Using interactive technologies to study the evolution of stars in astronomy classes

Svitlana L. Malchenko[1[0000-0001-8291-6642]], Davyd V. Mykoliuk[1] and Arnold E. Kiv[2]

[1] Kryvyi Rih State Pedagogical University, 54, Gagarin Ave., Kryvyi Rih, 50086, Ukraine
malchenko.svitlana@kdpu.edu.ua, mikoluyk99@gmail.com
[2] Ben-Gurion University of the Negev, P.O.B. 653, Beer Sheva, 8410501, Israel
kiv@bgu.ac.il

Abstract. In astrophysics, a significant role is played by observations. During astronomy classes in the absence of surveillance tools interactive programmes such as an interactive programme for space objects simulation can be used as Universe Sandbox². The aim of this work is to implement interactive programmes for effective astronomy teaching, understanding material and increasing cognitive interest. We observe the evolution of stars while using Universe Sandbox² during the study of the topic "Evolution of stars". Using this programme students have an opportunity to get acquainted with the existence of stars with different masses, their differences, to observe changes in the physical characteristics of stars such as: mass, temperature, speed velocity, luminosity, radius and gravity. It will help to develop the ability to analyze, to compare, to form scientific worldview, to develop the attraction for research, to raise the interest for studying astronomy.

Keywords: education, astronomy, computer technology, interactive programmes, Universe Sandbox².

Modern educational technologies are aimed at teaching students to work independently [9; 10; 13; 14], as this quality gives opportunity for them to adapt successfully in the conditions of a rapidly changing society. The ability to learn will allow them to improve experience and knowledge, to analyze and to use the achievements of science and technics in the professional activity. The number of hours to study astronomy is clearly not enough for its quality of teaching and for students to master it at a sufficient level, which also indicates the need to devote the most part of the material for independent study [11; 13]. However, most teachers consider students' independent work only as homework, textbook reproductive study, writing synopses, problem solving and preparing projects. Learning a new material independently is difficult for schoolchildren. Normally they do not do a boring work or they do it mechanically. In the context of the modern new Ukrainian school it is necessary to increase the role of independent work for obtaining sufficient astronomical knowledge but at the same time it is necessary to change the approach to the individual work. It should not be exclusively reproductive homework, it should include interesting tasks for students which they will perform both during and after the classes or at home [12].

Copyright © 2020 for this paper by its authors. Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).

CEUR-WS.org/Vol-2547/paper11.pdf

Modern technologies are developing enough fast and their use will help to enhance the study of astronomy. For example, such computer and mobile applications as Sky Map, Star Walk 2, etc. and 3-D pens for design 3-D models could be used [2, 5]. It is clear that the use of modern technologies requires additional time, knowledge and skills both of teachers and students.

Nowadays, while teaching astronomy didactic and psychological principles of developmental teaching, individualization and differentiation of teaching, activity and comprehension approaches must be implemented [16]. The transition to the competence approach means reorienting the process to the result of education in the activity, changing the emphasis on the accumulation of normatively defined knowledge, skills and abilities in order to form and to develop individual's ability for practical actions, the use of experience in specific situations [14]. The activity approach to the organization of the educational process in astronomy allows not only to solve the problem of effective mastering the astronomical knowledge successfully, but also to form students' ability to plan their activities independently and competently in different situations.

Today children comprehend the lesson material when information and communication technologies (ICT) are used with greater interest [19]. Such form of organization of various subjects' study becomes more effective and facilitates the new material perception by children. The use of ICT during astronomy lesson develops visual thinking, imagination, visual memory. It becomes possible with the use of star maps, educational pictures, demonstrations, video and audio materials, animated images that are presented in electronic form.

The use of interactive technologies affects the level of student's formation of high internal and external motivation, activity in information and cognitive activity while studying astronomy. And so that it manifests itself in self-determination and self-realization of the personality. Innovative technologies allow to reproduce the high level of visualization of the happening events and processes, the ability of simulation and occurring of their simulation with different values of parameters. Also it allows to reproduce individualization and differentiation of educational material in respect to the student's cognitive abilities as well as the ability to control mastering and understanding teaching material in the classroom for the teacher's management or independent work so that it enables to have an operational feedback for the correcting educational process.

