Formation of informational and digital competence of secondary school students in laboratory work in physics

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Abstract
The article deals with the formation of informational and digital competence of high school students. First and foremost, the existing digitalization strategies for society already approved in the world and in Ukraine, including the implementation of STEM education and the Digital Agenda, are considered. On the other hand, attention is paid to the inconsistency of the level of ownership and frequency of use of digital technologies with the requirements of these initiatives. The concept of informational and digital competence is analyzed in detail. Existing publications identify key components, skills and competencies required to achieve this competence. A survey is conducted to better understand the current situation. One of the tasks is to determine the level of use of digital information in the classroom by teachers and in students' preparation at home. The second task was to show how developing students' informational and digital competence can be done by active introduction of existing software and hardware in the educational process in physics, in particular, a laboratory workshop. The example of laboratory work carried out in educational institutions shows how modern software can be used to analyze the movement of bodies and determine the physical characteristics of this movement. The concrete ways of performing laboratory work, analyzing its results and drawing conclusions are given. It is in the combination of existing teaching practices with modern gadgets, specialized and general programs that the basic way of forming informational and digital competence is seen. Further ways of modernization and improvement of described methods for increasing the level of information and digital competence are proposed.

Keywords
Informational and digital competence, training programs, laboratory practicum,

1. Introduction

The rapid introduction of digital media in every area of life and the daily need for their use have become a prerequisite for the successful development of society and a comfortable human life. Many professions require a certain level of digital skills [1]. The forum "Digitalization: business talk, open opportunities", dedicated to topical issues of implementation of digital transformations and development of the digital economy in Ukraine, emphasized that digitization of the country should be comprehensive, not local[2]. A "shallow" approach to the use of digital technologies

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will not help to gain significant benefits for the economy and citizens of Ukraine. Instead of selective digitization that improves the quality of certain systems or spheres of citizens' lives, Ukraine should move towards a full and inclusive transition to digital technologies. Ukraine takes an active role in implementing and initiating government programs that aim at building digital competencies, especially in the fields of education and science. The concept of development of the digital economy and society of Ukraine for 2018-2020 and the plan of measures for its implementation envisages the development of digital infrastructure and its large-scale implementation in the education system [3]. The Digital Agenda of Ukraine 2020 states: "Outdated teaching methods, lack of teaching standards and properly trained teachers, and the inaccessibility of digital technologies for the educational process have led to extremely low levels of digital literacy in all existing segments of the public education system (preschool, primary, secondary, higher). ... This approach does not meet current requirements, is not cross-platform and has very doubtful results" [4]. Therefore, the New Ukrainian School should form the informational and digital competence that the European Parliament and the Council of the European Union in 2006 called a key component of lifelong learning, which involves active daily use of digital technologies [5]. Moreover, more than 50 digital professions will appear in the public register, and the number of students of general secondary education institutions with STEM specialties will quadruple. Digital teaching and learning is being gradually introduced in Ukraine and considered under the Education and Training 2020 strategic program [6].

Ukraine has favorable conditions for the introduction of STEM education. The resolution of the Ministry of Education and Science of Ukraine "On the foresight of sociological and economic development of Ukraine in the medium-term (until 2020) and long-term (until 2030) time horizons (in the context of human capital training)" is confirmed [7]. Also a powerful state institution, the department of STEM education at the Institute of Modernization of the Content of Education of the Ministry of Education and Science of Ukraine, was created and operates. Ukraine adheres to the international educational standards of quality in the Natural Sciences. The use of STEM learning tools is conditioned by psychological, pedagogical, organizational-methodological, logistical and ergonomic factors [8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31]. That contributes to the development of students' research activity and forms their informational and digital competence. On May 22, 2018, the Ministry of Education and Science approved the "Regulations on the National Educational Electronic Platform", the main goals of which are: technological support for the secondary education reform "New Ukrainian School"; provision of educational process participants with up-to-date electronic educational resources and services; free provision of e-textbooks for the students; creation of favorable environment for development of national production of electronic educational resources, services and e-textbooks; development of e-learning and formation of digital competence of participants in the educational process in Ukraine [32].

In June 2019, at the invitation of Hi Tech Office Ukraine, a representative of the State Innovative Financial and Credit Institution participated in an expert working group on "Digitalization of Education", which discussed the main problems and prospects of implementing digitalization in real life. The discussed problems concerned providing the conditions for creating National Coalitions for Digital Skills; involvement in European digital skills development initiatives; implementation of the Digital Agenda and the development of a digital education and digital skills system based on EU experience [4]. On June 6, 2019, the presentation of the concept of a national digital education project, designed to promote school education in a globalized world, took place. “The concept behind the project is to create a state-of-the-art digital school for any child from anywhere in the world. The school issues a state certificate of complete secondary education. The Digital School is a multifunctional educational digital information service in which a student can be trained in remote access”. Such a form will help talented children who are ahead of the school curriculum and address the issue of access to educational resources for children living in remote areas, rural areas or outside Ukraine [33].

