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Using the Proteus virtual environment to train future IT professionals

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Abstract. Based on literature review it was established that the use of augmented reality as an innovative technology of student training occurs in following directions: 3D image rendering; recognition and marking of real objects; interaction of a virtual object with a person in real time. The main advantages of using AR and VR in the educational process are highlighted: clarity, ability to simulate processes and phenomena, integration of educational disciplines, building an open education system, increasing motivation for learning, etc. It has been found that in the field of physical process modelling the Proteus Physics Laboratory is a popular example of augmented reality. Using the Proteus environment allows to visualize the functioning of the functional nodes of the computing system at the micro level. This is especially important for programming systems with limited resources, such as microcontrollers in the process of training future IT professionals. Experiment took place at Borys Grinchenko Kyiv University and Sumy State Pedagogical University named after A. S. Makarenko with students majoring in Computer Science (field of knowledge is Secondary Education (Informatics)). It was found that computer modelling has a positive effect on mastering

the basics of microelectronics. The ways of further scientific researches for grounding, development and experimental verification of forms, methods and augmented reality, and can be used in the professional training of future IT specialists are outlined in the article.

Keywords: augmented reality, virtual environment, Proteus, training, future IT professionals.

1 Introduction

The rapid development of the modern information space is inextricably linked to the modernization of the education system, the effectiveness of which depends largely on involvement of students and teachers into digital information environment. Recently, progressive educators are increasingly turning to augmented reality (AR) as an opportunity to supplement the physical world, including the educational space, through digital information. This process is provided by computer devices such as smartphones, tablets and AR glasses in real time.

No wonder leading methodologists perceive augmented reality as an innovative technology of training students, including IT professionals. It is a well-established fact that augmented reality, unlike VR (Virtual Reality), which requires a complete immersion in the virtual environment, uses the educational environment around us and imposes on it a certain piece of virtual information. This information is usually attributed to graphics, sounds, or touch responses.

As the virtual and real worlds coexist in harmony, users with augmented reality experiences are able to experience a new world where virtual information is used as an additional useful tool to assist in the daily educational process. Therefore, it can be argued that computer visualization of the educational process is a necessary and important component of augmented reality. Its implementation is possible, for example, through the use of virtual laboratories.

In the field of modelling of physical processes the Proteus Physical Laboratory may be as augmented reality because its micro-level instrumentation allows tracking the features of the information system.

The analysis of the real practice of realization of educational process at Borys Grinchenko Kyiv University and Sumy State Pedagogical University named after A. S. Makarenko testifies that the features of using the Proteus virtual environment as augmented reality in the preparation of future IT specialists (students of the specialty "Computer Sciences", field of knowledge "Secondary Education" (Informatics)) are still insufficiently developed.

2 Analysis of previous results

Various aspects of augmented reality application in the digital educational space have been the subject of research by a number of scholars. Noteworthy results of studies of Ukrainian scientists. Thus, Svitlana O. Sysoieva and Kateryna P. Osadcha have explored the possibilities of virtual, augmented and hybrid reality for the use of remote technologies at higher educational institutions [17]. Halyna V. Tkachuk outlined features of unique mobile content as augmented reality at the level of perspectives, advantages and disadvantages [18]. Maiia V. Marienko [15] and Mariya P. Shyshkina [13] considered augmented reality as a component of a cloud-oriented environment. Oleksandr V. Syrovatskyi [16], Serhiy O. Semerikov [9], Yevhenii O. Modlo [10], Yuliia V. Yechkalo [21], and Snizhana O. Zelinska [22] have characterized software for designing augmented reality in the preparation of future computer science teachers.

The analysis of the outlined works shows that modern authors highly appreciate the relevance of the introduction of augmented reality technologies in the educational process. Such activities are aimed at increasing students' motivation for learning, improving the quality of assimilation of information due to the variety and interactivity of its visual presentation, etc.

