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Stellarium Virtual Environment as a Means of Implementing Interdisciplinary Connections During the Study of Astronomy

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***Abstract*—The article is devoted to the study of the problem of implementing interdisciplinary connections in the educational process. It is outlined that interdisciplinary connections are a system of relations between knowledge, abilities and skills that are formed as a result of the consistent reflection of objective connections with reality in the means, methods and content of educational disciplines. Significant opportunities for the implementation of interdisciplinary connections belong to astronomy. As an educational subject, astronomy has a significant worldview potential, which is realized through connections with other disciplines (physics, mathematics, information technologies, geography, chemistry, history, literature), which are revealed in the educational process when solving applied problems from various subject areas. A methodical approach to the implementation of interdisciplinarity was implemented in the process of solving the integrated practical task «Verification of historical facts and events using the Stellarium virtual environment». Solving the tasks of integrated content ensures the formation of a unified natural and scientific picture of the world, intensify the research activities of students, promotes active mastery of modern technologies, the formation of professional interests, etc.**

Keywords—interdisciplinary connections, educational process, astronomy, virtual environments.

I. INTRODUTION

Formulation of the problem. The priority task of higher education is the formation of future teachers' ability to solve complex tasks using a systematic approach. The improvement of science education consists in the formation of high-quality fundamental education of students, but the knowledge of only certain concepts and facts does not contribute to the formation of a complete picture of the object or the process that is being studied. An effective means of implementing such a task is the use of interdisciplinary connections, which involve the transfer of research methods and models from one scientific discipline to another. Connections between various disciplines of professional training in higher education institutions are a reflection of the integration processes taking place in science and society; they ensure the resolution of contradictions between the knowledge of education seekers from various disciplines and the need for their comprehensive application in practice, in future scientific and professional activities.

Significant opportunities for the implementation of interdisciplinary connections belong to astronomy. As an educational subject, astronomy has a significant worldview potential, which is realized, in fact, through connections with other disciplines (physics, mathematics, information technologies, geography, chemistry, history, literature), which are revealed in the educational process when solving applied problems from various subject areas.

Analysis of recent research and publications. The analysis of the scientific works of domestic and foreign researchers showed that under interdisciplinary connections one should understand the system of relations between knowledge, abilities and skills that are formed as a result of the consistent reflection of objective connections with reality in the means, methods and content of educational disciplines. An important psychological-pedagogical condition for increasing scientific knowledge, accessibility of education, its connection with the surrounding reality, activation of activities and improvement of the process of formation of knowledge, abilities and skills of students is the observance of interdisciplinary connections [1]. Scientists have studied various aspects of the problem of implementing interdisciplinary links, namely: as a complex psychological and pedagogical problem; as a means of forming a flexible and productive system of knowledge and generalized ways of action, as a means of forming the scientific worldview of students; as a condition for improving the efficiency and effectiveness of learning, rationalizing work, reducing the duplication on students, eliminating duplication of educational material, and optimizing the learning process in general.

The importance of interdisciplinary connections and their role in the educational process has been studied in foreign pedagogical literature as well. The theoretical principles of the implementation of interdisciplinary connections are highlighted in the works of N.Heitzmann, A.Opitz, M.Stadler, D.Sommerhoff, M.Fink, A.Obersteiner, R.Schmidmaier, B.Neuhaus, S.Ufer, T.Seidel, M.Fischer, F.Fischer, C.Hmelo-Silver, H.Jeong and many others. Scientists [2] propose an interdisciplinary conceptual model and emphasize its importance for success in the organization of interdisciplinary research. In their scientific works, researchers [3] note that integration in the educational process ensures the activation of cognitive interest, the development of critical and creative thinking of students, and a deep conceptual understanding of various subjects.

Interdisciplinary connections implemented in education require students of education to use new and previously acquired knowledge from various disciplines, their application to real-world problems, which ensures an increase in the quality of education [4].

Scientists [5] summarized scientific works highlighting the theoretical and practical aspects of the integration of education and computer technologies. They believe that computer-assisted learning is interdisciplinary in its concept.

A significant number of works are devoted to the interdisciplinary approach in teaching the disciplines of the natural and mathematical cycle. At the same time, the problem of realizing the interdisciplinary connections of astronomy using computer technologies with history, geography, and literature is insufficiently covered, which determined the relevance of our research. The purpose of this study is to develop methodological foundations for the implementation of interdisciplinary connections in the process of studying astronomy using the example of an integrated practical task «Verification of historical facts and events using the Stellarium virtual environment».