These and a number of other initiatives and projects are focused on building digital competences, being components of the reform of Ukrainian education and the basis of a sound national digitalization policy. However, there is some distance between the development of society and the level of ownership of digital technologies, and previous researchers do not study the problem of forming and assessing the level of information and digital competence of students of general secondary education in the context of digitalization of society.

Our studies have shown that the problem of digital and informational competence formation was engaged in Svitlana M. Amelina [34], Albert A. Azaryan [35], Zinaida P. Bakum [36], Nadiia R. Balyk [37], Olga V. Bondarenko [38], Valerii Yu. Bykov [39], Olean O. Gritsenchuk [27], Anna V. Iatsyshin [40], Alla A. Kharkivska [41], Hennadiy M. Kravtsov [42], Olena H. Kuzminska [43], Svitlana H. Lytvynova [44], Oleksandr S. Martyniuk [45], Mariia S. Mazorchuk [46], Yevhenii O. Modlo [47], Natalia V. Moiseienko [48], Yuliia H. Nosenko [49], Oksana V. Ovcharuk [50], Svitlana V. Shokaliuk [51], Nataliia V. Soroko [52], Andrii M. Striuk [53], Svitlana O. Sysoieva [54], Rostyslav O. Tarasenko [55], Iryna M. Trubavina [56], Kateryna V. Vlasenko [57], Vasyl V. Yahupov [58] and others.

3D mapping technology of digital competence in the education system of Ukraine has been proposed by Morze et al. [59]. The developed 3D mapping reflects the tendency of understanding by teachers and students of higher education institutions and teachers of secondary schools of basic current educational trends, the use of innovative pedagogical technologies and digital tools in the educational process.

Researchers mostly refer to the Digital Agenda of Ukraine 2020, DigComp Digital Competence Framework [60] and Development Concept of digital economy and society of Ukraine for 2018-2020. Problem of formation and assessment of the level of informational and digital competence of students in secondary education has not yet found a holistic solution.

The purpose of the article is to outline the main problems of forming the level of informational and digital competence of students of general secondary education; to analyze the student questionnaire results to determine the level of use of informational and communication technologies and modern electronic gadgets in Physics classes; development of methodology and technique of using cross-platform programs for improvement and modernization of educational experiment in Physics.

2. Theoretical backgrounds

In the period of intensive development of digital technologies, among the key competencies [61, 62, 63, 64], the informational and digital competence is a priority. Specialists in different industries must have informational and digital competence. The concept of competence approach, laid down in the National Qualifications Framework, provides for conditions that ensure that national education is in line with current market requirements. The definition of "informational and digital competence" is constantly in the discussion field for both foreign and domestic educators. In sources, concepts and terms used by the international pedagogical community defining informational and digital competence as knowledge, skills, personal abilities in the field of information and communication technologies. The adoption of the Digital Agenda by the European Commission in 2010 set out goals, one of which is to raise the level of ICT practitioner skills of European citizens, including digital and media literacy, e-skills. Common terms of it nowadays are digital literacy (digital fluency), ICT skills, ICT literacy, ICT competence, media literacy, information literacy, communication competence [65]. By informational and digital competence we mean the ability to use the available informational and digital tools to obtain, process, disseminate and store the necessary information. Until recently, the most common considered competencies are used for mastering informational and digital competence. Among them:

1) the ability to systematize and summarize information found on-line;
2) the ability to read and understand in a dynamic and inconsistent hyper-textual environment;
3) the ability to construct information bases from various sources, relying on the ability to gather and evaluate facts and statements without prejudice;
4) search skills;
5) the ability to manage "multimedia flow" using information filters and agents;
6) the ability to create a "personal information strategy" and implement a portfolio approach with the selection of sources and delivery mechanisms;
7) an awareness of collaboration with other participants in the process and the ability to find contacts with them to discuss issues and get help.

Informational and digital competence consists of two components: general and professional. They can be represented in the form of cognitive activity (level of knowledge formation about information and ways of its transformation, cybersecurity, digital resources and possibilities of their use), procedural and motivational (leading motives that determine ways of reaching informational and digital competence), organizational and constructive (the level of ability to organize educational activities using informational and digital resources and the ability to engage subjects of study in educational activities), emotional and communicative (degree of communication skills and emotional attitude to the learning process), information (ability to work with educational and scientific information), reflexive and diagnostic (willingness to assess their knowledge and skills at each stage) components of informational and digital competence (figure 1).

There are a number of approaches to the design and assessment of digital competencies in modern methods. For example, Balyk and Shmyher [66] are proposing to shape this process by developing new digital content and creating a digital educational environment for partnerships between participants in the educational process.