Workshops provide the students with an opportunity to increase theoretical knowledge, to study principles of physical phenomena development, to use fundamentals of scientific experiments, and skills in mathematical analysis of measured results.

Due to the rapid development of computer technologies, it is possible to implement interactive technologies in the work of educational institutions [1; 6]. The implementation of such technologies improves and facilitates astronomy classes. Firstly, visual aids should be used because while learning astronomy it is difficult for pupils or students to understand and to get the idea without realizing how and in what way an astronomical (physical) process passes. Secondly, the use of computer programmes makes easy to implement practical tasks and laboratory work, moreover it allows to extent their quantity. Thirdly, taking into account the fact that it is given not enough time for astronomy study, so the organization of the independent work with the use of interactive technologies will increase the amount of knowledge or even will expand the students' horizons.

The aim of this work is to implement interactive computer and mobile programmes for the independent work in effective astronomy teaching as well as understanding material and increasing cognitive interest. An additional aim of this work is the introduction of astronomical practical work for children with educational needs.

Instead of the usual methods of teaching the desire to develop students' ability to work with multiple sources of information has come, and one of the main goals has become not only to provide graduates with specific knowledge but also a need to teach them how to learn. Exactly the mentioned previously will allow to improve experience and knowledge during the whole life, to analyze and to use achievements of science and technology in the professional activity.

The use of modern informational technologies in the process of organization of independent work simplifies teacher's organization of independent work in astronomy and has a number of advantages:

- modern educational products;
- possibility of choice of individual working schedule;
- the use of accents transfers on electronic transmitters;
- variability of tasks taking into account children's potential possibilities and capabilities;
- increase of students' professional motivation;
- an objective checking possibility of the level of mastering educational material.

The use of informational technologies in organization of students' independent work allows not only to intensify their work but also to make base of further permanent self-education.

E-learning environments, that help children to get learning material, include distance learning, interactive exercises, e-testing, mobile applications [15]. New informational technologies such as laptops, smartphones allow children with special educational needs to participate in the educational process without using functional restrictions and residence [4; 5; 17]. Mostly, it is a kind of salvation because due to the sufficient development of technology, they can get education of different levels even without leaving home. Distance learning is used in different countries of the world and that allows, for example, to live in Ukraine and study in Denmark.

Lately the problem of children's "inclusive education" in general educational establishments becomes more essential. And if this issue is studied at primary school, attention is paid not sufficiently to the study of children with the special needs in science and mathematics. ICT implementation allows a teacher to take into account the students' individual educational needs and consequently to involve such children to the astronomy study. Unfortunately, the astronomy study is paid not enough attention in secondary educational establishments and scientific literature. The educational process for children with the special educational needs at senior school lays in personality-centered education. In this case the role of a teacher is to find an approach to every student with individual needs and to involve him to cognition.

To strengthen an effect in the studies of children with the special educational needs, teachers use audio and video materials, pictures, fragments of films, other visual aids, but it is important to make visualization concrete [8]. It is possible and necessary to use a great quantity of illustrative material, atlases, star catalogue, map of the starry sky while teaching astronomy. Students with autistic disorder have unique possibilities for astronomy study. In astrophysics, a considerable role is played by supervisions.

Realistic observations cannot be made in astronomy classes, so virtual computer or mobile applications will help the teacher to increase practical and research components, to bring astronomy study closer to the modern scientific level. By doing their own research students do not only understand the learning material better, but also develop their own research skills, imagine the world's scientific picture better. The use of these applications is possible in the classroom and at home while accomplishing individual work. Learning with the help of computer programmes (applications) makes easier the understanding of the material and contributes raising of cognitive activity.

Interesting graphic arts, pictures, virtual trip are interesting and encourage the effective astronomy self-learning as they are children's visual acquaintance with these programmes. Such programmes can be used in the educational; process for the students with the special educational needs because students can accomplish the majority of the mentioned tasks independently. While working with computer programmes a student can choose complication and speed of work taking into account his own individual features. Thanks to the free access to these programmes all students have an extracurricular time to continue studying, to analyse material independently and to make conclusions.

One of the most interesting question for students and one of the task for an astronomer is star evolution. The theme "Evolution of stars" in the 10-11th grades is devoted about one hour for the study on the standard level. Video, animations, other visualization give an opportunity to understand the physical processes that take place and how physical parameters depend on the evolution process. In this work we also represent interactive computer programmes, for example, *Universe Sandbox*^{2} which is used as an interactive computer programme for space objects simulation.

