UDC 378.147
DOI https://doi.org/10.24919/2308-4863/68-2-36

Dmytro SVERDLICHENKO,
orcid.org/0009-0005-6444-7084
fourth year student at the Department of Physics and Mathematics
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
(Kyiv, Ukraine) sverdlichenko.dmitry.of01@gmail.com

Sergii PODLASOV,
orcid.org/0000-0002-3947-4401
Senior Lecture at the Department of Physics and Mathematics
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
(Kyiv, Ukraine) s.podlasov@kpi.ua

Oleksii MATVIICHUK,
orcid.org/0000-0002-4732-9677
Candidate of Pedagogic Sciences, Associate Professor,
Associate Professor at the Department of Physics and Mathematics
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
(Kyiv, Ukraine) o.matviychuk@kpi.ua

HOME EXPERIMENTS AS A MEANS OF FORMING STUDENTS' EXPERIMENTAL SKILLS

Readiness and the ability to conduct experimental research and analyze the obtained results are integral components of an engineer's competence. Students initially acquire basic experimentation skills while performing laboratory work, particularly physics labs. Traditionally, laboratory experiments are conducted in educational laboratories using real equipment and instruments. However, the use of information and communication technologies has enabled the widespread adoption of innovative methods for conducting laboratory sessions, such as screencasting, computational experiments, remote-controlled experiments, virtual experiments, or some combinations. These forms of experimentation have gained significant popularity during distance learning. Each form of conducting lab sessions has its advantages and disadvantages and contributes to the development of specific experimental skills, which are analyzed in the study.

Students have significant opportunities to acquire experimental skills through home-based experimental research and solving experimental tasks. These tasks become especially relevant in the context of forced distance learning when students do not have access to real experimental equipment and instruments. But the lack of access to real equipment is a major drawback of home-based experimentation. Nevertheless, the use of sensors embedded in modern smartphones significantly expands the range of home experiments and sometimes allows students to conduct research at home that would otherwise require expensive, high-quality equipment. In addition to students gaining hands-on experience in experimental activities, home experiments promote the development of elements of engineering thinking, as sometimes it is necessary to design and create experimental equipment for these experiments.

Key words: *experimental skills, home experiments, experimental problems.*

Дмитро СВЕРДЛІЧЕНКО,
orcid.org/0009-0005-6444-7084
студент IV курсу фізико-математичного факультету
Національного технічного університету України
«Київський політехнічний інститут імені Ігоря Сікорського»
(Київ, Україна) sverdlichenko.dmitry.of01@gmail.com

Сергій ПОДЛАСОВ,
orcid.org/0000-0002-3947-4401
старший викладач фізико-математичного факультету
Національного технічного університету України
«Київський політехнічний інститут імені Ігоря Сікорського»
(Київ, Україна) s.podlasov@kpi.ua

Олексій МАТВІЙЧУК,
orcid.org/0000-0002-4732-9677
кандидат педагогічних наук,
доцент кафедри фізико-математичного факультету
Національного технічного університету України
«Київський політехнічний інститут імені Ігоря Сікорського»
(Київ, Україна) o.matviychuk@kpi.ua

ДОМАШНІ ДОСЛІДИ ЯК ЗАСІБ ФОРМУВАННЯ ЕКСПЕРИМЕНТАЛЬНИХ УМІНЬ УЧНІВ

Готовність й уміння проводити експериментальні дослідження та опрацьовувати одержані результати є однією із складових компетентності інженера. Первинні уміння експериментування студенти набувають під час виконання лабораторних робіт, зокрема, лабораторних робіт з фізики. Традиційно лабораторні роботи проводяться у навчальних лабораторіях з використанням реального обладнання та приладів. Однак застосування інформаційно-комунікаційних технологій дозволило широко запроваджувати новітні форми проводити лабораторні заняття з використанням скрінкастингу, обчислювального експерименту, експерименту з дистанційним керуванням, віртуального експерименту або їх певної комбінації. Найбільшого поширення такі форми набули під час дистанційного навчання. Кожна з форм проведення лабораторних занять має свої переваги й недоліки і формує певні експериментаторські уміння, склад яких проаналізовано в роботі.

