QR Codes as an Educational Tool for Implementing the BYOD Approach in Physics Lessons

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***Abstract* - The integration of students' own computer means into the learning process can be solved within the implementation of the BYOD approach (Bring Your Own Device). One of the digital technologies used in education today that works in favor of the BYOD approach are the use of QR codes. The authors analyzed the practices of using the BYOD approach. Examples of the use of QR codes are given: the creation of information leaflets; organization of surveys, tests, web quests, and virtual exhibitions; expanding the content of textbooks; information support of objects of study, visualization and/or research of phenomena and processes. It is shown that the use of QR codes in physics lessons within the framework of the BYOD approach allows not only to solve educational goals but also to increase interest in learning, develop teamwork skills, and expand students' cultural horizons, that is, develop universal students' skills. Ukrainian resources for generating QR codes are provided. The results of an expert analysis of ways to use QR codes in teaching physics are presented. It was found that the most effective is the use of QR codes when organizing web quests and for the purpose of informational support of objects of physics study.**

***Keywords* - BYOD approach; QR code; digital technologies; teaching physics; ways of using QR codes; innovative educational approaches.**

I. INTRODUCTION

The need to involve IT in the organization and support of the educational process today is indisputable. A significant number of teachers in the world use digital technologies and tools to visualize educational material, organize surveys, keep electronic journals, etc. Many teachers use specialized software to conduct virtual experiments and model various processes or phenomena.

Ukrainian teachers, along with the use of multimedia, note that schools have problems with sufficient computers and students' access to them [1]. Only computer science lessons are held in computer classes. Other studies do not involve students' access to computer technology. This often leads to pupils using their mobile devices, which teachers do not like. Teachers note that young people actively use their digital means more for entertainment (social networks, games, surfing the Internet) and less for learning (finding the necessary materials for homework) [2].

After the pandemic, the usage of computers for distance learning became the norm. Teachers actively use Zoom, Google class, etc., but at the same time also note the active use of pupils' own mobile devices (and often not for educational purposes). The teachers believe that this reduces the cognitive activity of pupils.

This actualizes the contradiction between the spread of digital technologies among young people, the openness of young people to the use of mobile devices anywhere and anytime, and the limited ideas of teachers on how to use the activity of young people about their own mobile devices for educational purposes.

Traditional pedagogical approaches to the organization of the educational process increasingly do not satisfy the needs of both teachers and schoolchildren ineffective, intensive knowledge of the surrounding world. A traditional approach is focused on the formation of knowledge. This approach is authoritarian, as it lacks conditions for the manifestation of individual interests and creative abilities, and learning. The authors have analyzed the essence of the main approaches to teaching physics in Ukrainian schools. The authors focus on modern approaches, but to compare them with the traditional approach, they will also refer to the latter's principles (Table 1).

TABLE I. APPROACHES TO TEACHING PHYSICS IN SCHOOLS (SOURCE: MADE BY AUTHORS)

Approach	Characteristic
Traditional	Communication of ready-made knowledge to students. Learning by example. Inductive logic of presentation (from partial to general). Mechanical memorization. Survey methods on reproduction. External evaluation of results.
Interactive	Constant, active interaction of all participants in the educational process. The student and the teacher are equal educates. Simulation of life situations, use of role-playing games, and joint problem-solving based on the analysis of circumstances and the relevant situation.
Problem-centered	Creation of a problem situation and independent activity of students in solving it. Independent research work of students to solve a system of interrelated intra- and inter-subject

	educational problems.
Task-based	A list of general education skills and abilities is being formed. The system of problems should cover all the main phenomena, concepts, and laws, and the problems should be solved in order of increasing complexity so that each previous problem was a certain basis for solving the next one. Based on the teacher's analysis of the student's ability to solve the problem, a conclusion can be drawn about the understanding content of the relevant theoretical provisions.
BYOD approach	Involvement of students' IT and mobile devices (mobile phone, tablet, laptop) in the educational process for quick access to reference information, modeling processes, speeding up calculations, etc.