A DigComp digital competence framework has been created to support the development of digital competence for European citizens [60]. It outlines what competencies are needed today to use digital technology in a confident, critical, collaborative and creative way to achieve

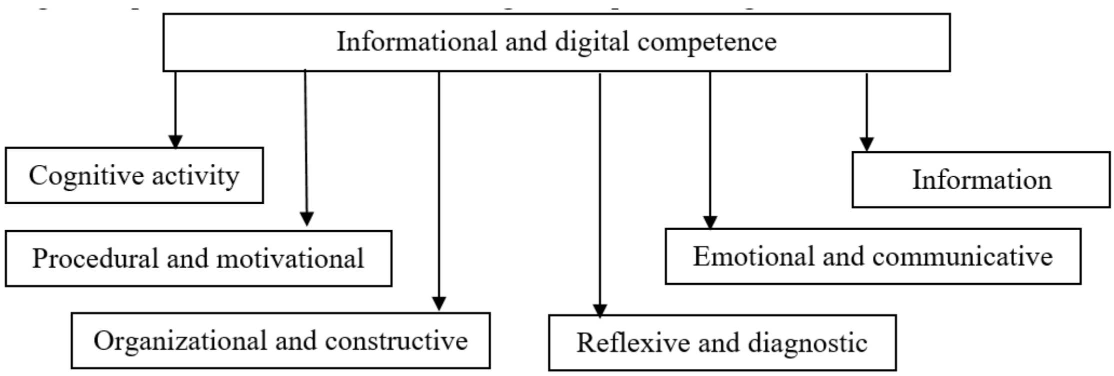

Figure 1: Components of information and digital competence.

work, learning, leisure and participation goals in the digital community. European experts in 2017 prepared the Digital Competence Framework for Citizens 2.1. The document contains descriptors (expected results by levels) of eight skill levels. They are defined by the formulation of the European Qualifications System (EQF). Each level description contains the knowledge, and skills described in one descriptor for each level of each competency: 168 descriptors were described in total. Each descriptor is an experimentally verified indicator that has been included in this document by generalizing the requirements in the education system and in the employment field of the European Union.

Europass is a tool for assessing digital competence. It can be used to create a competence unit dedicated to evaluating data, informational and digital content. Yes, a person must be able to analyze, compare and critically evaluate the reliability and reliability of data sources, informational and digital content; analyze, interpret, and critically evaluate data, information, and digital content. Many European initiatives are aimed at promoting innovative learning strategies. Individualized learning, self-regulated learning, and collaborative learning are all considered essential for the introduction of digital technologies in education. Maintaining the digital competence of pupils and teachers is an important task of European education policies.

Competences, including informational and digital, are categories that belongs to the sphere of relations between knowledge and practical activity of a person. It integrates knowledge, skills and assimilated modes of activity in relation to specific conditions, in a specific situation [3]. Therefore, the influence of the environment, conditions and lifestyle of the individual and society, have a significant impact on the directions of formation of informational and digital competence.

3. Findings

In order to analyze the level of informational and digital competence of students in the process of teaching physics, we suggested that they answer the questionnaire.

1. Are hardware (digital boards, laptops, projectors, specialized training programs, computer experiments) and digital gadgets used in physics lessons?

1) Yes.
2) No.

2. Do you use modern gadgets (tablets, laptops, smartphones) when preparing for physics lessons?
   1) Yes.
   2) No.
3. In your opinion, is it advisable to use modern technologies in the study of physics?
   1) Yes.
   2) No.
4. How freely do you think you use informational and digital technologies at the user level (use of Internet resources, use of applications, use of specialized software and hardware)?
   1) Freely.
   2) Sometimes need help.
   3) Need help frequently.
   4) Do not use (use it rarely).
5. What do you think is the concept of informational and digital competence (choose one)?
   1) Ability to use pre-configured firmware for a specific task.
   2) Theoretical knowledge regarding the work of a program or gadget.
   3) Ability to use existing software to perform daily tasks, as well as understanding the basic principles of their work.
   4) A thorough understanding of the operating principles of software and hardware gadgets used in daily business.
6. What is the importance of information security when using modern software and gadgets (on scale 5 - very important, 1 - absolutely not important)?|
   1) 5
   2) 4
   3) 3
   4) 2
   5) 1
7. What information security tools do you use when studying / preparing for training?
   1) No tools
   2) I try not to open the suspicious sites / run the suspicious programs.
   3) I use the basic tools of operating systems.
   4) Use antivirus.
8. Are there any information security tools on computers / gadgets used by the teacher when teaching physics? Which?
   1) Yes.
   2) No.
9. In your opinion, how can you improve students' competency when using software and gadgets in the physics training process?
   1) Constantly use them.
   2) The teacher should encourage students to use them more actively.
   3) The teacher should give practical advice on their use.

4) One lesson should be learned in the practice of using information and communication technologies when studying physics.
5) Teacher should not care about this.

The purpose of the survey was:

1) to determine the level of use of modern electronic gadgets by students in the study of physics in and outside the classroom;
2) to get an appreciation of their modern electronic gadgets;
3) to determine students' understanding of the concept of informational and digital competence;
4) to get from students an assessment of the ways to increase the level of informational and digital competence.