It is worth to mention about researches about forms, methods and conditions of using augmented reality when teaching physics in higher education (Tetiana V. Hruntova [5], Andrey V. Pikilnyak [5], Andrii M. Striuk [5], Yuliia V. Yechkalo [5]), in the study of chemical disciplines (Oksana M. Markova [12], Yevhenii O. Modlo [12], Pavlo P. Nechypurenko [11, 12], Tetiana V. Selivanova [8, 11], Ekaterina O. Shmeltser [12], Tetiana V. Starova [8, 11], Viktoriia G. Stoliarenko [12], Anna O. Tomilina [11], Aleksandr D. Uchitel [11]), geography (Elizabeth FitzGerald [4]), as well as in the educational space of the secondary school (Artem I. Atamas [14], Zhanna I. Bilyk [14], Viktoriia L. Buzko [1], Alla V. Bonk [1], Olexandr V. Merzlykin [7], Viktor B. Shapovalov [14], Yevhenii B. Shapovalov [14], Iryna Yu. Topolova [7], Vitaliy V. Tron [1, 7], Aleksandr D. Uchitel [14]).

We also distinguish the principles, approaches and working conditions of virtual laboratories. Thus, research on the application of Proteus simulation software in the teaching of electronic information specialty (Zhong-jian Cai [2] and Shi-bin Tong [2]) was carried out. Research on the application of simulation bench in experimental teaching of electrical engineering and electronics (Rongli Wang [19], Xiaojing Li [19] and Hongyue Liu [19]) is

presented. A softwar-in-the-loop approach for automation and supervisory systems education (Antonio José Calderón [3] and Isaías González [3]) is considered. The PI-based implementation for modeling and simulation of the continuous-time LTI system and its Matlab-Simulink-based application (Zong-Chang Yang [20]) are outlined.

The purpose of this article is to use Proteus virtual environment as augmented reality in the training of future IT professionals.

3 Research methodology

The achievement of the goal of the research was facilitated by the use of a set of appropriate methods: scientific literature analysis in order to establish the state of elaboration of the problem under study, determination of the categorical and conceptual apparatus of the research; synthesis, generalization, systematization for theoretical substantiation and practical elaboration of research problem, including playback in the simulator environment of work of adders; modelling method for visualization of physical processes; empirical: diagnostic (conversation, content analysis, testing) to track the dynamics of professional training of students; a pedagogical experiment to prove the effectiveness of using the Proteus virtual environment; mathematical methods (McNemar's test) to assess the significance of improvements on the results of experimental work.

The research was performed within the framework of the complex scientific theme of the Department of Computer Science and Mathematics of Borys Grinchenko Kyiv University "Theoretical and practical aspects of the use of mathematical methods and information technologies in education and science" (SR No. 0116U004625) and the scientific topic of Department of Informatics of Sumy State Pedagogical University named after A. S. Makarenko "Development of intellectual skills and creative thinking of pupils and students in the study of mathematics, physics, computer science" (SR No. 0112U003078).

We have used the experience of teaching "Basics of Microelectronics" and "Computer Architecture", the study of which involved the involvement of specialized tools to model the work of individual components of the computer system.

4 Results and discussion

One of the major problems of professional training of future IT professionals is the low level of students' motivation to study. As noted by scientists [16, 17], it is possible to increase students' interest in learning

through updated forms and methods of the educational process, in particular those based on the use of information technologies, first and foremost, augmented reality. The experience of professional training of IT specialists shows that the existing level of psychological, methodological training of students and teachers for use in the augmented reality in educational process, as well as the corresponding technical equipment in the vast majority of educational institutions do not meet the requirements of today. At the same time, we believe that the active use of augmented reality in the educational process is only a matter of time.

There are many approaches to using augmented reality technology in education today. Such mobile learning systems are conventionally divided into three main areas by modern researchers [8]:

1. 3D image rendering for visual presentation of training material.

2. Recognition and marking of real objects. Such capabilities make it possible to implement mobile, space-oriented learning systems.

3. Interaction of a virtual object built by a computer (smartphone) with a person in real time.

These directions of augmented reality help students through simulations and models to better understand the course material, create and manage tasks, evaluate, comment, and organize effective communication with teachers and other students.

To implement augmented reality technology in the learning process can be used:

1. Tutorials that contain special augmented reality objects; special mobile applications, printed illustrations are transformed into animated, three-dimensional animated objects that can perform certain movements and be accompanied by sound information.

2. Educational games. Best practice shows that in many cases the information provided in the form of interactive games is positively received by the students, activates motivation to participate in the process and promotes the development of learning materials.

3. Simulation of objects and situations. Creating graphic objects and constructing certain situations that can be used to learn the material, saves considerable material and financial resources, as well as conduct practical classes directly in classes.

