

2. ПЕДАГОГІЧНИЙ ТА ПСИХОЛОГІЧНИЙ ДОСВІД



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TESTING OF THE COURSE “BASICS OF ELECTRONICS” OF THE TRANSDISCIPLINARY KNOWLEDGE BASE OF THE VIRTUAL STEM CENTRE OF THE “JUNIOR ACADEMY OF SCIENCES OF UKRAINE”

Summary.

The implementation of the STEM approach in education is important for the development of the competitiveness of the national economy and human capital. STEM disciplines can be integrated at four levels. Electronics plays an important role in the implementation of the STEM approach in secondary science education. The problems and perspectives of teacher training for STEM education, especially in the implementation of the engineering component, are highlighted. Examples of the use of computer modelling in the teaching of electronics and the need for teacher training are considered. The attitude of teachers to the course “Fundamentals of Electronics”, developed on the basis of the Virtual STEM-Centre of the “National Centre Junior Academy of Sciences of Ukraine”, is investigated. The thematic sections of the course include lectures and practical classes adapted to distance and blended learning. The acquired skills can be used for laboratory work, including the use of Arduino and mobile applications for experiments at home. The course also covers new interdisciplinary areas such as chemotronics and bioelectronics, expanding the opportunities for teachers and students. The course was tested during the All-Ukrainian Physics School and the Regional STEM School Seminar; which confirmed the high interest of the participants and the effectiveness of the teaching methods.

Keywords: STEM education; electronics; distance learning; Arduino; modelling environment; transdisciplinarity.

Strengthening the role of the STEM approach in education is an important area of innovation in education that responds to the needs of the economy and society in order to increase the competitiveness of

the national economy and the development of human capital [1; 2]. For curriculum development and didactic purposes, four levels of STEM integration are traditionally distinguished [3; 4]:

- disciplinary: concepts and skills are taught separately in each discipline.

- multidisciplinary: concepts and skills are studied separately in each discipline, but within a common theme;

- interdisciplinary: closely related concepts are studied and relevant skills developed in two or more disciplines;

- transdisciplinary: knowledge and relevant skills from two or more disciplines are applied to solve real-world problems.

An organic didactic platform for the integration of STEM subjects at the interdisciplinary and transdisciplinary levels is electronics, whose knowledge base is mainly physics and mathematics. This discipline is one of the main branches of engineering, in which scientific and mathematical tools are used to design systems based on specifications, to optimise the use of materials and energy, and to analyse the safety and reliability of products [5].

Without electronic devices and systems, the main elements of which are modern semiconductor devices, it would be virtually impossible to develop science and technology. Electronics are now used in all sectors of the national economy and in the everyday life of a modern person, so it is important to attract new specialists in this field, and knowledge of its basics is useful regardless of profession. However, in order to create and use electronic devices and systems, it is important not only to know their external characteristics and design, but also to have a sufficient understanding of the physical principles of their operation.

For the effective development of STEM education, including the use of electronics, it is necessary to: develop scientific and methodological support and introduce modern teaching aids; train and improve the skills of scientific and pedagogical staff; expand the network of regional STEM centres/laboratories; conduct scientific and applied research; analyse the process of development and dynamics of STEM education, identify problems and predict further trends in the implementation of STEM education [2].

The need for teachers to master interactive teaching methods, particularly with the use of computer simulation environments, is a pressing pedagogical issue in the context of STEM education [6]. Examples of the possible use of computer modelling in the study of electronics include [5]:

- Demonstration and verification of theoretical laws such as Ohm's law and Kirchhoff's laws for calculating currents and voltages in electrical circuits;

- Comparing the behaviour of real and ideal (only available in simulations) electronic components;

- Study of electronic circuits or processes that are difficult to understand and analyse theoretically in secondary school, such as unstable circuits, noise effects, behaviour of non-linear circuits, or spectral analysis of AM and FM radio signals.

Research suggests that most science teachers have a more or less established understanding of the STEM concept. A survey of teachers conducted in [7] showed that the majority of them see the engineering component of STEM as a bridge between science and mathematics, with educators leaning towards inter-, multi- and transdisciplinary STEM perspectives rather than disciplinary ones. At the same time, as shown in [8; 9], teachers' readiness for STEM education is not yet high. In particular, a study of the readiness of mathematics and science teachers, based on their understanding of each STEM component, revealed difficulties with the engineering component [8].