Learning with a traditional approach corresponds to a passive model of learning: the pupil listens, perceives, and remembers. Another model of learning, the active model, involves situations where the pupil himself is looking for a solution, solving a problem, analyzing the optimal solution, etc. (Figure 1), and therefore uses all the technologies, methods, and means that are available to him. Since young people are used to solving current problems using the Internet, they actively use their own mobile devices.

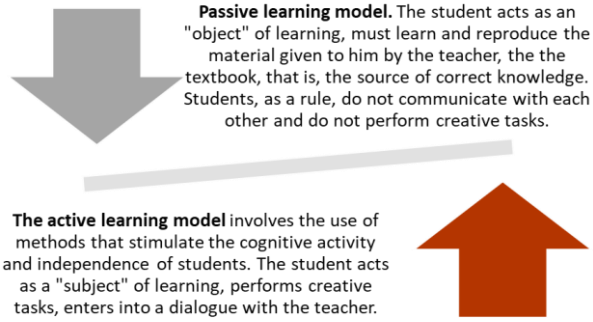

Figure 1. Comparison of passive and active learning models (source: made by authors)

This argues for the expediency of organizing the educational process based on the BYOD approach (Bring Your Own Device). Therefore, the goal of the study was to determine modern educational tools for the implementation of the BYOD approach in the example of teaching physics.

II. CHALLENGES OF USING THE BYOD APPROACHES IN THE TEACHING OF PHYSICS

There are many options for using mobile devices to teach physics. Smartphones are increasingly used in universities during the study of mechanics [3], acoustics [4], and thermodynamics [5] because they provide a unique way to conduct a simple scientific experiment.

A. Analogues of measuring devices

V. Sipiy believes that modern smartphones have a huge number of sensitive and accurate sensors, which allow measuring in real-time and storing various data about the external environment in the device's memory. For the most part, it is available to users to obtain data about movement, and the strength of light and sound flows, the smartphone can be used to replace such physical devices as a stopwatch, metronome, sound generator, stroboscope, etc. [6]-[7]. With the help of a smartphone, you can examine, for example, the volume of sound created by various sources [8].

B. Slow motion mode

But when using the BYOD approach in teaching physics, smartphones are not only analogs of measuring devices. The teacher can use such a function of the smartphone as a slow-motion video mode. For example, when measuring the uniformly accelerated motion of a falling body near the Earth's surface, an inclined plane is traditionally used to "reduce" the acceleration (so that it can be measured) – this approach was proposed by Galileo.

Now the free fall of the body in the vertical direction can be recorded by the student using the slow-motion function of the smartphone. This is somewhat equivalent to a decrease in the value of the free-fall acceleration g. A standard video consists of a sequence of images captured at 30 frames per second. The slow motion function, available in several smartphones, allows you to shoot videos at a speed of 120 to 960 frames per second. For example, the image scan time is approximately every 4.2 m/s for a video shot at 240 frames per second. This corresponds to the required accuracy for measuring the free-fall acceleration g [9].

The above examples of the use of mobile devices are not implemented by every smartphone. Also, not every smartphone of Ukrainian pupils has the opportunity to install specialized applications. This leads to the search for other areas of use of the mobile phone within the BYOD approach. One of these is the use of QR codes.

Analysis of the scientific results of the introduction of QR codes as an educational tool shows that QR codes are an effective tool that stimulates the interest and cognitive activity of lower secondary school pupils, and increases their motivation to learn [10]. N. Mileva and D. Stoyanova describe the use cases of QR codes: QR codes are printed on transparent films and placed on the corresponding pages of the textbook (educational content is deepened by additional resources); QR codes are printed on a separate sheet according to the topic of the lesson and have questions and tasks with multimedia materials related to QR codes; QR codes are printed on worksheets, but for collectively checking the answers and fixing errors.