4. Skills training supplements. When teaching certain subjects, it is possible to create content in augmented reality format, which can be

used as a tool for acquiring certain professional skills. It can be used by students for self-testing [6].

To date, the main technical advantages of using AR and VR in education are highlighted in scientific sources. Consider them in detail.

Start with clarity. Indeed, 3D graphics make it possible to reproduce detail of even the most complex processes invisible to the human eye, and it is also possible to increase the level of detail. Virtual and augmented reality allows you to reproduce or simulate almost any process or phenomenon. Next one is a security. The practical aspects of any activity can be safely practiced on a virtual or augmented reality device. In terms of engagement, AR and VR technologies make it possible to simulate any mechanics of action or behavior of an object, to solve complex mathematical problems. Among the benefits are focusing, so space modelled in VR can be easily viewed in a 360 degree panoramic range without being distracted by external factors, and etc.

Equally important are the organizational benefits of using augmented reality in education: the integration of different disciplines and visualization of the learning process; construction of an open system of education that provides an opportunity for each student to create a personal learning trajectory; expanding the boundaries of study through the use of study materials from leading universities in the world; improving the quality of students' independent work; increasing motivation for learning.

The analysis of real practice shows that in the field of modelling of physical processes as a popular example of augmented reality is the Proteus Physical Laboratory.

Scientific sources analysis for the training of IT specialists allows us to say that the fulfilment of professional tasks in the field of IT necessitates mastering the architecture of the computer and the basics of microelectronics, which is not trivial for many reasons, one of them is the inability to see the features of circuit design, implemented at the micro level. At the same time, acquaintance with them is the basis not only for understanding the processes that take place inside the computer system, but also for finding new, non-existing, approaches in the organization of its work.

Visualization of circuit solutions implemented at the micro level is possible based on a simulation method that is based on the replacement of real objects by their conditional samples. Modelling can describe the structural components of the object, their interaction and performance. With a well-constructed model, you can estimate the state of the object, predict the consequences.

Since all the processes that take place in the middle of the computing system are based on the operation of physical devices, it is advisable to perform their simulations in a physical process simulator environment. Among the variety of software (Electronics Workbench, LabVIEW, Micro-Cap, NI Multisim, Proteus, etc.), we choose Proteus, where you are able to create wiring diagrams, edit the parameters of their components, use different virtual devices (generators, meters, etc.), which are implemented as mathematical models that simulate the operation of various functional nodes.

The computer tools available in Proteus, in our view, can best visualize the temporal and spectral characteristics of the signals, the transient and transmitting characteristics of the four-pole, the logical states of the inputs and outputs of the digital elements, including the demonstration of the operation of the adders — nodes of the computing system determine the sum of two operands (a digital scheme that performs adding numbers).

No computer system can be built without a central processor, which is responsible for responding to external and internal events. This response is made possible by the correct and interconnected work of a large number of basic elements. In modern processors, both arithmetic and logic operations are performed by ALU (Arithmetic Logic Unit), a device whose operation is based on combinatorial elements. It should be noted that the adder is the basis for constructing hardware solutions of arithmetic and logic operations: subtraction, multiplication, division, comparison, bit operations, etc. That is why we consider it important to be aware of the ideas that underpin the work of summary devices.

The group of adders include:

1. module adder 2;
2. half adder;
3. complete adder.

The adder of Module 2 differs from the half adder only by the presence of the transfer output, and from the total adder by the presence of the transfer output for the higher digit and the transfer input from the lower digit. These inputs and outputs are designed to build a multi-bit adder based on a single-bit adder.

Below is a demonstration of the work of adders in the Proteus environment.

1. *Modulator adder 2*

Modulator 2 is often called an *XOR* element because its operation is based on the use of the logic function "exclusive OR" — the result will be false if and only if its two input elements are the same.