In [9], a study was conducted on the readiness of physics teachers to implement STEM education. The results of the survey showed that more than half of the respondents had not yet tried to implement the STEM approach to teaching, although more than 60 % of the respondents were inclined to the desirability of introducing STEM education at secondary and high school levels, and more than 80 % considered the introduction of STEM education in distance learning to be possible or limited. All teachers surveyed expressed interest in STEM education, which indicates their desire to learn and improve their teaching skills in order to integrate STEM education, especially in developing and implementing tasks. They also consider STEM important for themselves and their pupils. Most of them know the terminology of STEM education and can identify the place of projects in the curriculum according to the topic, but they do not have convincing experience in conducting such lessons.

In [10], the current practice of three teachers in teaching physics was examined for the possibility of implementing a STEM approach. The research showed that although the teachers had a clear theoretical understanding of the STEM concept, in practice they encountered difficulties of various origins. For example, all three teachers understood that the STEM approach involves tasks for students in the form of independent creative solutions to a particular problem that may occur in reality, but continued to use tasks that were carried out according to specific instructions. According to the authors, physics teachers should be supported in translating their own understanding of the STEM concept into real classroom practice. The authors of [11] also concluded that the level of training of physics teachers is insufficient, even against the background of positive internal and external motivation.

Work [12] notes that teaching students using STEM technologies increases the level of skills in

formulating problems, searching for their solution, conducting experimental research, processing the results of the experiment, which generally ensures the formation of interdisciplinary experimental skills. At the same time, a blended learning approach is optimal for STEM education, as students need time to complete independent tasks. In addition, its use in the educational process is known to intensify the learning process by providing constant access to educational resources anytime and anywhere. The STEM approach is a powerful tool for building the personalities of an information society capable of lifelong self-improvement.

This also makes STEM essential in the context of pandemics and challenges of various origins, such as martial law. The same study found that students were most interested in laboratory work using STEM tools, but about 50 per cent of respondents said they had difficulty processing the results of experiments. The authors recommend conducting frontal laboratory work with the use of digital measuring complexes, and for students to conduct experiments independently at home, they should use improvised materials and a smartphone with applications such as **Phyphox** (<https://phyphox.org/>).

In Ukraine, according to the current curriculum, phenomena related to the movement of charged particles in a vacuum, gases and solids, as well as information about vacuum and semiconductor electronic devices, are studied to a limited extent in the school physics course in grades 8 and 11. Existing textbooks on electronics are mainly aimed at students in higher education institutions, both electrical [13] and non-electrical [14].

Therefore, the development of methodological support and training of teachers in the use of modern teaching tools for the implementation of STEM education is an urgent task for our country. For the study of electronics in extracurricular education, the **MANLab** (<https://manlab.science/>) has developed the course “**Fundamentals of Electronics**” for students in grades 8–11 (<https://imzo.gov.ua/osvita/pozashkilna-osvita-ta-vihovna-robota/navchalni-programi/doslidnitsko-eksperimentalniy-napryam/>). This course is the result of the systematisation of numerous pedagogical and methodological developments [15] by the MANLab staff.

The aim of the study is to investigate the attitude of teachers to the course “Fundamentals of Electronics” of the transdisciplinary knowledge base of the **Virtual STEM Centre of the “Junior Academy of Sciences of Ukraine”** (<https://stemua.science/%D0%94%D0%BE%D1%81%D0%BB%D1%96%D0%B4%D0%BD%D0%B8%D1%86%D1%8C%D0%BA%D1%96%D1%80%D0%BE%D0%B1%D0%BE%D1%82%D0%B8/>).

The course “Fundamentals of Electronics” consists of 11 thematic sections, each of which includes lectures and practical classes that logically

complement each other. The practical part of the course is partly adapted for distance and blended learning and does not require the use of sophisticated scientific equipment. We have systematised the basic knowledge, skills and practical abilities that the course curriculum provides and that can be used in the future to solve problems based on the STEM approach (*Fig. 1*).

It should be noted that the skills of working with modelling and measurement computer environments can be used by teachers to carry out educational demonstrations and by students to carry out laboratory and research work in physics in the context of distance learning. The ability to process experimental data using mobile applications such as Arduino Science Journal and Phyphox will allow students to carry out laboratory work at home.

Knowledge of microcontrollers will be consolidated by creating a digital measurement complex based on the latest **Arduino Nano 33 BLE Sense** platform (<https://docs.arduino.cc/hardware/nano-33-ble-sense/>), which can be used in educational research not only in electronics, but also in physics, chemistry and biology. In addition, the course’s practical work allows students to acquire skills that may be needed in real life, such as working with measurement equipment, reference books, radio installation and soldering.