Великі можливості для набуття студентами експериментаторських умінь надають домашні експериментальні дослідження та розв'язування експериментальних задач. Особливо актуальними такі завдання і задачі стають в умовах вимушеного дистанційного навчання, коли студенти не мають доступу до реального експериментального обладнання та приладів. Що правда, останнє є найбільшим недоліком домашнього експериментування. Однак застосування датчиків, вбудованих у сучасні смартфони суттєво розширює коло домашніх експериментів, а подекуди дозволяє виконувати вдома такі дослідження, для яких могло б знадобитися коштовне, високоякісне обладнання.

Крім набуття студентами досвіду експериментаторської діяльності, домашні експерименти сприяють розвитку елементів інженерного мислення, скільки для їх проведення буває необхідно ще й сконструювати і виготовити експериментальне обладнання. В роботі наведені приклади «експериментального обладнання», яке може бути використаним для проведення домашніх дослідів або формулювання умови експериментальних задач.

Опитування студентів, проведене після виконання ними домашніх дослідів засвідчило доцільність застосування такої форми роботи при організації навчального процесу.

Ключові слова: *експериментаторські уміння, домашній експеримент, експериментальні задачі.*

The Problem Statement. The education of engineering personnel involves the acquisition of theoretical knowledge by students and the acquisition of skills to apply it to solve research problems, as defined by industry standards of higher technical education (see, for example, the standard of specialty 142 "Power Engineering") (Standart, 2018).

The forced distance learning in Ukraine has significantly affected the ability of technical university students to conduct experimental research. Therefore, the problem of finding methods and tools that would allow students to acquire experimental skills in distance learning becomes more and more relevant.

Research analysis. Galatyuk M. Y. (2010) proposes to understand experimental competence as "a holistic system education, which consists of a set of relevant mental and practical abilities, skills, cognitive motives, as well as methodological knowledge and is a product of adequate purposeful educational and cognitive activity, the carrier of which is subject of this activity (student)". It is also emphasized that "experimental competence is an appropriate way of thinking".

Kurbanbekov B. A. et al (2016) defined the experimental research competence of a bachelor of science in physics as the ability and willingness of an individual to independently and effectively conduct experimental research, predict its results, and put them into practice.

Atamanchuk P. S. (2019) and Menderetsky V. V. (2006) identified such key research skills: "formation research goals and objectives; planning of research activities; selection and preparation of equipment for work; analysis of observations and research; interpretation of the results of the experiment, formulation of conclusions at the end of the work". The content of the listed skills is revealed in detail in the works (Заболотний, Демкова, 2015), (Кузьменко, 2013), (Слюсаренко, 2018) et al.

However, educators in many countries report an unsatisfactory level of students' experimental skills. Most often, complications arise when planning and conducting an experiment (Arnold et al., 2014), (Bitzenbauer, Meyn, 2021), (Kurbanbekov et al., 2016) and analyzing experimental results.

Teachers try to compensate for gaps in students' experimental skills by creating in their consciousness indicative basis for activity. For this purpose, various didactic materials are used. Galatyuk M. Y. (2010) used a plan for developing an experimental model and a guide to conducting pedagogical observations, Vorholzer A. et al. (2020) – special instructions, Nguyen, V. B. et al. (2019) – "work pages" and some others. Despite the differences in names and forms, all these materials resemble, to some extent, teaching materials used in traditional methods of conducting laboratory sessions in universities. Of course, on the one hand, such materials facilitate the accelerated acquisition of experimental skills by students, but on the other hand, they limit their independence and initiative.

The aim of the research is to analyze the possibilities of home experiments in the formation of experimental skills of higher education students and to compare them with the possibilities of other forms of organization of students' experimental activities in the formation of components of experimental competence.

Results and discussion.