$$Y = \left(A\overline{B} \vee B\overline{A} \right) = (A \oplus B)$$

The simplest demonstration of its features in the Proteus environment is by "manually" controlling the state of the appendices A and B with the keys (Fig. 1). The status of the output is monitored by the color of the indicators.
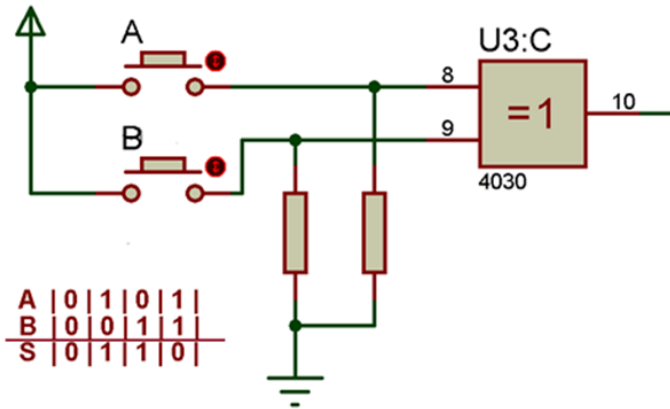
Fig. 1. The truth table for the states of the module adder 2 and a diagram of its construction in Proteus

2. *The half adder*

The half adder is slightly more complicated in structure: it calculates, in addition to the sum, also the state of the CH (Carry High) signal of the transfer (the transfer signal to the next (higher) category, if such transfer is required).

The truth table for the half adder is shown in table 1.

It is easy to notice that the state "1" at the output of CH is a conjunction of the additives $A * B$, and the state of the output of the sum S is the same as that of the module 2. We use this feature to build a circuit of element connections for constructing a half adder in ISIS Proteus environment (Fig. 2).

Table 1. Truth table for the half adder

Inputs	A	0	1	0	1
	B	0	0	1	1
Outputs	S, the sum	0	1	1	0
	CH, transfer signal to the higher category	0	0	0	1
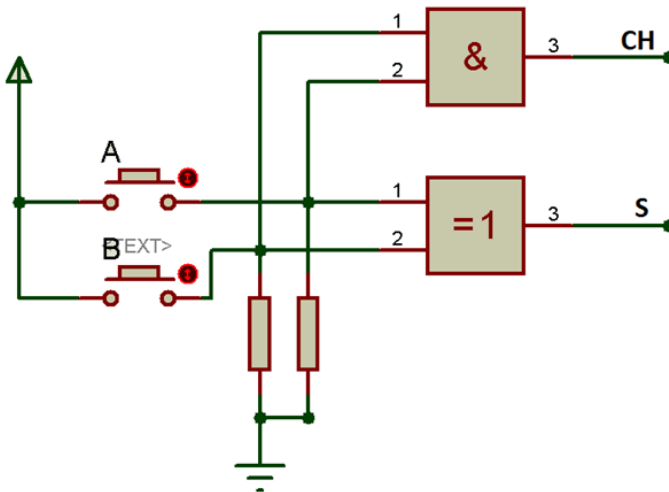
**Fig. 2.** Schematic of element connections for constructing a half adder

3. *Complete adder*

The complete adder is characterized by the presence of three inputs, which serve the same digits of two additions and the transfer signal from the lower digit, and two outputs: one realizes the arithmetic sum of the module 2 in this category, and the other — the transfer signal to the next (higher) category. Note that such adders are oriented to positional numerical systems.

Let us construct a truth table for him, supplementing Table 1 with another line of inputs — the transfer signal from the lower order — CL (Table 2). This will extend Table 1 to eight columns, of which the first four (1..4 for which SL = 0) are already implemented hardware.

Table 2. The truth table for the complete adder

	Column number	1	2	3	4	5	6	7	8
	A	0	1	0	1	0	1	0	1
Inputs	B	0	0	1	1	0	0	1	1
	$A \oplus B$	0	1	1	0	0	1	1	0
	CL(in)	0	0	0	0	1	1	1	1
Outputs	$S = (A + B) \oplus CL$	0	1	1	0	1	0	0	1
	CH(out)	0	0	0	1	0	1	1	1
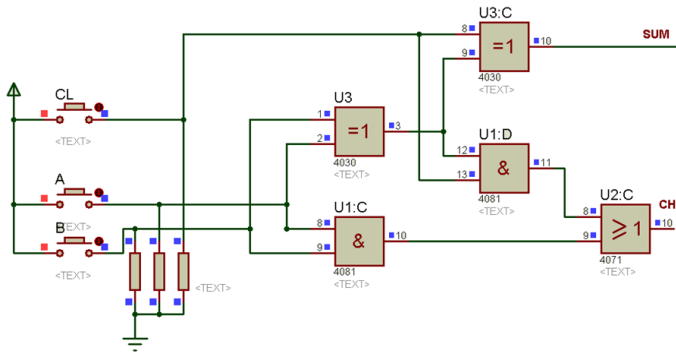
Fig. 3. Simulation of the complete adder in Proteus
(inputs: A = 0, B = 0, CL = 0, outputs: S = 0, CH = 0)