Universe Sandbox is a physics-based space simulator that allows you to create, to destroy and to interact on an unimaginable scale [3]. Universe Sandbox was introduced in 2008. Moreover, its current version is now available. It includes desktop and virtual reality mode. Universe Sandbox^2 fully supports three of the major VR solutions: HTC Vive, Oculus Rift+Touch and Windows Mixed Reality. With a headset this simulator allows to create one's own virtual reality in order to see and to interact with digital content in the environment. This virtual reality is great for demonstrating scale and distance in a tangible way. Also it can make astrophysical concepts tangible for students like nothing else. With its help the influence of gravity on various objects in the universe can be seen and planetary systems can be simulated.

It is possible through mapping walls and objects, then through superimposing images, that it makes to look like as right objects in front of you. This also allows interactions between the real and digital worlds as, for example, with the use of Universe Sandbox. It means that it is possible to explore the Solar System in a living room and to smash stars against walls.

The laws of physics are performed for planets, stars and other space objects, therefore, this programme may become highly interesting for studying not only astronomy but also physics.

The lesson goal of the topic “Stars. Evolution of the stars” is to understand how, why, where and from what stars are formed. The classes are offered to combine traditional learning tools and the use of modern electronic technologies. After learning new material, the computer programme Universe Sandbox^2 is introduced to the students. It has the ability to:

- consider and modify our Solar System with known planets, starting with Mercury and ending with Neptune;
- change mass of the planets;
- make your own Planetary system;
- observe the collision process of galaxies with further development of this process;
- control the motion of asteroids, meteorites and comets;
- monitor the moment of birth and death of the stars (this process is shown in details);
- monitor the situation in which the Sun goes out and how the Solar system model will look like without the Sun;
- put Black Hole in galaxy or a planetary system and to analyze what could happen.

As a practical exercise, it is suggested that students use the Universe Sandbox^2 to explore the evolution of the Sun and any other stars with larger mass. Students can accomplish this task under the teacher’s guidance (if it is possible in the class or after it) or independently at home, at the end of the lesson or at the next lesson. Students make conclusions concerning the time of evolution, the final stage of the evolution of the stars, and the change in the physical parameters of the studied stars.

Task for students: using a computer programme watch the evolution of stars with different masses. Complete the table in order to do the analysis.

	Initial data	Intermediate data	Final data
Mass, M○ Radius, km Surface temperature, K Volume, V○ Time, billion year			

It is the brief instruction to the programme in order to accomplish the task. In order to watch the evolution of the star of the Sun type, a student must launch the Universe Sandbox^2 programme, open the MENU (press the “Home” button, it is on the top left). In the menu press “Open” button, then select the “Explosions” tab, and open the simulation called “Stellar Evolution of our Sun”, and for the other stars you need to click on the star itself and informational panel with physical characteristics (mass, radius, density, temperature and speed) will appear on the right side of the monitor. The additional information about the star (title, age, surface temperature, luminosity, rotation speed, gravity attraction) will appear on the informational panel.

Stars with different masses at different stages of evolution are shown in Fig. 1-3.