Among other things, the “Fundamentals of Electronics” course provides for the study of new areas of knowledge related to electronics, such as chemotronics and bioelectronics, creating additional interdisciplinary links with chemistry and biology.

Thus, mastering the proposed course “Fundamentals of Electronics” is useful for both teachers and students in extra-curricular and optional classes, as it significantly improves the quality of science studies due to the multidisciplinary inherent in this course.

The course was first tested in March–June 2022 as part of the All-Ukrainian Physical School in a remote format under martial law. Both students in grades 8–11 and teachers participated in the online lessons. The use of a simulated computer environment during the lessons made it possible to improve the learning of the educational material and also aroused the interest of the teachers in further mastering the work with it. The most interesting topics of the course for both students and teachers were “Radio Communications. Modulation and Detection”, “Digital Engineering”, “Chemotronics and Bioelectronics”. During the Digital Engineering lesson, issues related to the Arduino Nano 33 BLE Sense platform were addressed and examples of methods for conducting laboratory and educational research using it were given. The interest of the participants in the creation and use of such a CEC is confirmed by a significant increase in the number of additional questions about

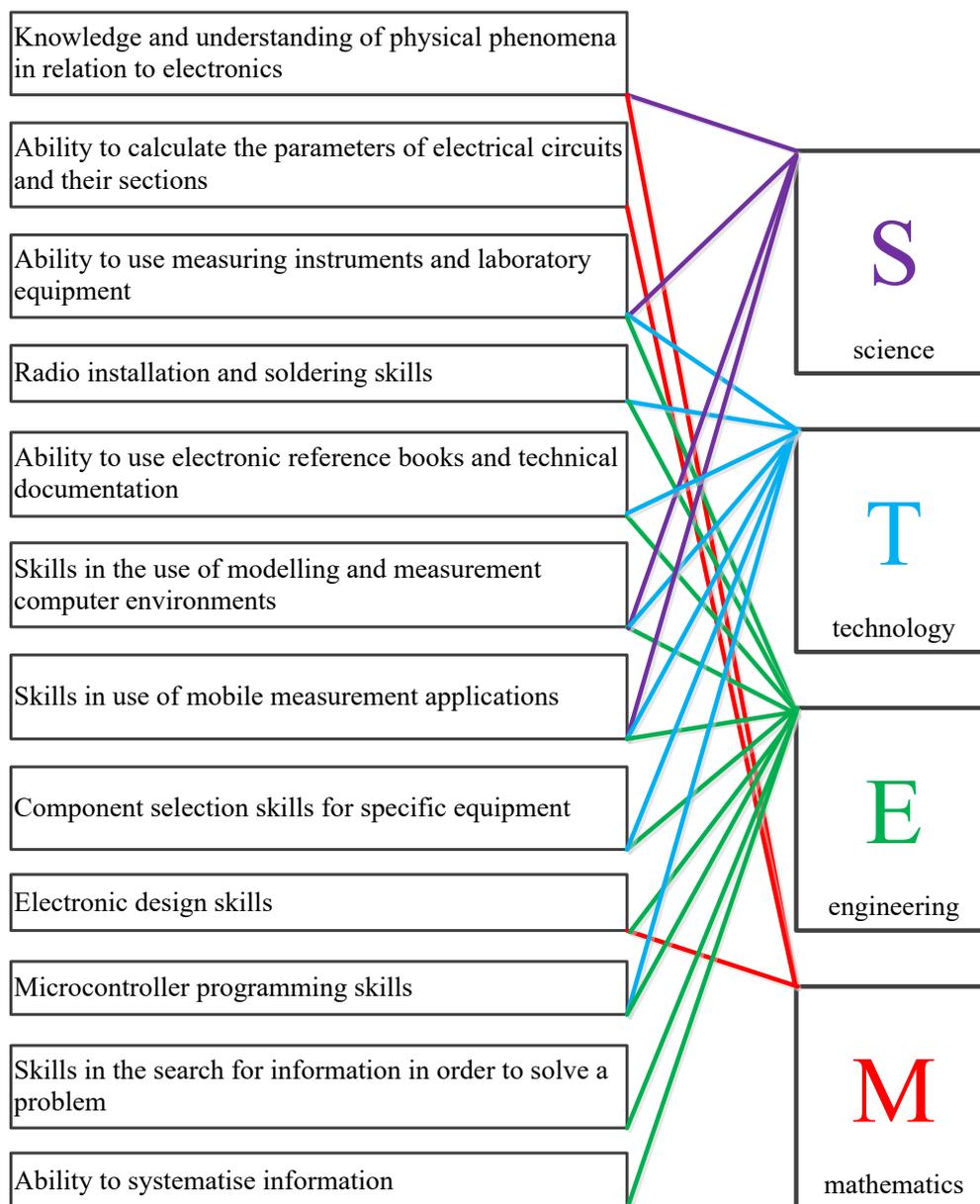


Fig. 1. Basic knowledge, skills and practical abilities developed in the Fundamentals of Electronics course

the possibilities of adapting this platform for certain experiments.