II. Theoretical Fundamentals Of Research

Finding out the content of the concept of «interdisciplinary connections», it was found that there is a significant number of its interpretations in modern pedagogy. Interdisciplinary connections are considered to be a means of complex formation of the future specialist, and interdisciplinary integration in the educational process organically combines the material of a new topic with previous and subsequent knowledge, defines logical connections between different disciplines, sections, topics, outlines the purpose of different disciplines in future professional activity. At the same time, teachers of educational institutions must constantly improve teaching methods; systematically study and analyze the effectiveness of the applied forms and methods of education; to search for ways to introduce innovative, active learning methods that allow students to develop thinking, use the acquired knowledge in practice-oriented activities that are as close as possible to professional ones.

S. Honcharenko interprets interdisciplinary connections as a didactic tool, which involves a complex approach to the formation and learning of the content of education, which makes it possible to make connections between disciplines for an in-depth, comprehensive consideration of the most important concepts and phenomena [6]. It is worthwhile noting that the problem of improving the quality of education, developing independence and creative activity of students and preparing them for independent acquisition of knowledge and creative activity cannot be fully solved without establishing a holistic picture of the world based on interdisciplinary connections in the educational process.

In our research, we consider interdisciplinarity as a scientific and pedagogical innovation that gives rise to the ability to see, recognize, and perceive what is inaccessible within the boundaries of a single discipline with its specific, narrowly focused object, subject, and research methods.

Astronomy plays an important role in the implementation of interdisciplinarity. Astronomy occupies a special place among the sciences of the natural cycle. It has become a stereotype that it completes the stage of formation of a natural and scientific picture of the world in students, and is the final link for a holistic perception of the world. In fact, astronomy shows us our place in the universe, points to the unity of man and the universe, demonstrates the universality of the laws of nature, completes the cycle of physical-mathematical and natural-science subjects in high school, completes the formation of a scientific worldview, demonstrates the effect of physical laws on different space-time scales, applies mathematical methods of learning about nature and, at the same time, shows the power and greatness of human cognitive abilities. The formation and development of astronomical concepts occurs during the study of physics, geography, chemistry, and mathematics. It should be noted that the connection of the disciplines of the natural cycle with astronomy and astronomy with the disciplines of the natural cycle is important not so much for the creation of an astronomical picture of the world as for the formation of a holistic natural scientific picture of the world. The use of the Stellarium virtual planetarium for verification of historical events and facts deserves special attention, especially in the conditions of distance learning [7], which ensures the implementation of interdisciplinary relations of astronomy with subjects of the social and humanitarian cycle. The graphical interface of this program with the help of the keyboard provides wide opportunities for controlling the time, the telescope, the possibility of updating, adding new objects of the Solar System based on data from Internet resources, adding your own remote objects, landscapes, images of constellations, scripts, etc. [8, 9]. In particular, the authors of [8] describe the use of Stellarium for educational purposes and propose to use the capabilities of Stellarium to develop the research skills of students in the study of exoplanets, where the implementation of interdisciplinary links between astronomy, mathematics, chemistry, and biology can be traced.

The process of solving such tasks activates the intellectual and research activity of education seekers, which contributes to the growth of the quality of the educational process and ensures the formation of both key and subject competence [10]. To implement interdisciplinary connections in the process of studying astronomy, we offer an integrated practical task, which consists in checking the solar eclipse, which is the basis of the plot “Words about the Ihor regiment”, using the Stellarium virtual environment.

III. Research Methodology

This event took place in the distant past in a state called Kievan Rus (Fig. 1a), when Russia was not even mentioned in historical chronicles. This event is described in many annals, it is the basis of the plot “Words about Ihor’s regiment” about the unsuccessful campaign of the Novgorod-Siversky prince Ihor Svyatoslavych against the Polovtsy in 1185AD. Shortly before the battle, on May 1, 1185AD, a solar eclipse occurred, which was regarded by the Rus’ warriors as a harbinger of trouble. “...And when they were going to the Donets river, in the evening hours Ihor, looking at the sky, saw that the Sun was shining like the Moon. And he said to his boyars and his troops: “You see? What kind of sign is this?” And they, looking up, saw it all and bowed their heads, and said: “Prince! This sign does not bode well at all”. But Ihor said: “Brothers and worriors! No one knows the secrets of God, but God is the creator of the sign and the whole world. And what God will do for us, whether for good or for our misfortune, we will see”. And, having said this, he waded the Donets” [13].