The survey was conducted among students of grades 9–11 who participated in the 26th All-Ukrainian tournament of young physicists, which took place in Lutsk in 2017, the 21st All-Ukrainian tournament of young inventors and innovators, which took place in 2018 in Kyiv, as well as students of Chervonograd secondary school No 12.

218 students participated in the survey, including:

- 74 students of 11th grade (34% of all respondents);
- 72 students in grade 10 (33% of all respondents);
- 72 students in grade 9 (also 33%).

In terms of age distribution, the largest number of participants were 15 years old, namely 83 (accounting for 38% of all respondents), and 16 years old for 78 persons (36% of all respondents). Interviewees aged 14 years were 40 (18%) and 17-year-old students were 17 (8%).

As shown in figure 2, in the course of the survey, the majority of students confirmed the use of modern digital media, namely 148 participants (68%). The rest (70 students) answered this question in the negative. Most also answered positively about using modern gadgets for home preparation. Answer "Yes" gave 165 respondents (76%), 55 students answered negatively (24%). The overwhelming majority consider the use of informational and digital means appropriate for the study of physics, namely 204 respondents (94% of all).

Figure 3 shows, that most students also confirmed that they were able to use modern digital media freely, with 148 participants, representing 68% of those polled. 62 participants (28%) indicated that they sometimes need help with their work and 6 students often need an outside help. Only 2 students responded that they could not use modern electronic gadgets.

In order to assess students' understanding of the concept of informational and digital competence, the respondents were offered different options for defining it, among which one had to be chosen. The answer "Ability to use already existing applications and devices, as well as understanding the basic principles of their work", selected 87 respondents, representing 37%. The other respondents chose the following options:

- A thorough understanding of the operating principles of software and hardware for devices used in daily activities – 71 students (30%);
- Ability to use pre-configured firmware – 46 students (19%)

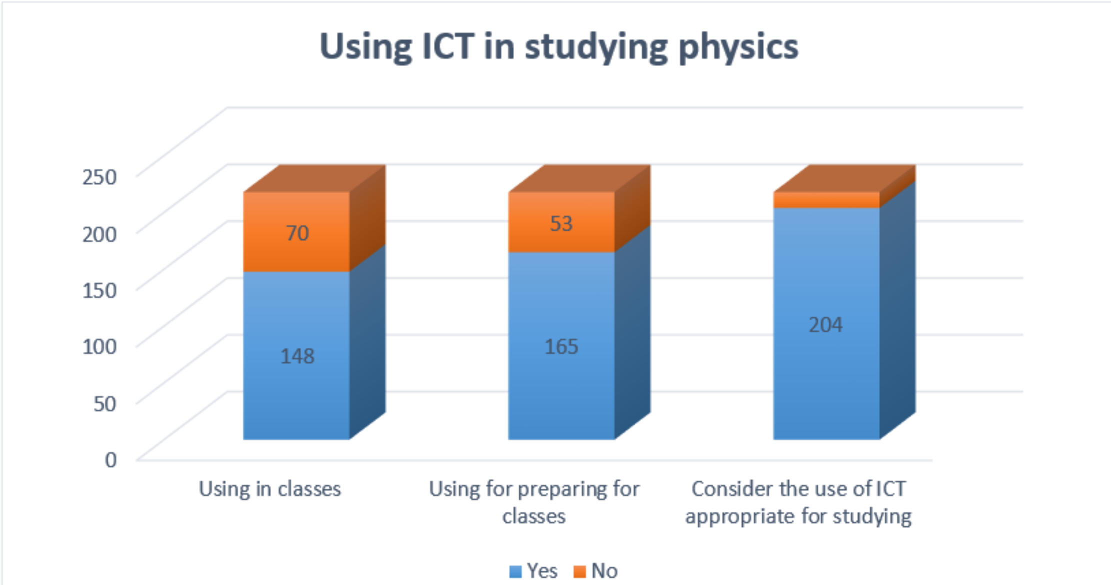

Figure 2: Using ICT in learning physics by students.

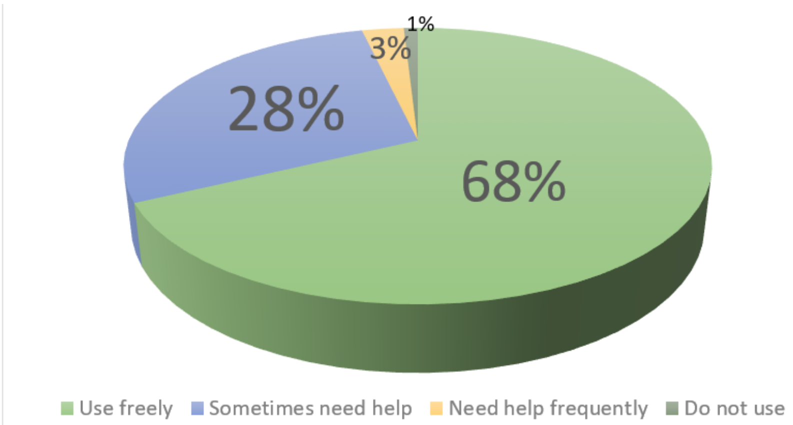

Figure 3: Students' ICT skills.