In [11] T. Chicioreanu, E. Bilal, and M. Butnariu noted the use of QR codes by university professors to accompany professional activities to facilitate access to information that is given by a long internet address. The authors claim that professors are satisfied with such a digital tool for education.

Research [12] justifies that the use of QR codes in the classroom is simple. It does not depend on the discipline but allows you to combine real objects with any additional web content. J. Artal-Sevil, E. Romero, and J. Artacho

claim that QR codes allow you to generate virtual reality and augmented reality environments in the classroom, and also focus on the fact that the QR code can have access to text, videos, and photos. A QR code can be used in educational activities for reading and writing (educational material to deepen knowledge or a simple questionnaire where the student inserts information).

E. Artemova, Y. Shishalova, S. Melnikov, O. Orekhova, and G.Nikiporets-Takigawa [13] proved that the use of QR codes contributes to the development of professional skills, providing an increase in the quality indicators of the educational process. According to the authors, with the help of QR codes, effective educational activities for students are organized.

Another positive aspect of the use of QR codes is noted in [14]. S. Sharara and S. Radia suggest using QR codes to replace paper information leaflets. Patients then immediately access the necessary information on their own personal devices. The contactless way of transmitting information is more and more not dangerous, which became especially relevant during the spread of Covid-19.

There is also confirmation of the feasibility of using QR codes in teaching physics. I. Astra, L. Suryadi, and F. Bakri [15] explore the development of analytical skills in physics lessons and present the didactic development of a physical workshop equipped with 3D media based on QR-Code technology. The worksheet has been designed based on "using discovery learning stages".

Thus, the analysis testifies to the positive impact of the use of QR codes in the educational process and the commitment of professors and teachers to the use of such technologies in the world. This was the impetus for the study of the practices of using QR codes by Ukrainian physics teachers.

III. EXAMPLES OF USING QR CODES IN TEACHING PHYSICS

One of the digital technologies used in education today that works in favor of the BYOD approach are the use of QR codes. Virtually any mobile device can easily recognize and decode information encrypted using a QR code.

Today, the use of QR codes in education can be seen on posters and stands, and in libraries, teachers offer interactive lessons using QR codes and develop textbooks with QR codes.

Some possibilities for using QR codes in the educational process are given below.

- *Hyperlinks to multimedia sources and resources*. When accompanying the lesson with a presentation, students can be provided with handouts with QR codes for access to auxiliary applications (hyperlinks to multimedia sources and resources: video, audio applications, websites, drawings, animations, electronic educational publications, libraries, etc.). You can also place QR codes on the presentation slides. Instead of typing a URL into their phones, students can scan a code to get more information instantly.
- *Project activity*. During the organization of project activities, you can create link collections, information blocks, comments on project support website pages, and posters. Students can create their own portfolios or annotations on read books, educational and methodological literature on the researched topic and place them on the project website in the form of QR codes.
- *Survey and testing.* QR codes will allow you to organize quick surveys and conduct testing both in the classroom and outside it (web services ClassTools, Plickers, Mentimeler, etc.). For example, a printed QR code with the correct answers or a hint with an algorithm for solving the problem can be placed on each test ticket.
- *Game forms of activity*. QR codes can be used in-game quests to offer game tasks at one or more stages of the relevant events, in educational crossword puzzles.
- *Covers educational and methodical literature*. It is advisable to use QR codes to place reference material, information about the author, publisher, or any additional information on the covers of educational and methodological literature.
- *Information stands*. It is advisable to use QR codes for information saturation of standard information stands in classrooms, laboratories, recreation areas, libraries, museums of educational institutions; for placing the results of the educational process, etc.
- *Appendices to educational facilities*. QR codes can be placed on parts of mechanisms, electrical diagrams, and other physical objects. For example, QR codes placed on the periodic table of elements can contain physical and chemical properties of elements; QR codes placed on laboratory (demonstration) equipment may have a hyperlink to a virtual laboratory or control questions for self-study.