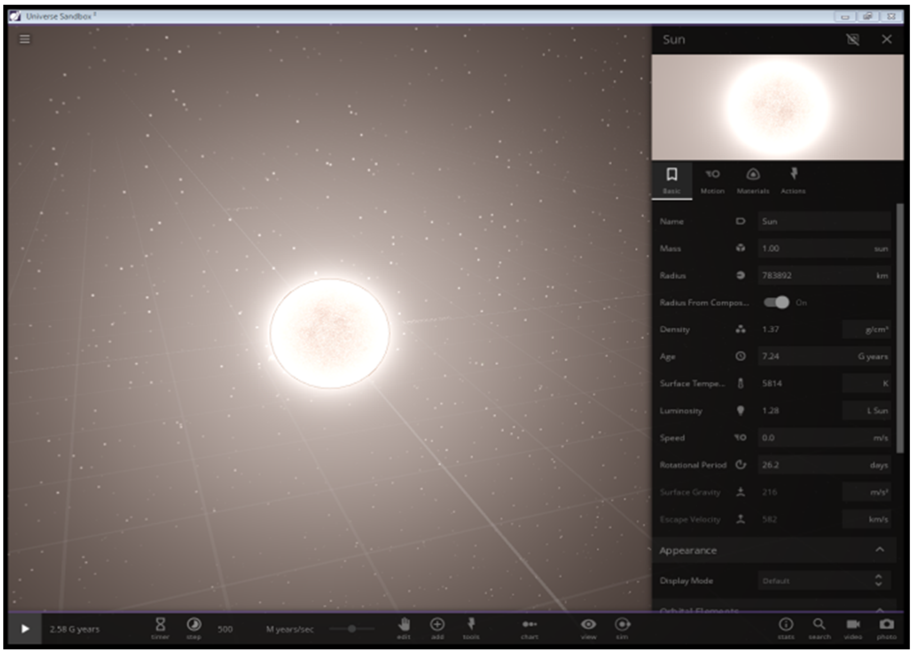

Fig. 1. Star of the Sun type with age of 7 million years

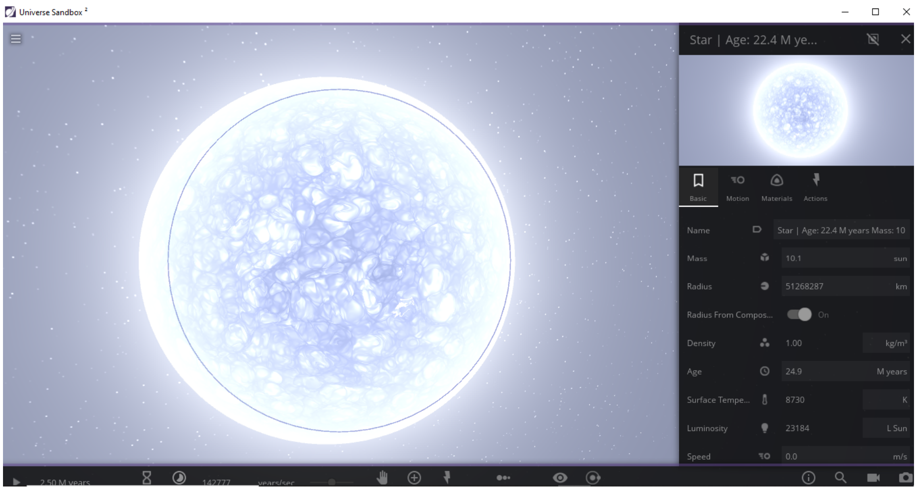

Fig. 2. Star with mass of 10 Sun masses with age of 22.4 million years

Table 1 presents the evolution process of the stars with the Sun mass. The evolution of the star was observed from the stage of the main sequence to the stage of the red giant. From the data in the table all physical characteristics were increasing in the process of stars' development. A red giant was formed with a smaller mass but larger in size in the process of this model development as a result of simulation.