The main material presentation. Any skill that a person acquires by performing the corresponding activity independently. According to higher education curricula, first-year students acquire their experimental skills in the study of physics by completing laboratory assignments on campus. However, students can also develop these skills by conducting experiments at home. This is especially important for distance learning.

In laboratory work students study some phenomena's, objects or their properties by conducting experiments using instruments, technical devices, and special educational equipment.

The value of laboratory work as a teaching method lies in "its ability to bridge the gap between theory and practice, to train students in research methods under natural conditions, to develop skills in the use of equipment, to teach them how to process measurement results and draw correct scientific conclusions" (Fitsula, 2006: 109).

During the lab session "...under the guidance of a teacher, a student conducts natural or simulated experiments, or experiments designed to confirm certain theoretical principles of a particular academic discipline, acquires practical skills in working with laboratory equipment, apparatus, computer equipment, measuring equipment, experimental research methods" (Fitsula, 2006: 142). The laboratory method of teaching is quite complicated, it requires the use of special equipment and the careful preparation of both the teacher and the students. However, with the use of Bring Your Own Device (BYOD) technology, some science lab work may not require specialized equipment (Zdeshchyts & Zdeshchyts, 2022).

The methodology for conducting laboratory sessions in a teaching laboratory (natural experiment) is well established. Students typically begin by independently studying the methodological instructions, which include the objectives of the work, its theoretical underpinnings, descriptions of laboratory equipment, the sequence of measurements and data analysis, and the tasks to be completed. As a result, the methodological instructions provide a fairly rigid framework for experimental activities, often not allowing much room for students to plan experiments or select equipment.

In addition to labs where students work with real equipment, teaching can also be done using demonstrative, computational, and interactive computer-based experiments. These methods have become widely used in moving to distance learning.

Demonstration experiments are most commonly used during lectures to provide visual representations of physical laws and their consequences. However, in the conditions of distance learning, such experiments in the form of screen casting have gained significant popularity as a substitute for a real experiment (Suhonen & Tiili, 2021), (Kalenik, 2020). In this method, the teacher shows a video with a real experiment, and the students record the data, process them and draw up the results. When using this method, the teacher shows a video of a real experiment, and the students record the data, process it, and write up the results. The obvious disadvantages of this method are the inability of students to select devices, plan an experiment, and work directly with the devices, i.e., the student acts as an observer and learns only to process and document the results of the experiment.

Computational experiment (Isychko, 2012), involves performing calculations according to the mathematical model of a physical phenomenon or object, and, if necessary, constructing graphs. Based on the results obtained, students draw conclusions about the course of the physical process, or the properties of the object of study. This form of laboratory training does not involve the use of instruments, measurements, and often the processing of experimental data. This means that a significant part of the experimental skills are not formed. It is most appropriate to use this form of organization of laboratory classes when their purpose is to analyze the consequences of physical laws by students.

An interactive computer experiment involves conducting experiments without direct contact of the student with the experimental setup, or in the complete absence of the setup. In the first case, students have remote access to the equipment, while in the second case, they manipulate a computer model (simulator) of real experimental equipment. The latter type of experiment is often referred to as a virtual lab.

When using remote access, students see on-screen images of the controls and monitoring elements. The real equipment is located in the lab and is accessed through a computer network. Under these conditions, the experiment's planning is limited by the capabilities of the software that facilitates the computer-to-equipment connection. Students do not have the opportunity to select equipment, and they do not work with it in a hands-on manner. It should be noted that most laboratory work in the general physics course does not provide for remote access, and this form of teaching is most often used in advanced courses in the study of special disciplines.