Further testing of the methods of the course “Fundamentals of Electronics” with the participation of teachers of physics, astronomy, mathematics as well as leaders of extracurricular clubs took place on 30 September – 1 October in Chernivtsi as part of the regional seminar “Scientific STEM School for Teachers”. During the event the following activities took place:

– Lecture classes: “General Information. Semiconductor electronic components”, “Amplifiers”, “Digital technology”;

– Laboratory works: “Study of an oscillating circuit”, “Study of an electric circuit with a semiconductor diode”, “Modelling and study of an amplifier” and “Digital measurement complex based on Arduino Nano 33 BLE Sense”.

The labs were carried out using a computer simulation environment and their topics were chosen considering the fact that the school physics course includes a training demonstration of damped oscillations in a resonant circuit and the lab “Study of an electric circuit with a semiconductor diode” [14; 15]. The third lab allows to consolidate the skills of working with the modelling computer environment, and the model created in it can be used by teachers to explain to students the amplification properties of a transistor, especially in distance learning. For the fourth laboratory activity, the participants were divided into groups of 2–3 people, each equipped with Arduino Nano 33 BLE Sense platforms, breadboards and autonomous power supplies to create a digital measurement complex.

In total, 11 teachers participated, including 5 males aged 25 to 62 years and 6 females aged 38 to 65 years, whose data are summarised in *Table 1*.

Table 1

Attributes of participants
(CG – club leader; Ph – physics; A – astronomy; M – mathematics)

№	Attributes	Participant No.										
		1	2	3	4	5	6	7	8	9	10	11
1	Age	25	27	34	50	62	38	40	42	51	58	65
2	Gender	M	M	M	M	M	F	F	F	F	F	F
3	Subjects	CG	Ph, A	Ph, A, M	Ph, A							

At the end of the seminar, participants were asked to fill in a questionnaire which included the following evaluation questions (“Rate from 1 to 5, where 1 is the least interesting, 5 is the most interesting”):

– Which part of the “Fundamentals of Electronics” course did you find most interesting?

– Would you like to take the full “Fundamentals of Electronics” course? If so, which of the sections of the full course that you did not study during the event would be of interest to you (Fig. 2)?

– Which labs did you find most interesting?

Do you find it useful to use the Multisim simulation environment or similar in the educational process?

Do you plan to use the Multisim simulation environment or similar in your future work?

Do you consider it useful to use digital measurement complexes on Arduino platforms in the educational process?

Do you plan (or do you wish) to use digital measurement systems on Arduino platforms in your future work?

What is your own progress after completing the course? Please rate from 1 to 5, where 1 – I have not learnt anything new, 5 – I have learnt new useful knowledge and skills.

№	Section Title	Mark
1	Electrical Signals. Radiation and waves	
2	Electric circuits. Passive electronic components. Resistors	
3	Alternating current rectifiers.	
4	Generators. Feedback	
5	Radio Communication. Modulation and detection	
6	Chemotronics and Bioelectronics	

Fig. 2. An example of a question in the questionnaire

As can be seen from Table 2, the topic ‘Digital Technology’ attracted the most interest – 52 out of 55 points – which is in line with the results of the first course test.

Table 2

Results of the participants’ assessment of the level of interest in the lecture topics

№	Topic name	Participant No.											Sum
		1	2	3	4	5	6	7	8	9	10	11	
1	General Information. Semiconductor Electronic Components	4	3	5	4	4	5	5	5	5	5	5	50
2	Amplifiers	4	3	5	5	5	4	5	4	4	4	3	46
3	Digital Technology	5	5	5	5	5	5	5	5	5	3	4	52

When asked about their willingness to take the full “Fundamentals of Electronics” course, 10 out of 11 respondents gave a positive answer.

Table 3 shows that the most interesting topics for further study of basic electronics for the participants were “Electrical signals. Radiation and Waves” and “Radio Communication. Modulation and detection”.