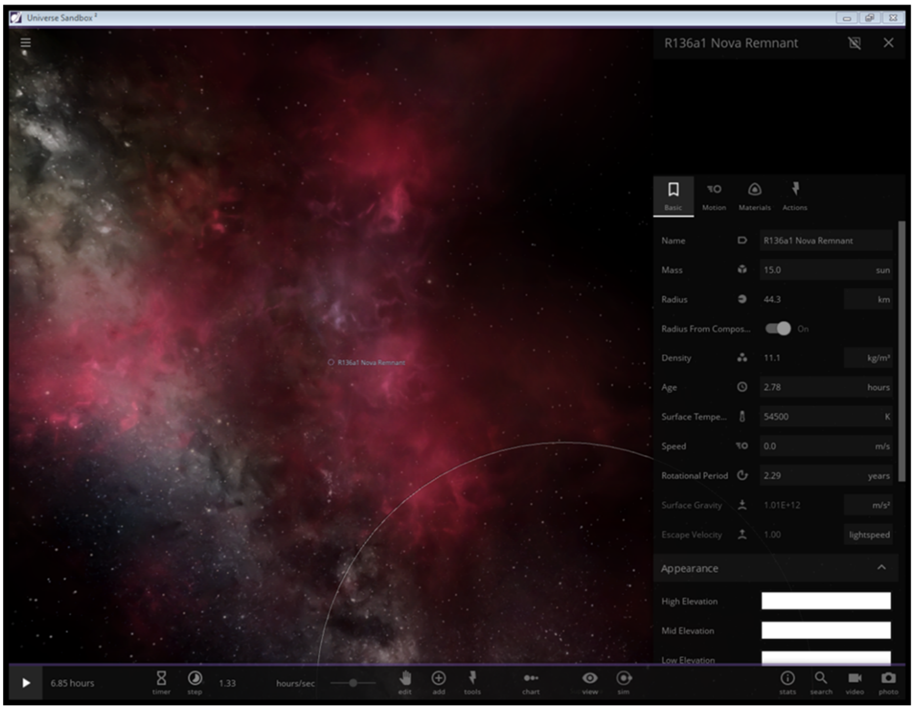

Fig. 3. Star with mass of 15 Sun masses 2,78 hours later after the explosion

Table 1. Star with the Sun mass

	Initial data	Intermediate data	Final data
Mass, M○	1	1,2	0,541
Radius, km	6955000	848960	1219169
Surface temperature, K	5775	5805	5173
Volume, V○	1,03	1,82	6,51
Time, billion year	4,66	8,55	11,2

The star evolution model is standard and is already presented in the programme. During the development of this model the star size enlarges, change of temperature and mass are observed.

The results of observations on the model of a massive star are given in Table 2. As Table 2 shows, the radius, temperature and volume of the star increased. As a result of the evolution, a star of considerable size with the same mass but with a lower temperature was formed. At the final stage of evolution, a clear cloud of gases emerged near the star.

Table 2. Star with 10 Sun masses

	Initial data	Intermediate data	Final data
Mass, M○	10,1	10,1	10,1
Radius, km	7025583	26323386	55057486
Surface temperature, K	19964	13917	8133
Volume, V○	1030	62877	495659
Time, billion year	22,4	23,4	25,1

Table 3 presents the evolution of the star with 260 Sun masses. The evolution was observed from the stage of the main sequence to the stage of supernova. From the data in the table all physical characteristics were increasing in the process of evolution of the stars. A black hole was formed as a result of development simulation of this model.

Table 3. Star with 260 Sun masses

	Initial data	Intermediate data	Final data
Mass, M○	260	265	15
Radius, km	22325550	29243869	44,3
Surface temperature, K	54500	56000	54227
Volume, V○	33048	74274	$25 \cdot 10^{16}$
Time, billion year	1,70	1,75	–

Students have an opportunity to get acquainted with the existence of stars with different masses, their differences, to observe changes in the physical characteristics of stars such as mass, temperature, speed velocity, luminosity, radius and gravity thanks to practical task accomplishment with the help of this programme. It is also necessary to pay attention to the time of evolution of stars with different masses, it can take a long period of time: from several millions to tens of billions of years.

At the end of this class, students can answer the questions:

1. What is protostars?
2. What is realization of a stellar evolution?
3. What changes during the evolution of the stars?
4. Can we study the stellar evolution when we observe the life of a single star? Why?
5. Are all stars born from collapsing clouds of gas and dust?
6. How different is evolution of stars of different masses?
7. Does the mass of the stars change during their life?
8. How does the size of the stars change during stellar evolution?
9. What is the duration of life of stars?
10. When does the star become a black hole?
11. Which stars have the smallest size?
12. Tell about the evolution of low-mass stars.
13. What is the difference evolution of giant and supergiant in comparison to low-mass stars?
14. What happens after a low-mass star ceases to produce energy through fusion?

Students also can prepare presentation about the life cycle of a Sun-like star, brown dwarfs and sub-stellar objects, red-giant-branch phase, planetary nebula, etc.

The task of modeling the evolution of stars was offered to the students of the 11th grade of Kryvyi Rih Lyceum No 35, who study astronomy at the standard level, and and also this task was offered to the students who study physics at Kryvyi Rih State Pedagogical University as a major subject. Pupils as well as students performed this task after having studied the theme "Stars. The evolution of stars" after classes.