(a) (b)

Fig. 1. (a) – The principalities of Kievan Rus’ (1054AD – 1132AD) [11], (b) – place of battle [12]

Historians still have not decided where exactly the unsuccessful battle of Ihor Svyatoslavovych with the Polovtsy took place in 1185AD. More than 800 years have passed since the historical events. During this time, the site of the battle turned into the Wild Field, and then into the Luhansk Region, as it is known to the modern generation. Most of the geographical names were changed, and due to the industrial development, the riverbeds were also changed, and some of them were ‘dried’ on purpose. Therefore, historians still cannot choose which modern river was the legendary Kayala, which is mentioned in the “Word about Ihor’s Regiment” [14]. According to [15], on the evening of May 9, 1185AD, Kievan Rus’ troops crossed the river of Siverskyi Donets in the area of the Izyum mound. The author believed that the Kayala is the present-day Makatykha River. Most versions are based on the name of the modern river of Siverkyi Donets, which, according to historians, was called the Don or the Great Don in the time of Prince Ihor. The writer Borys Yarotskyi in the book “Traces of Prince Igor lead to Kremenschina” convinced that the legendary battle took place near the Mechetna River [14].

According to the results of the above studies, we will assume that Prince Ihor Svyatoslavovych could observe a solar eclipse on the territory of modern Ukraine in the area of the current Kreminna, Luhansk region with geographical coordinates 49,1°N, 38,25°E (Fig. 1b). We will check with the help of modern specialized programs whether a solar eclipse really occurred on the territory with the specified coordinates on May 1, 1185AD, characterize it and compare it with historical chronicles. To do this, we will first use the program for calculating solar eclipses EmapWin [16]. As can be seen from Fig. 2, the band of total solar eclipse in this territory on May 1, 1185AD, passed at slightly higher latitudes, so at that time Prince Ihor should have observed a partial eclipse of the Sun. Let us check whether this event really took place with the Stellarium astroprogram and ‘see’ the solar eclipse through the eyes of Ihor Svyatoslavovych. To do this, we will input the geographical coordinates of the battle site in the environment of this program (49,1° N, 38,25° E), the date (May 1, 1185 AD) and virtually observe the celestial sphere during the day. The main result of these virtual observations is shown in Fig. 3.

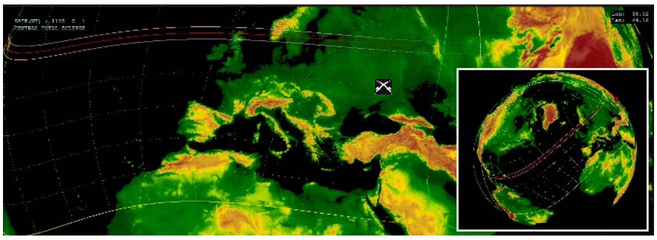

Fig. 2. Eclipse Software EmapWin [16]

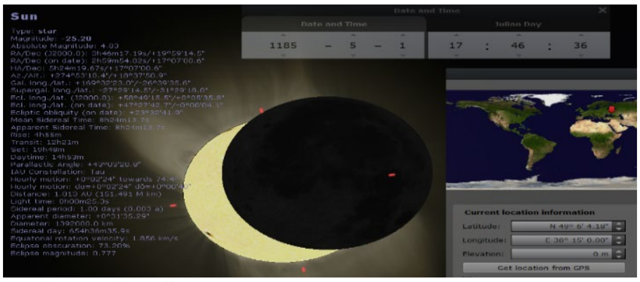

Fig. 3. Solar eclipse on May 1, 1185 AD [9]

The result of modeling this event allows us to draw the following conclusions:

1. The eclipse of the Sun really took place in the mentioned territory on May 1, 1185 AD.

2. It was partial and took place in the evening (maximum eclipse phase – 73.2%, time – 17 h 46 min). “...And when they were going to the Donets River, in the evening hours Ihor, looking at the sky, saw that the Sun was shining like the Moon”.

3. The duration of the eclipse is 1 hour 55 minutes (16 hours 47 minutes - 18 hours 42 minutes).

4. Theoretically, we will calculate the expected decrease in illumination during this eclipse, using formulas related to the laws of optics and astronomy. The general formula for calculating illumination during a solar eclipse is as follows: $E = E_0\left(1-k\right)$, where E is the illuminance during the eclipse, E_0 is the initial illuminance before the eclipse, k is the eclipse coefficient (in our case k=0,732^2=0,536). Therefore, E/E_0=1-k=1-0,536=0,464, i.e., the illumination decreased by approximately 3,73 times.