Consider the formation of output signals: sums — S and transfer to the highest digit — CH. To simplify the considerations, add the table to the auxiliary row "A + B". It is obvious that $S = (A + B) \oplus CL$, so we use the element *XOR* (U3: C, Fig. 3) to generate the sum signal. Generate a carry signal using the Perfect Disjunctive Normal Form:

$$CH = \left(A \wedge B \wedge \overline{CL}\right) \vee \left(A \wedge \overline{B} \wedge CL\right) \vee \left(\overline{A} \wedge B \wedge CL\right) \vee (A \wedge B \wedge CL).$$

Using the rules of logic algebra, we obtain:

$$CH = (A \wedge B) \vee (A \oplus B) \wedge CL.$$

The forming element $(A \wedge B)$ is already involved (U1: C), we supplement the scheme with the element *AND* (U1: D) to form the product $(A \oplus B) * C$ and form a transfer signal with the element *OR* (U2: C, Fig. 3).

Let's show the implementation of the complete adder in Proteus. The status of the outputs can be easily traced by logical indicators (Fig. 3–5).
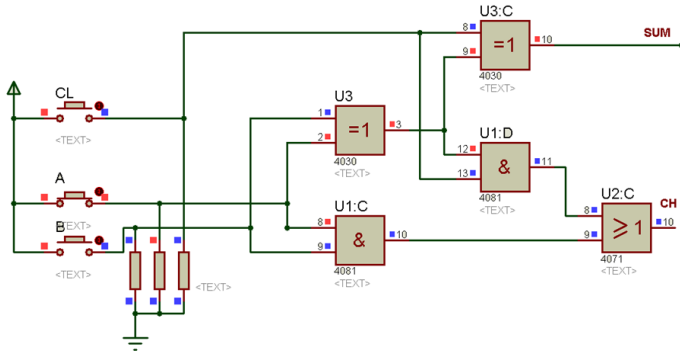
Fig. 4. Simulation of the complete adder in Proteus
(inputs: A = 1, B = 0, CL = 0, outputs S = 1, CH = 0)
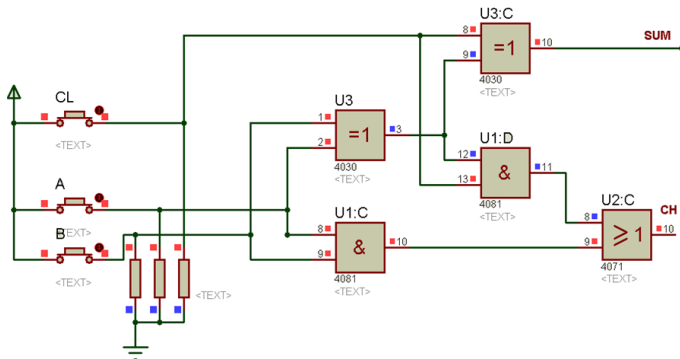
Fig. 5. Simulation of the complete adder in Proteus
(inputs: A = 1, B = 1, CL = 1, outputs S = 1, CH = 1)

The simulation confirms the correct operation of the circuit for all eight input variants.

The use of the Proteus virtual environment for simulation of the work of the adders took place on the basis of Borys Grinchenko Kyiv University and Sumy State Pedagogical University named after A. S. Makarenko during 2017–2019. Until 2017, the study of the basics of microelectronics was

only at a theoretical level. In order to determine the appropriateness of using computer simulation in the training of IT professionals and computer science teachers, we conducted a double survey of students' attitudes toward conducting a laboratory workshop. The following question was asked: "Do you need to use computer simulation to study the basics of microelectronics?" ("Yes" and "No" answers).

Of the 58 students who participated in the experiment, a random sample of 20 people was randomized. The results of the dual survey responses were evaluated according to the McNemar's test, which provides a scale of 1 or 0 ("Yes" or "No", respectively).

Under these conditions, it is possible to determine the impact on students' perceptions of computer modelling as a means of mastering the basics of microelectronics. The results of the survey are given in Table 3.