In physics lessons, QR codes can be used at any stage – from setting goals to homework.

QR codes can be utilized to set the algorithm of laboratory work or provide step-by-step instructions for its implementation. They can be used to expand the information space of the topic being studied when learning a new subject. By marking the elements or objects of a specific physical phenomenon with QR codes, educational videos or accompanying drawings can be provided. Self-check or mutual check can also be organized using QR codes. For example, students can solve a problem and then use a QR code to check their answers. The motivation, in this case, is to solve the problem faster and check it.

Fixing and repeating the studied material can be made more engaging with QR codes. Crossword puzzles, dominoes, lotto, and other games can be played using QR codes with coded physical terms, formulas, names of famous physicists, historical dates, and events.

The authors offer several other ways of using QR codes in physics lessons.

Information leaflets. In modern textbooks, little attention is paid to scientists, and if there is a mention of them, it is only the years of life and a few suggestions about the contribution to one or another branch of physics. With the use of the QR code, it becomes possible to expand the scope of such information through the creation and use of information leaflets that connect the QR code and larger information content for a more detailed study of the life and work of physicists. Leaflets with QR codes can be printed or sent to students, and they can familiarize themselves with the information on their own (Figure 2).

Figure 2. An example of using QR codes in information leaflets with physics tasks (source: made by authors)

Surveys, testing. Another way of using QR codes is online testing, which provides a test of students' knowledge, prevents writing off, and eliminates the subjectivity of the teacher, and the results are immediately displayed in the system.

A task in the form of a QR code can be offered during surveys at one of the stages of the lesson. The students can decipher the code to complete the task (Figure 3).

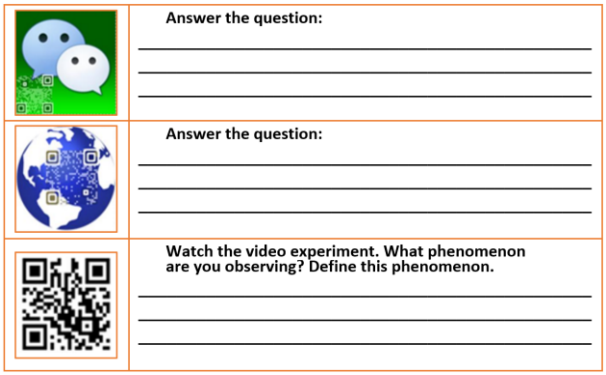

Figure 3. An example of a survey card (source: made by authors)

Web quests. Various web quests can be organized with the help of a QR code, which students tend to enjoy.

A web quest is a game activity of the type of a regular quest, in which the teams have to go through as many stations as possible in a limited time and answer questions or complete tasks that are encrypted using a QR code. Class students are grouped into teams. Each team receives:

- a smartphone with an installed application for reading QR codes and a presentation for photo tags;
- a map (printed or electronic) with stations indicated on it;
- a worksheet for recording the answers received at the stations.

The teams pass the points stations in the specified order. At each station, students have to decipher the QR code, answer the questions and enter the answer in the worksheet, make a photo tag, and place it on the appropriate slide of the presentation.

For each completed station, teams receive a certain number of points (provided they have a photo tag). The team is also awarded points for correct answers. If there is no answer (on the condition of passing this station), the team can be fined.

Physical web quest stations can be varied. For example, when studying the topic "Heat phenomena", the local stations can be the "Historian", "Metric", "Technique", and "Literature" stations. Here it is advisable to provide high-quality physics problems (it is better to choose short problems so that there are no difficulties with reading QR codes).

Textbooks. QR codes can also be used to display additional information in textbooks or special workbooks. For example, you can additionally place reference materials, links to videos of physics experiments, or simply link to online testing on the Internet in them via QR codes. QR codes can be used to organize a self-test of knowledge on the topic covered (Figure 4). Students receive a list of questions, the correct answers to which are posted in advance at various Internet addresses presented in the form of QR codes.