A computer simulator is a form of computer experiment. In this form, the computer reproduces the appearance of real laboratory equipment on the screen and, according to the mathematical model of physical laws, reacts to the researcher's actions (changes instrument readings, moves objects, etc.). Such works can be classified as simulators (Podlasov, Matviychuk, 2023). Also, when using them, students cannot design the experiment and select the equipment, as all of this is embedded in the program code that implements the simulator. Nevertheless, Masril et al (2019) concluded that students' experimental competence is significantly improved when using virtual laboratories. Moreover, Usman M. et al (2021) believes that computer simulations can completely replace real laboratory work. However, as Saltykova & Zavrazhna (2020) emphasized, in the absence of real actions, students do not develop the ability to work with real equipment, the ability to assess the influence of external factors on the results of measurements. Other researchers express a similar opinion, believing that virtual laboratory experiments offer significant advantages over real ones only when studying phenomena that cannot be directly observed.

A full-scale home experiment provides much more opportunity for the development of experimental skills, especially in distance learning. To conduct these experiments, students independently select and, if necessary, construct equipment, prepare the research plan, analyze and process experimental results, and draw conclusions. Of course, in case of complications, the student can turn to the tutor, but the tutor only gives advice, the final decision remains with the student. Thus, when performing the tasks of the home experiment, the student's personality develops, his/her perseverance in achieving the goal, showing attention to the "details" of the experiment, accumulating experience of cognitive and performing activities, elements of not only experimental but also research competence are formed (Holovan, Yatsenko, 2012), engineering thinking develops.

Certainly, the available equipment and "measuring instruments" limit the possibilities of home experiments. However, using a modern smartphone allows you to perform a wide range of different measurements, thanks to the presence of a stopwatch, the possibility of video recording and built-in sensors, whose signals are used to measure such quantities as acceleration, magnetic field induction, light brightness, sound intensity and others. Freely available applications PhyPhox, Physics ToolBox Suite, and Lab4U convert sensor signals into a data set that can be transferred to a remote computer in MS Excel spreadsheet format for further processing. The PhyPhox website (https://phyphox.org/, https://phyphox.org/topic/tools/) provides numerous examples of experiments that can be used as the basis for home research and experimental problems for students. In the first case, students explore the consequences of physical laws, and in the second, they use the data obtained in the experiment to determine the quantities sought by the problem condition.

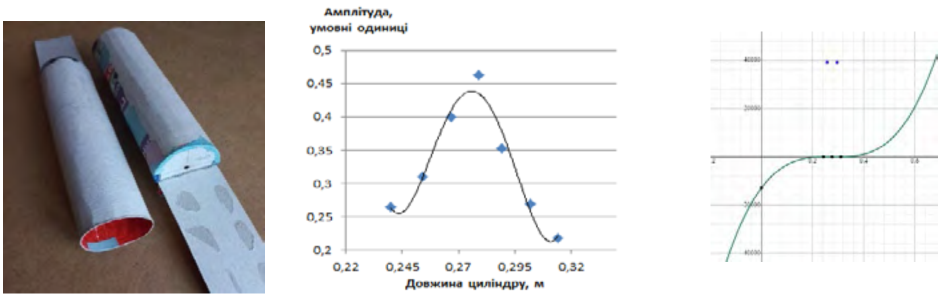
Here are some examples of home research.

Example 1 is analogous to the well-known laboratory work to determine the CP/CV ratio of air based on the results of measuring sound velocity.

For this investigation, students should have two smartphones and make coaxial cylinders with the small holes in the closed ends of each them (Fig. 1a).

Cylinders are easy to make out of a cardboard box under the flakes. The length of such a "resonance box" can be changed by moving the tubes relative to each other. A sound emitting smartphone is placed near the end of one cylinder and a sound receiving smartphone is placed near the other. By moving the cylinders relative to each other, it is necessary to determine the distance between the holes that corresponds to the maximum sound amplitude. The ratio of molar heat capacities can be found from calculated sound velocity.