- Theoretical knowledge of the work of one or another information system – 32 students (14%).

To identify ways to increase the level of informational and digital competence that students see, several options have been proposed, among which respondents have chosen the right one. At the same time, one student could choose from several options. The frequency of occurrence of each of them is given below.

The conducted survey confirms that students use information and communication technologies on physic lessons and when doing homework. The vast majority of students see the prospect of using such technologies in and out of lessons. Moreover, for the most part, the

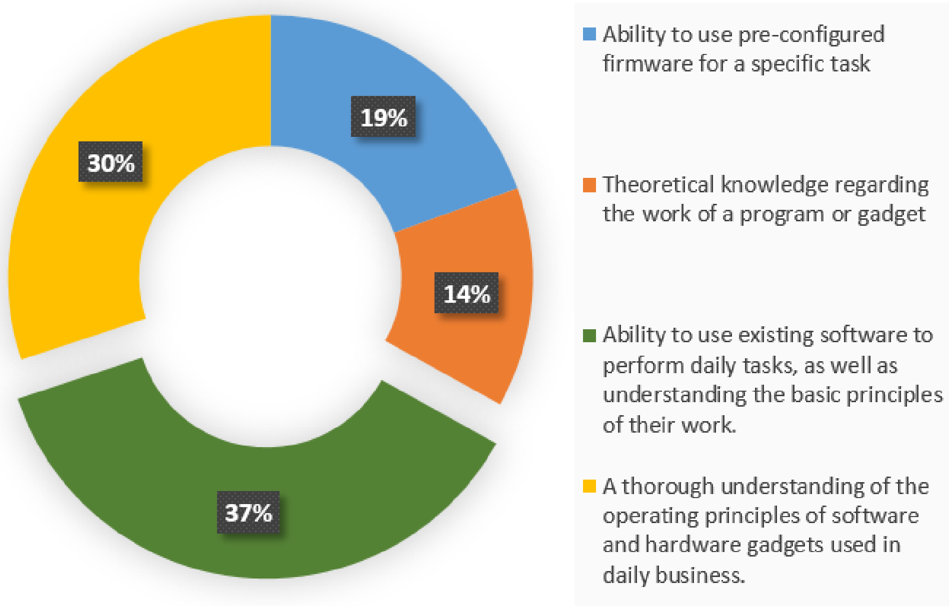

Figure 4: Understanding the concept of informational and digital competence.

respondents confirmed that they do not need any outside help in using modern information and digital tools. More attention should be paid to the formation of terminological base in students, since only one third correctly interprets this concept. This is probably due to the fact that it is not considered in the school course of physics or other disciplines of the modern school program. The options that prevailed when choosing ways to enhance the informational and digital competency should be considered when the teacher is preparing the lesson. As it turned out, the main requirement is the ability of the teacher to use these tools, give advice to students and introduce them into the educational process.

Finding useful tools for students, which could be implemented in the educational process is rather difficult task. Moreover, in most cases teacher is the one, who find useful and cheap software and hardware for lessons. Even after finding instruments teacher need to find methods to use them in classes. Some practical cases of using nowadays software for laboratory works are given below.

Laboratory work "Determination of body acceleration in the course of uniformly accelerated rectilinear motion" is part of the Physics course in the 10th grade [67]. During the laboratory work, students form an inclined plane, as shown in figure 6.

During the work student is is asked to measure the time of movement of the body (black ball) on the inclined bar from beginning to end three times. The student measures the path, that the body traverses with a ruler, the movement time – with a stopwatch. The experiment is repeated four times and the measurement results are recorded in a table. Then the average value of the acceleration of the body is determined.

However, such an approach results in significant measurement errors during the experiment. It also stipulates that the student is directly involved in the construction of the laboratory bench

