle — natural science, biology, chemistry and physics.

Conclusion.

The use of hydroponic installations in school project activities will help students not only in learning, but also in adult life. The general skills of project activities and specific ways of working with modern agricultural complexes will give the student the opportunity to analyze physical and biochemical phenomena and processes, establish a link between natural science disciplines, compare previously studied with new knowledge and use them to solve practical problems. The basic agronomic competencies laid down by school projects on hydroponic systems will help students professionally engage in city farming on a small or industrial scale.

The results and effects of using the method will lead to in-depth assimilation of educational material in many subjects due to the connections of theory and practice, variable ways of obtaining and reproducing knowledge, generalization and systematization of material, which will increase not only motivation and quality of education, but will develop curiosity, independence, craving for new knowledge, the ability to adapt

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CONTENTS

PEDAGOGY

МАЗМҰНЫ

ПЕДАГОГИКА

ЭКОНОМИКА

СОДЕРЖАНИЕ

ПЕДАГОГИКА

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