To conduct such an experiment, the student must be able to create a plan, build equipment, select and use measuring instruments correctly, and also to use mathematical software packages for data analysis, such as MS Excel (or others). (Figure 1b). Furthermore, it is desirable to use a program to determine the maximum of the approximation function (Fig. 1c), for example Symbolab (the derivative graph constructed by the Symbolab program allows the student to estimate the possible error in determining the resonant frequency, hence the CP/CV error). According to the



а) б) в)

Fig. 1. Home experiment to determine the speed of sound
a) experimental "equipment"; b) dependence of sound wave amplitude of fixed frequency on tube length – MS Exel approximation; c) a derivative of the approximating function found in https://www.symbolab.com/solver

results of the study, the student must write a report and prepare to defend the research results.

Example 2 is an analog of a laboratory experiment to study the plane motion of a rigid body using a Maxwell's pendulum. In this case, a hollow metal serves as the pendulum and a pencil act as the axis. The moment of inertia of such a "pendulum" is calculated from the time dependence of its fall on the distance traveled. At home, the easiest way to obtain such a dependence is to record the movement of the "pendulum" on video and use the Tracker motion analysis program (https://physlets.org/tracker/) as shown in Fig. 2.

The same experiment can be the basis of the experimental problem of determining the moment of inertia of the "pendulum" by the known acceleration of the movement of its axis. Some other possible experimental problems are mentioned in our work (Podlasov S. et al, 2023).

Regardless of the form of the task for conducting the necessary experiment, the student must prepare a plan of the experiment, select or fabricate the necessary equipment, perform the planned measurements, process and analyze the obtained results and draw conclusions about their reliability. The only difference is that in the case of a laboratory experiment, a report of the work must be written, while in the case of an experimental problem, its solution should be presented.

Despite the advantages of home experiments for developing experimental skills, they also have some disadvantages. The most important of these is the limited capabilities of the "research" equipment, which does not allow for complex experiments. In educational laboratories, students have the opportunity to work with modern instruments and equipment, that are not available to them at home. Furthermore, while experiments in an educational laboratory are typically performed by all students within a predetermined time frame and with pre-prepared equipment, the home experiment requires much more effort and time and is to somewhat similar to inventive activity. For this reason, not all students are willing and able to conduct experiments at home. According to our data, despite the prospect of extra credit, only 25% to 60% of students in different groups perform such experiments.

In the spring semester of the year 2022/23 we offered the students of specialty 143 of the Institute of Thermal and Atomic Energy of NTUU "KPI named after I. Sikorsky" to solve at home the experimental problems on the topic of damped mechanical vibrations using the application Phyphox (Podlasov S. et al, 2023), also electrical damping