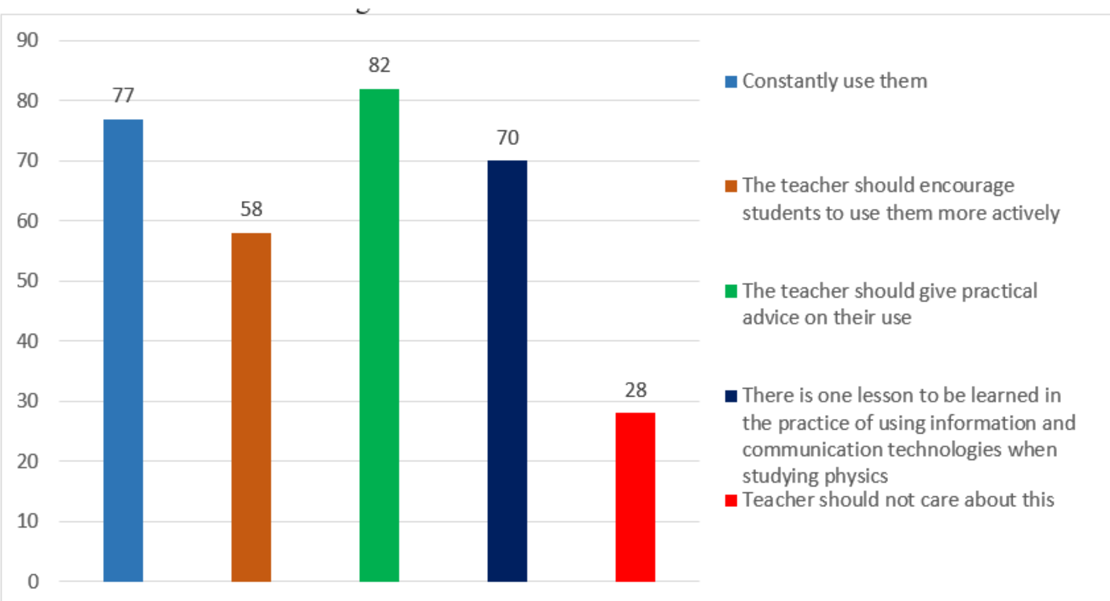

Figure 5: Ways to increase the level of informational and digital competence.

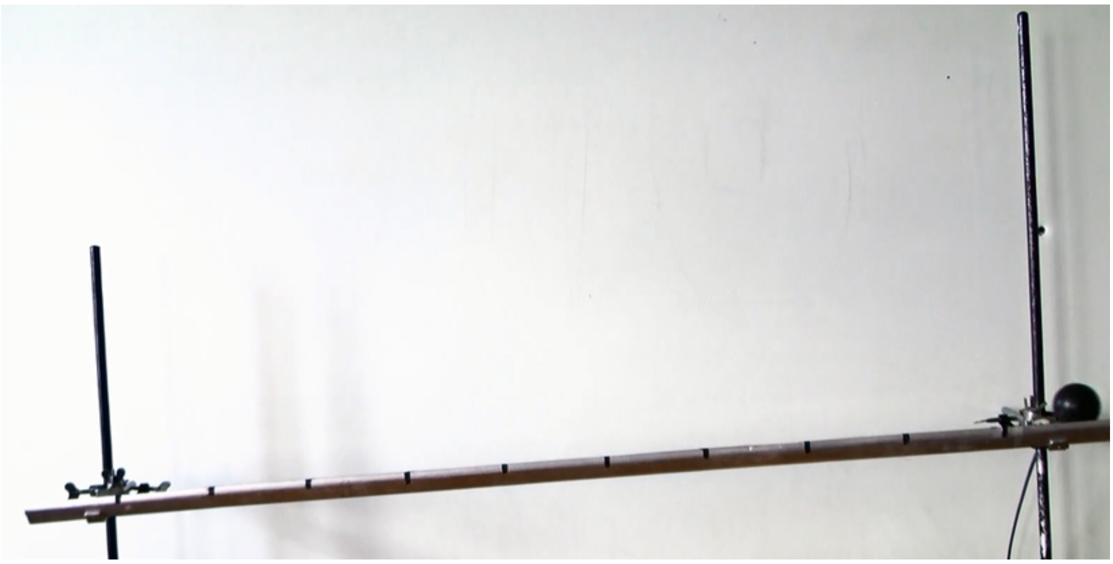

Figure 6: An incline plane for laboratory work.

and must make measurements in real time. This complicates the process of conducting the experiment at home or taking measurements outside the classroom.

At the present stage of information technology development, there are many software tools for video processing. They are used not only for physical research, but also in other fields, such as sports. However, such programs can be used by students in carrying out laboratory work, in particular in the study of mechanical movements.

The object tracking programs allow you to identify a particular object to which the market is programmatically assigned to a given template. Then frame by frame the program determines the position of the marker in the given coordinate system. Knowing the position of the object in different planes at each time makes it possible to determine the speed of the object, its acceleration, trajectory, and so on based on the data obtained. In more complex studies, an object is specified by its mass or other parameters, which allows it to calculate values of other physical quantities. This technology is actively used in the crash-test of cars, where markers mark points on a dummy and then programmatically calculate the parameters of their movement and interaction with other bodies. It is clear that within the physics lesson, it is necessary to use affordable and simple software.

As an example, let's consider the cross-platform software Tracker. It is based on the "Xuggle" software engine for video processing, which is also publicly available. In addition to exploring real-life videos, you can also download special models to emulate physical processes.