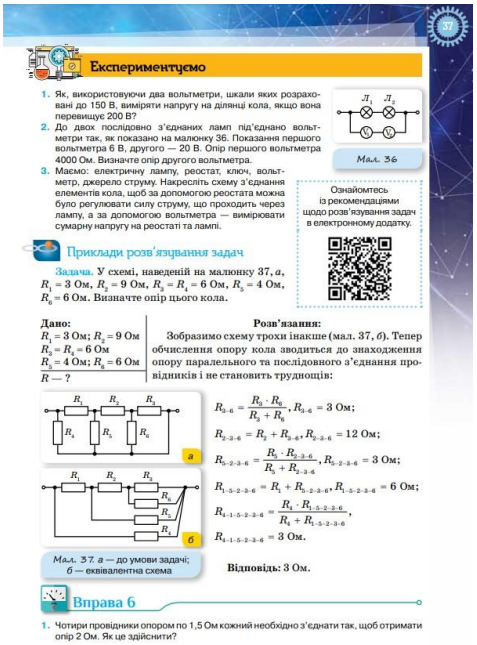

Figure 4. An example of using QR codes in a Ukrainian physics textbook (Source: [16])

Virtual exhibitions. The development of a virtual exhibition is necessary, for example, when studying the topic "Heat engines. The principle of operation of heat engines. Efficiency of a heat engine". The physics teacher needs to find images of heat engines on the school website or his own website, encrypt the hyperlinks to them in the form of QR codes, print them with signatures, and hang them on the walls of the classroom. Children can familiarize themselves with the exhibits of the exhibition during extracurricular hours.

Informational support of objects of study. QR codes are placed on laboratory equipment and allow visualization of operating rules, safety techniques, etc. Codes may provide a hyperlink to a virtual physics lab. In the office (laboratory) physics, you can use QR codes to provide information about the purpose of the equipment, conditions of use, history of creation, etc.

Study of physical phenomena and processes during laboratory work. For example, students can be offered to plot the Maxwell distribution function for O_2 (M=0.032kg/mol) at T=300K). Before the lesson, the physics teacher should code different options for model research tasks (Figure 5).

Figure 5. An example of a task (source: made by authors)

An expert assessment was carried out on the effectiveness of ways to use QR codes in a teacher's professional activity. Five service physics teachers who have at least 5 years of work experience and who implement the BYOD approach in their professional practice are involved in the examination.

Among the possible ways of using QR codes at physics lessons, the following were evaluated: 1) information leaflets; 2) surveys, 3) instructions; 4) web quests; 5) virtual tours, and exhibitions; 6) information support of physical objects of study. The experts had to rank the ways from the most effective (rank 1) to the most, in their opinion, ineffective (rank 6). Based on the results of the examination, we received data (Table 2).

TABLE II. THE RESULTS OF THE EXAMINATION (SOURCE: MADE BY AUTHORS)

Ways of using QR codes	Experts					Sum ranks	d	d2
	1	2	3	4	5			
1	4	1	3	6	3	17	-0,5	0,25
2	5	6	6	3	5	25	7,5	56,25
3	6	5	5	5	4	25	7,5	56,25
4	1	2	1	2	1	7	-10,5	110,25
5	3	4	4	4	6	21	3,5	12,25
6	2	3	2	1	2	10	-7,5	56,25
∑	21	21	21	21	21	105		291,5

The concordance coefficient W=0.66 indicates an average degree of agreement of opinions.

Pearson's test was used to assess the significance of the concordance coefficient: $\chi 2 = 5(6-1)\ 0.666 = 16.66$

For the significance level $\alpha=0.05$ calculated $\chi 2$ (16.66) is greater than the tabular one (11.07050), therefore W=0.666 – the value is not random.