Note that these formulas are quite general, and the actual reduction in illumination depends on many factors, including weather conditions and observation location. Let’s find the change and value of the apparent magnitude of the Sun during the eclipse. According to Pogson’s formula: $m - m_0 = -2,5lg\left(\frac{E_0}{E}\right)$, where m is the apparent magnitude of the Sun during the eclipse, m_0 is the apparent magnitude of the Sun before the eclipse (-26,71^m). For our case:

$$m - m_0 = -2,5lg\left(\frac{E_0}{E}\right) = -2,5lg\left(3,73\right) = -1,43.$$

$$m_0 = -26,71 + 1,43 = -25,28.$$

Therefore, the apparent magnitude of the Sun during the eclipse increased by 1,43^m and is equal to -25,28^m, which correlates well with the data shown in Fig. 3.

5. Using the data of the Stellarium virtual environment, we will calculate the dimensions of the areas of total and partial eclipse under study, guided by the geometric constructions that students are able to perform (Fig. 4).

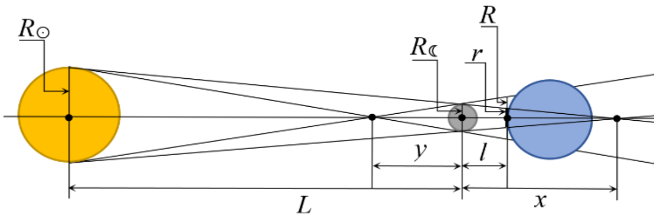

Fig. 4. Solar eclipse scheme

Calculation of the radius of the total solar eclipse area:

$$\frac{R_{\odot}}{L+x}=\frac{R_{☾}}{x}=\frac{r}{x-l}\Rightarrow\begin{cases}x=\dfrac{R_{☾}\cdot l}{R_{\odot}-R_{☾}}=378217\,km\\ r=\dfrac{x-l}{x}\cdot R_{☾}=104,9\,km\end{cases},$$

where $R_{\odot}$ = 696000 km is the radius of the Sun, $R_{☾}$ = 1737,4 km is the radius of the Moon, L = 151135000 km is the distance from the Sun to the Moon during the ecplipse, l=355380 km is the distance from the Earth to the Moon (Fig. 3, data from Stellarium). Calculation of the radius of the area of partial solar eclipse:

$$\frac{R_{\odot}}{L-y}=\frac{R_{☾}}{y}=\frac{R}{y+l}\Rightarrow\begin{cases}y=\dfrac{R_{☾}\cdot l}{R_{\odot}+R_{☾}}=376376,7\,km\\ R=\dfrac{y+R_{☾}}{y}\cdot R_{☾}=1745,6\,km\end{cases}$$

The results of theoretical calculations of areas of total and partial eclipse at the moment of maximum eclipse (Fig. 3) are visualized in Fig. 5.

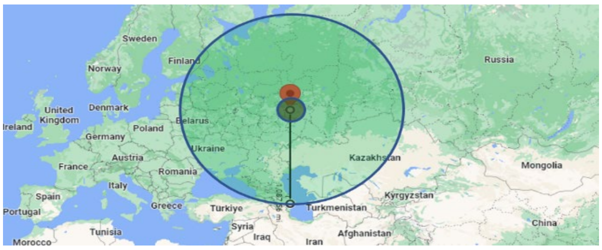

Fig. 5. Theoretically calculated area of the eclipse [17]

As we can see, theoretical calculations correlate well with virtual observations in specialized programs [10, 16].

A survey of students majoring in Secondary Education (Physics) and Secondary Education (Natural Sciences) at Ternopil Volodymyr Hnatiuk National Pedagogical University on the effectiveness of using interdisciplinary connections in educational activities showed that 70% of students believe that solving problems of integrated content ensures the formation of a single natural science picture of the world and activates research activities.

IV. CONCLUSIONS AND PROSPECTS OF RESEARCH

The study theoretically substantiates the importance of interdisciplinary connections in the educational process. It is outlined that interdisciplinarity in its broad sense provides synergy of various sciences (disciplines), which involves the development of integration processes, interaction of methods, tools for obtaining new scientific knowledge. The interdisciplinary approach is aimed at developing the individual interests of students, motivates them to master academic disciplines using different approaches and means; promotes the expansion of scientific outlook, provides opportunities to practically implement modern trends in education; promotes the encouragement and continuous analysis of acquired knowledge; increases their quality. The proposed methodical approach during the implementation of the integrated practical task "Verification of historical facts and events using virtual environments" allows to significantly increase the interest of students in the study of astronomy, contributes to the process of formation of competencies of students. The prospects for further research are seen in the implementation of interdisciplinarity in the study of natural sciences using the STEM approach, the use of digital educational laboratory equipment, taking into account the educational and research activities of students.

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SECTION 6
Information Technology in Education