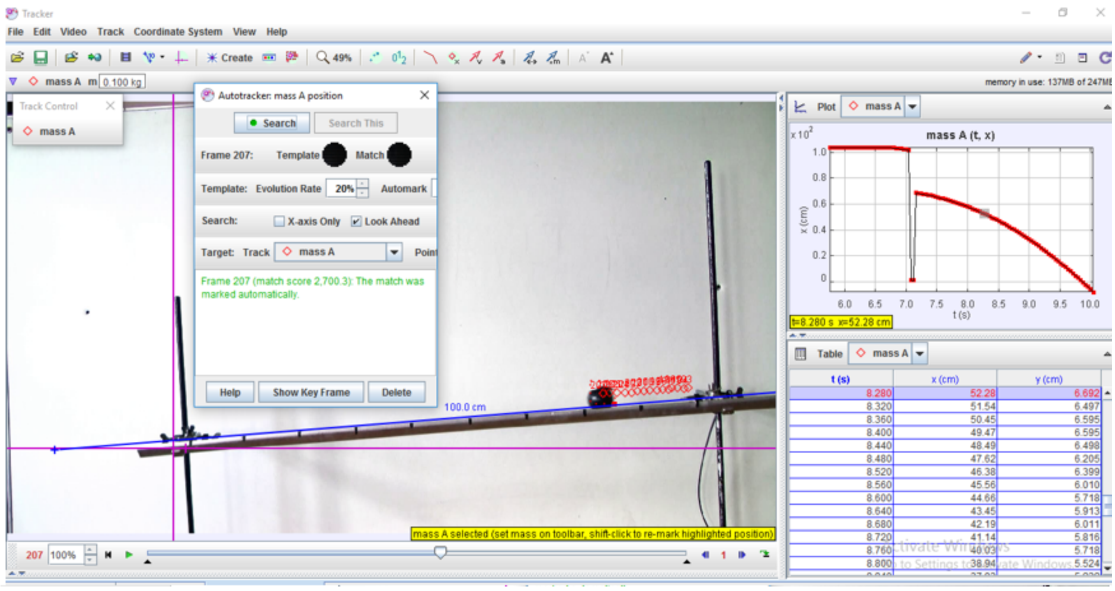

Figure 7: The main window of Tracker during measurement.

The main window shows a workspace with a video snippet. Above it is the control panel. It can perform functions like importing files to a program or saving data to a disc, changing the settings of a video or part of it, tracking, building a coordinate system, changing the display settings or call for help.

To perform the laboratory work described above, the student must complete the following steps:

1. Take one or more video clips of the ball moving along an inclined plane.
2. Upload the video file to a pre-downloaded application.
3. Determine the scale, that is, mark a special line on the video and specify its real size in the corresponding window of the program.

4. Mark the coordinate system.
5. Create a new Mass object that will be a body.
6. Use auto-tracking to bind this object to a real body and create a template for the program to follow.
7. Run tracking.
8. After receiving the results, analyze the chart to change the position of the body in space, determine the acceleration on the task of laboratory work, repeat the experiment, if necessary, to find the experimental error.

Also the VidAnalysis Free program was considered. This is a paid subscription program to exclude ads, but it can be used with a free version that is fully functional. The work of the program can be examined by the example of the above-mentioned laboratory work.

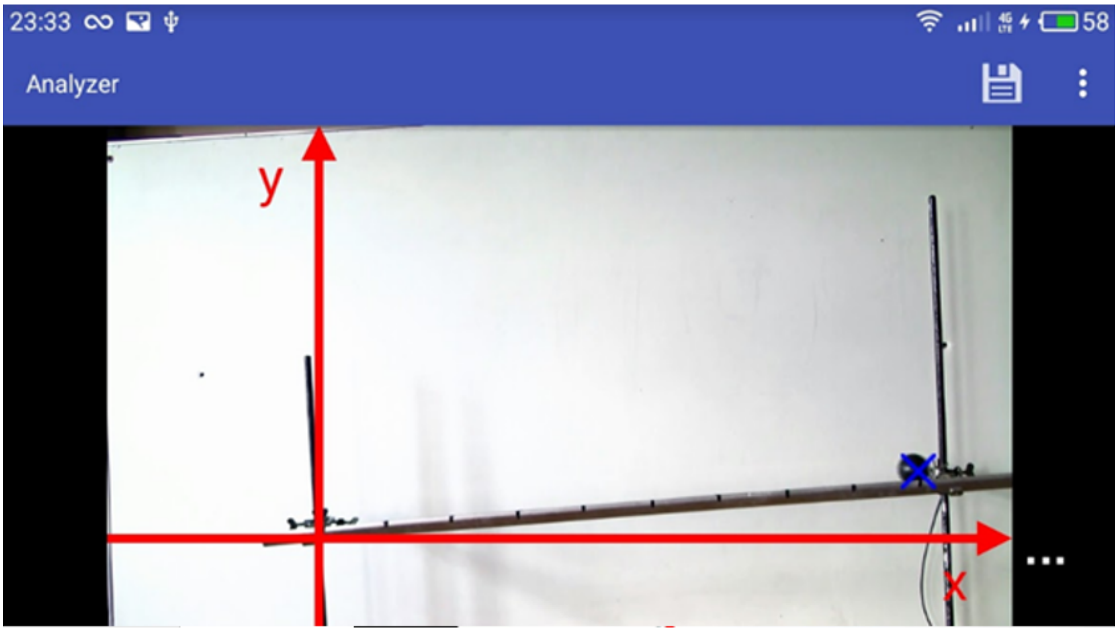

Figure 8: The main window of the VidAnalysis Free program.