Finally, we can do the following conclusions:

1. Universe Sandbox[2] is a simulation software which allow to explore a star evolution in the virtual reality (using HTC Vive, Oculus Rift+Touch or Windows Mixed Reality). Computer simulation of the stars evolution in astronomy study provides students with knowledge on the peculiarities of stars with different masses (form, size, temperature). Furthermore, it helps to understand the evolution of the stars with different masses, to recognize the physical characteristics and processes taking place into the stars, to consider the conditions of the formation of supernovae, neutron stars and black holes. It will help to develop the ability to analyze, to compare, to form scientific worldview, to attract for a research, to raise the interest to astronomy study.
2. The basic result of implementing practical works in astronomy are the obtained knowledge and abilities which allow students to determine learning tasks; to find the optimum methods of tasks realization; to use different information sources; to estimate the results; to organize one's own research activity. Therefore, practical tasks in astronomy have an important place in the educational activity, so that the conducting of such tasks is possible even without the special astronomic equipment.
3. Interactive programmes implementation will help students to master the material better, it will allow to visualize educational material, to develop students' spatial representation, to increase the level of cognitive activity and to provide an effective self-mastering the knowledge in astronomy. Besides the implementation of computer interactive programmes, ICT allows to organize an individual work in astronomy and to involve children with special educational problems into the process of studying astronomy.
4. Experience of using the opportunities of modern computer technologies shows their high efficiency in the course of school astronomy. ICT open new opportunities in order to create virtual space, in which it is possible to observe the processes that are inaccessible in realities due to the classroom conditions.

References

1. Abykanova B., Nugumanova S., Yelezhanova Sh., Kabylkhamit Zh., Sabirova Zh. The Use of Interactive Learning Technology in Institutions of Higher Learning. International Journal of Environmental & Science Education **11**(18), 12528-12539 (2016)
2. Chen, C.H., Yang, J.C., Shen, S., Jeng, M.C.: A Desktop Virtual Reality Earth Motion System in Astronomy Education. Educational Technology & Society **10**(3), 289–304 (2007)

3. Giant Army: Universe Sandbox. http://universesandbox.com (2019). Accessed 28 Nov 2019
4. Heta, A.V., Zaika, V.M., Kovalenko, V.V., Kosova, E.A., Leshchenko, M.P., Leshchenko, P.A., Matiukh, Zh.V., Netosov, S.I., Nosenko, Yu.H., Somenko, D.V., Somenko, O.O., Tarasiuk, M.D., Tymchuk, L.I., Chernov, A.A., Shyshkina, M.P., Yatsyshyn, A.V.: Suchasni zasoby IKT pidtrymky inkliuzyvnoho navchannia (Modern ICT tools for inclusive education support). PUET, Poltava (2018)
5. Ivanova, A.I.: Vykorystannia IKT dlia navchannia ditei z osoblyvymy osvitnimy potrebamy na zaniattiakh z astronomii (Use of ICT for teaching children with special educational needs in astronomy classes). In: Chashechnykova, O.S. (ed.) Proceeding of the 3rd International scientific and methodical conference on Development of intellectual abilities and creative abilities of students and students in the process of teaching disciplines of the natural and mathematical cycle (ITM * plus – 2018). 8-9 November 2018, Sumy, vol. 1, pp. 189–190. FOP Tsoma S.P., Sumy (2018)
6. Kennewell S., Tanner H., Jones S., Beauchamp G.: Analysing the use of interactive technology to implement interactive teaching. Journal of Computer Assisted Learning **24**(1), 61–73 (2008). doi:10.1111/j.1365-2729.2007.00244.x
7. Kolgatin, O.H., Kolgatina, L.S., Ponomareva, N.S., Shmeltser, E.O.: Systematicity of students' independent work in cloud learning environment. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 6th Workshop on Cloud Technologies in Education (CTE 2018), Kryvyi Rih, Ukraine, December 21, 2018. CEUR Workshop Proceedings **2433**, 184–196. http://ceur-ws.org/Vol-2433/paper11.pdf (2019). Accessed 10 Sep 2019
8. Kolomoiets, T.H., Kassim, D.A.: Using the Augmented Reality to Teach of Global Reading of Preschoolers with Autism Spectrum Disorders. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 237–246. http://ceur-ws.org/Vol-2257/paper24.pdf (2018). Accessed 30 Nov 2018
9. Lavrentieva, O.O., Rybalko, L.M., Tsys, O.O., Uchitel, A.D.: Theoretical and methodical aspects of the organization of students' independent study activities together with the use of ICT and tools. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 6th Workshop on Cloud Technologies in Education (CTE 2018), Kryvyi Rih, Ukraine, December 21, 2018. CEUR Workshop Proceedings **2433**, 102–125. http://ceur-ws.org/Vol-2433/paper06.pdf (2019). Accessed 10 Sep 2019
10. Lutsenko, V.V.: Orhanizatsiia samostiinoi roboty studentiv v umovakh osobystisno-oriientovanoho navchannia (Students’ Individual Work Organization under the Conditions of Personally-Oriented Teaching). Dissertation, H. S. Skovoroda Kharkiv State Pedagogical University (2002)
11. Malchenko, S.L., Shevchenko, O.O.: Orhanizatsiia samostiinoi roboty pry vyvchenni astronomii (Organization of independent work in the study of astronomy). In: Proceedings of the International Scientific and Practical Conference on Actual problems of natural and mathematical education in secondary and high school. Kherson, June 26-28, 2014, pp. 67–69 (2014)
12. Malchenko, S.L., Tkachuk, D.L.: Vykorystannia informatsiino-komunikatsiinykh tekhnolohii pry vyvcheni astronomii dlia pidvyshchennia piznavalnoi aktyvnosti uchniv (Use of information communication technologies at astronomy lessons). Cherkasy University Bulletin: Pedagogical Sciences 11, 35–42 (2016)
13. Malchenko, S.L.: Vykorystannia informatsiinykh tekhnolohii pry orhanizatsii samostiinoi roboty z astronomii (The use of information technology in organizing independent work on astronomy). In: Proceedings of Ukrainian Scientific and Practical Conference with