Table 3

Results of the participants’ assessment of the level of interest in further study of the fundamentals of electronics

№	Topic title	Participant No.											Sum
		1	2	3	4	5	6	7	8	9	10	11	
1	Electrical signals. Radiation and waves	3	4	5	5	3	4	5	5	4	5	4	47
2	Electric circuits. Passive electronic components. Resistance	4	2	5	5	4	4	5	4	3	4	3	43
3	AC rectifiers	3	5	5	5	5	3	5	3	3	4	3	44
4	Generators. Feedback	4	2	5	5	4	5	5	3	4	4	5	46
5	Radio Communication. Modulation and detection	5	5	5	4	3	4	4	5	4	5	3	47
6	Chemotronics and Bioelectronics	2	5	3	3	4	5	3	4	5	5	5	44

The usefulness of using the Multisim simulation environment was rated by the participants with 49 points and the CEC on the Arduino Nano 33 BLE Sense was rated with 51 out of 55 points (Table 4).

Table 4

Results of the participants' assessment of the level of interest in the laboratory topics

№	Topic title	Participant No.										Sum	
		1	2	3	4	5	6	7	8	9	10		11
1	Study of an oscillating circuit	4	4	4	3	5	4	5	4	4	4	5	46
2	Study of an electric circuit with a semiconductor diode	4	4	5	4	5	4	5	5	4	5	5	50
3	Modelling and study of the amplifier	4	3	5	5	5	4	5	4	5	5	2	47
4	Digital measurement complex on Arduino Nano 33 BLE Sense	5	5	5	5	5	5	5	5	5	5	2	52

When asked about further use of the modelling computer environment, 9 out of 11 respondents answered “yes”, one respondent answered “maybe”, and 10 out of 11 respondents confirmed their desire to use digital measurement complexes in their future work on Arduino platforms. At the same time, one of them noted that he was already using them, but that this was the first time he had seen the Arduino Nano 33 BLE Sense platform, and 4 other respondents noted that they wanted to use them, but had not yet had the opportunity.

Workshop participants rated their own progress at 52 out of a possible 55 points. At the end of the questionnaire, one participant expressed gratitude for the opportunity to develop at a difficult time for the country, and another added the comment “New super useful information and practical skills” when assessing his own progress.

The results of the pilot project of the course “Fundamentals of Electronics” indicate the need for it among teachers of physics, astronomy and mathematics, as well as among leaders of extracurricular clubs, which in turn confirms the relevance and necessity of further didactic research. The high level of interest in studying topics related to waves, radiation and radio communication, on the one hand, and the fact that physics and astronomy are usually taught by the same person, on the other, make the development of such a transdisciplinary field as radio astronomy relevant to STEM education. A convincing indicator of the usefulness of seminars, workshops and in-service training courses with electronics curricula is the high marks given by teachers to their own progress after completing these events, offered by the National Centre “Junior Academy of Sciences of Ukraine”.

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АПРОБАЦІЯ КУРСУ «ОСНОВИ ЕЛЕКТРОНІКИ» ТРАНСДИСЦИПЛІНАРНОЇ БАЗИ ЗНАТЬ ВІРТУАЛЬНОГО STEM-ЦЕНТРУ МАЛОЇ АКАДЕМІЇ НАУК УКРАЇНИ

Анотація.

Упровадження STEM-підходу в освіті є важливим для розвитку конкурентоспроможності національної економіки та людського капіталу. STEM-дисципліни можуть бути інтегровані на чотирьох рівнях. Електроніка відіграє важливу роль у впровадженні STEM-підходу в навчанні природничих наук у середній школі. Висвітлено проблеми та перспективи підготовки вчителів до STEM-освіти, зокрема у впровадженні інженерного компоненту. Розглянуто приклади використання комп'ютерного моделювання в навчанні електроніки та необхідність підвищення кваліфікації педагогів. Досліджено ставлення викладачів до курсу «Основи електроніки», розробленого на базі віртуального STEM-центру Національного центру «Мала академія наук України». Тематичні розділи курсу охоплюють лекційні та практичні заняття, адаптовані до дистанційного і змішаного навчання. Набуті навички можуть бути використані для виконання лабораторних робіт, включаючи використання Arduino та мобільних застосунків для експериментів вдома. Курс також охоплює такі нові міждисциплінарні напрями, як хемотроніка та біоелектроніка, що розширює можливості для викладачів та учнів. Апробація курсу відбулася під час Всеукраїнської фізичної школи та обласного семінару STEM-школи, що підтвердило високий рівень зацікавленості учасників та ефективність навчальних методик.

Ключові слова: STEM-освіта; електроніка; дистанційне навчання; Arduino; моделювальне середовище; трансдисциплінарність.

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