Thus, the expert evaluation of the ways deserves trust: the most effective is the use of QR codes when organizing web quests and for the purpose of informational support of objects of physics study.

IV. CREATION OF QR CODES

A QR code can be created by using specialized online services that enable the encryption of necessary information in a single click. The most common software tools for generating and recognizing QR codes are QR-droid (https://play.google.com/store/apps/details?id=la.droid.qr), QR Reader (https://play.google.com/store/apps/details?id=uk.tapmedia.qreader), QR Barcode Scanner (https://play.google.com/store/apps/details?id=com.gamma.scan) and others. Often, scanners for reading QR codes are found as standard tools of many modern smartphones and are also found in messengers (in particular, Viber or Telegram).

Among Ukrainian-language online resources for creating QR codes, the following can be distinguished: qrcodes.com.ua, qr-code.com.ua, and ua.qr-code-generator.com.

There are many tools on the Internet that offer other, both free and commercial, services for converting various information into a QR code without downloading desktop software. Such online services can be effective, but the disadvantage can be the unauthorized use of the entered information in the public space. Therefore, it is not advisable to encrypt confidential information through online services.

Stand-alone, desktop, applications are more guaranteed to keep data confidential and that data will not be sent over the Internet. Such tools are called online or offline QR code generators.

When generating QR codes for the educational process, using different methods, you can customize the design of the code itself (the shape of the main part of the code, the shape of the square frame, the shape of the square itself, the color of the code, add a logo or image), the content of the code (you can add a small text, a link to the website, sound, video, e-mail address), the size of the generated code itself and the image format, etc.

V. CONCLUSION

Consequently, the spread of digital technologies and means affects both young people (use digital technologies and means actively) and the educational process, which acquires signs of active learning. The introduction of active teaching methods today is perceived as involving

young people in an independent search for answers to various educational tasks. Young people, in turn, use this purpose all available, including mobile ones, devices, and technologies that promote the BYOD approach to learning.

The tools for implementing the BYOD approach are, for example, mobile devices. Smartphones have sensitive and accurate sensors for measuring in real-time and can preserve data about the external environment (data and movement, the strength of light and sound fluxes, stopwatch, metronome, sound generator, stroboscope, etc.). Reachable for some smartphones is slow motion video mode.

The analysis of findings showed a significant potential for the use of QR codes for the BYOD approach implementation as an educational tool, which simplifies access to Internet resources, can build augmented reality or can provide multimedia support.

At the same time, in the context of Ukrainian schools, there are limitations on the use of certain smartphone functions, but QR codes are widely accepted for use.

QR-codes in the teaching of physics today are used in the following directions: the creation of information leaflets; organization of surveys, tests, web quests, and virtual exhibitions; improvement of textbooks; informational support for objects of physics study, visualization, and research of physical phenomena and processes.

The use of a QR code in physics lessons as part of the BYOD approach allows not only solves educational tasks in teaching physics but also provides an opportunity to involve students' personal devices in their educational activities, promotes increased interest in learning, develops teamwork skills, expands cultural horizons students, trains the skills of scanning QR codes and using relevant applications, that is, develops universal skills of students.

The QR code makes the lesson interesting, which additionally motivates students to study: it is convenient for students to read interesting content and, if necessary, quickly save it in the memory of smartphones. The approach, along with the visual channel of perception of initial information, allows you to use an additional (tactile) channel, which expands the information space of students.

The conducted expert analysis of the ways of using QR-codes in the teaching of physics showed that the most effective is the use of QR-codes when organizing web quests and for the purpose of informational support of objects of physics study.

The conducted research showed the expediency of using QR codes in the educational process in general and in teaching physics, in particular, and at the same time actualized other areas of research: the development of web quests to accompany the school physics course using QR codes, the research of the level of those educational results that are acquired using QR codes; analysis of mobile applications for teaching physics within the BYOD approach.

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