International Participation on Innovative dimension of the development of natural-mathematical and technological education, vol. 15, pp. 97-100 (2015)

14. Modlo, Ye.O., Semerikov, S.O., Shmeltzer, E.O.: Modernization of Professional Training of Electromechanics Bachelors: ICT-based Competence Approach. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 1st International Workshop on Augmented Reality in Education (AREdu 2018), Kryvyi Rih, Ukraine, October 2, 2018. CEUR Workshop Proceedings **2257**, 148–172. http://ceur-ws.org/Vol-2257/paper15.pdf (2018). Accessed 21 Mar 2019
15. Olefirenko, N.V., Kostikova, I.I., Ponomarova, N.O., Bilousova, L.I., Pikilnyak, A.V.: E-learning resources for successful math teaching to pupils of primary school. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 6th Workshop on Cloud Technologies in Education (CTE 2018), Kryvyi Rih, Ukraine, December 21, 2018. CEUR Workshop Proceedings **2433**, 443–458. http://ceur-ws.org/Vol-2433/paper30.pdf (2019). Accessed 10 Sep 2019
16. Tkachenko, I.A.: Metodychna systema navchannia astronomii v pedahohichnykh universytetakh (Methodical system of teaching astronomy at pedagogical universities). Dissertation, Pavlo Tychyna Uman State Pedagogical University (2016)
17. Tkachuk, V.V., Yechkalo, Yu.V., Markova, O.M.: Augmented reality in education of students with special educational needs. In: Semerikov, S.O., Shyshkina, M.P. (eds.) Proceedings of the 5th Workshop on Cloud Technologies in Education (CTE 2017), Kryvyi Rih, Ukraine, April 28, 2017. CEUR Workshop Proceedings **2168**, 66–71. http://ceur-ws.org/Vol-2168/paper9.pdf (2018). Accessed 21 Mar 2019
18. Ustinova, V.O., Shokaliuk, S.V., Mintii, I.S., Pikilnyak, A.V.: Modern techniques of organizing computer support for future teachers' independent work in German language. In: Kiv, A.E., Soloviev, V.N. (eds.) Proceedings of the 6th Workshop on Cloud Technologies in Education (CTE 2018), Kryvyi Rih, Ukraine, December 21, 2018. CEUR Workshop Proceedings **2433**, 308–321. http://ceur-ws.org/Vol-2433/paper20.pdf (2019). Accessed 10 Sep 2019
19. Zhaldak, M.I.: Problemy informatyzatsii navchalnoho protsesu v serednikh i vyshchykh navchalnykh zakladakh (Problems of informatization of educational process in secondary and higher educational institutions). Kompiuter v shkoli ta simi 3, 8–15 (2013)