To perform the task of laboratory work the student will perform the following procedure:

1. Download video footage to your phone.
2. Mark the coordinate system.
3. Specify the scale for which to mark two points on the video and write the real distance between them.
4. Next, in the frame of the video, the subject should be marked with a special marker.
5. Open the results of the study in tables.
6. Based on the obtained data, make calculations according to the task of the laboratory work.

In addition to using basic software, the student can also deploy cloud environments in the work scenario. This allows to upload the results in tabular form and to carry out a more detailed and in-depth analysis. An example of this is Google Drive. After collecting the data, the program will prompt you to save it. With an Internet connection and a Google Drive mobile application, it is possible to download the spreadsheet there. With the help of Google Sheets, students are able to independently build graphical dependencies of speed, acceleration, coordinates on time, to find the value of acceleration, according to the task of laboratory work.

In addition, the teacher may provide a laboratory work using the Atwood machine. With it, the student will be able to check the laws of the path and speed. The Atwood machine consists of a vertical riser on top of which a light block is mounted through which a light thread with weights at both ends is thrown. The weight of the weights is known and even. There are also additional weights to give the weights acceleration. On a riser there are centimeter divisions to determine the length of the path that the tractor travels. In order to conduct the experiment, the student must minimize the movement of the weights at different masses of additional weights and track one of the weights with a special program, such as Tracker. Figure 9 shows a view of the main window of the program during laboratory work.

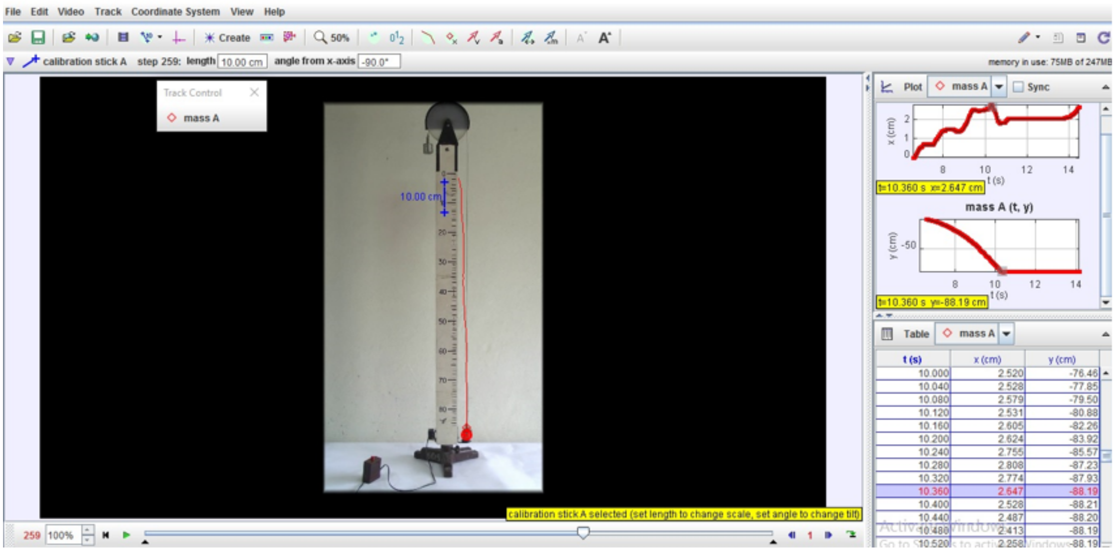

Figure 9: Tracker application window when performing laboratory work with the Atwood machine.

Thus, to verify the law of the path, the student must complete the following steps:

1. Put on the right load an additional tractor of mass (m).
2. Position the lower base of the right load a certain distance from the lower position (S).
3. Record the motion of the system on video.
4. Upload the file to the application.
5. Mark the scale line (blue line in figure 4).
6. Start auto-tracking. In this case, determine the object template.
7. Determine the acceleration of the body by the results obtained.
8. Repeat the experiment for another distance S.

4. Conclusions

Competence approach to learning changes some principles of learning and poses new challenges for teachers and students. Now, instead of simply accumulating knowledge, it is necessary to accumulate experience and develop skills. This expands the possibilities of using modern tools and devices during training. Today, students use digital technology in preparation for lessons. However, in physics lessons, the use of modern gadgets and software is not common practice. At the same time, physics lessons provide many opportunities for the application of information technology. This allows to form the information and digital competence of students in the learning process. The combination of specialized programs, mobile devices and cloud technologies, especially in the laboratory workshop, will have a positive impact on the formation of information and digital competence of students. It will also improve the skills of using these tools, will positively affect the measurement results (reduce measurement error) and will expand the range of tabular data, to form graphs of the dependence of different physical quantities. Prospects for further research are aimed at developing methods and techniques for the modernization of physical equipment based on modern software and hardware to ensure the development of information and digital competence of students.

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