Table 3. Results of the double poll

the first poll	the second poll		
	Yes	No	The sum
Yes	A=2	**B=3**	5
No	**C=12**	D=3	15
The sum	14	6	20

Tested hypothesis H_0: computer simulation does not affect the learning of microelectronics basics according to the subjective estimates of students. According to the results obtained ($B < C$), an alternative hypothesis H_1 is built: computer simulation has a positive effect on the learning of microelectronics. The McNemar's test is used for $n = B + C = 15 < 20$, so the value of the statistics is $T = 3$ (least of B and C). The probability of occurrence of values not exceeding T is 0.018, which, in turn, is less than half the established significance level of 0.05. This means rejecting hypothesis H_0 and accepting H_1. Therefore, according to the results of the experiment, we can conclude that it is advisable to use the Proteus virtual environment as augmented reality in computer simulation (the work of the adders described in the article) for students to study the basics of microelectronics.

In addition, an analysis of the results of a survey of teachers (12 people) and students (58 people) on the use of augmented reality in the educational process makes it possible to find out the following. According to the

respondents, the use of augmented reality in education significantly increases the interest of students. 93% of respondents answered this question in the affirmative. According to 82% of respondents, the use of augmented reality can improve the level of competence formation. For example, students and teachers have often referred to the following competencies: mastering system information and basic knowledge of computer graphics, the ability to build graphic objects, including three-dimensional ones, and create computer animation to perform professional tasks effectively; knowledge and understanding of the architecture and software of high-performance parallel and distributed computing systems, numerical methods and algorithms for parallel structures. In addition, according to the majority of experts (87%), the educational process has significantly succeeded in diversifying innovative forms of work with the audience. Yes, a series of master classes was implemented within the framework of the activities of the student scientific group "Computer Systems", which operates at Borys Grinchenko Kyiv University.

5 Conclusions

1. It is established that the application of augmented reality as an innovative technology of students' training comes in the following directions: 3D image visualization; recognition and marking of real objects; interaction of a virtual object with a person in real time. The main advantages of using AR and VR in the educational process are highlighted: clarity, ability to simulate processes and phenomena, integration of educational disciplines, building an open education system, increasing motivation for learning, and etc.

2. It has been found that in the field of physical process modeling, the Proteus Physics Laboratory is a popular example of augmented reality. Using the Proteus environment allows to visualize the functioning of the functional nodes of the computing system at the micro level. This is especially important for programming systems with limited resources, such as microcontrollers. The experiment found that computer modelling had a positive effect on the acquisition of microelectronics.

3. Research perspectives include the following: identifying effective augmented reality forms, methods, and tools that can be used in the professional training of future IT professionals.

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Використання віртуального середовища "Proteus" для підготовки майбутніх фахівців у галузі інформаційних технологій

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Анотація. На основі огляду літератури було встановлено, що використання доповненої реальності як інноваційної технології навчання студентів відбувається у таких напрямках: 3D-рендерінг зображень; розпізнавання та маркування реальних об'єктів; взаємодія віртуального об'єкта з людиною в режимі реального часу. Висвітлено основні переваги використання доповненої та віртуальної реальності у навчальному процесі: чіткість, вміння моделювати процеси та явища, інтеграція навчальних дисциплін, побудова відкритої системи освіти, підвищення мотивації до навчання тощо. Виявлено, що в цій галузі моделювання фізичного процесу, лабораторія фізики "Proteus" є популярним прикладом доповненої реальності. Використання середовища "Proteus" дозволяє візуалізувати роботу функціональних вузлів обчислювальної системи на мікрорівні. Це особливо важливо для систем програмування з обмеженими ресурсами, наприклад для мікроконтролерів у процесі підготовки майбутніх фахівців у галузі інформаційних технологій. Експеримент проходив у Київському університеті імені Бориса Грінченка та Сумському державному педагогічному університеті імені А. С. Макаренка зі студентами спеціальності "Інформатика" (галузь знань — середня освіта (інформатика)). Було встановлено, що комп'ютерне моделювання позитивно впливає на оволодіння основами мікроелектроніки. У статті окреслено шляхи подальших наукових досліджень щодо обґрунтування, розробки та експериментальної перевірки форм, методів та доповненої реальності, які можуть бути використані у професійній підготовці майбутніх фахівців у галузі інформаційних технологій.

Ключові слова: доповнена реальність, віртуальне середовище, "Proteus", підготовка, майбутні фахівці у галузі інформаційних технологій.