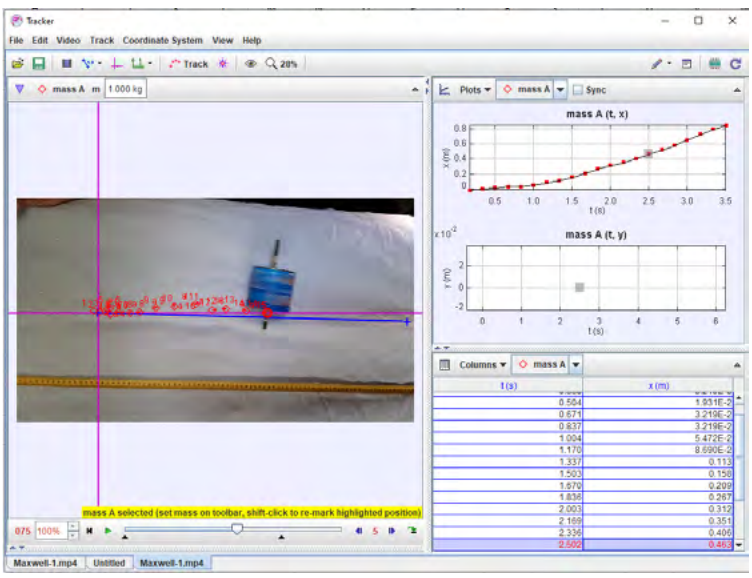
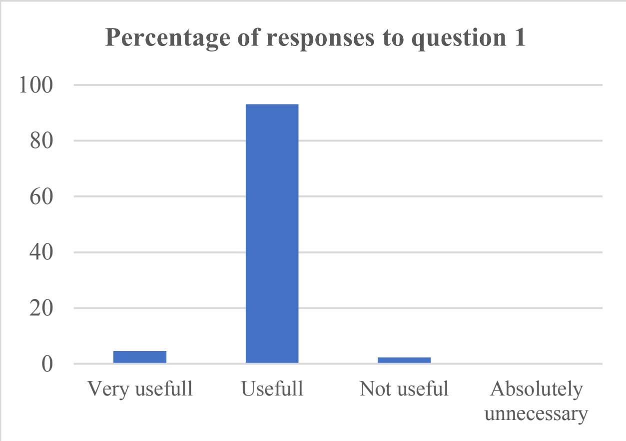
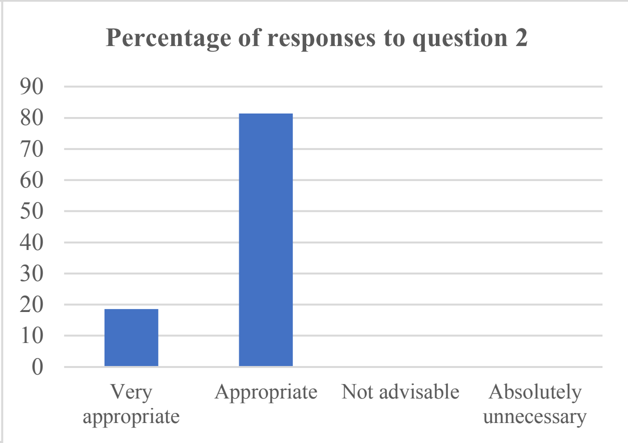


Fig. 2. Application of the Tracker application for analysis of Maxwell's "pendulum" movement



а)



б)

Fig. 3. Distribution of answers of students about usefulness and feasibility of applying experimental problems in the study of physics

oscillations and transient processes in an electrical RC circuit using the program Falstad electrical circuit modeling. After completing the assigned tasks, the students were surveyed. Fig. 3 shows the distribution of responses to two key questions: "1) Do you find it useful to solve experimental problems useful to understand theoretical concepts?" (Fig. 3a); "2) Do you consider it worthwhile to use experimental problems in the study of physics?" (Figure 3b). From the distribution of responses, it is clear that despite the complexities associated with the need to create "experimental equipment", students unanimously agree with the usefulness of using experimental problems.

Conclusion. Comparison of students' activities in carrying out home experiments and labs with the use of various means shows that despite the limitations associated with the used equipment and devices, the most complete experimental skills of students are formed in the independent experimentation at home. Moreover, another important consequence of students' independent home experiments is the development of engineering thinking in future professionals.

BIBLIOGRAPHY

1. Галатюк М. Ю. Формування експериментальної компетентності у контексті розвитку навчально-пізнавальної компетентності старшокласників. *Збірник наукових праць Кам'янець-Подільського університету ім. І. Огієнка. Сер. Педагогічна.* 2010. Вип. 16. С. 143–145.
2. Голований М. С., Яценко В. В. Сутність та зміст поняття «дослідницька компетентність». *Теорія та методика навчання фундаментальних дисциплін у вищій школі* : збірник наукових праць. 2012. Вип. VII. Кривий Ріг : Видавничий відділ НМетАУ. С. 55–62.
3. Ісичко Л. В. Використання математичного моделювання у навчанні фізики студентів вищих навчальних закладів : автореферат дисертації на здобуття наукового ступеня кандидата педагогічних наук. Кіровоград. 2012.
4. Заболотний В. Ф., Демкова В. О. Експериментальна компетентність як складова професійної підготовки студентів. *Вісник Чернігівського національного педагогічного університету. «Серія: Педагогічні науки».* 2015. Вип. 127. С. 49–52.
5. Здещиц В. М., Здещиц А. В. Використання технології BYOD в освітньому процесі в умовах дистанційного навчання студентів-фізиків. Кривий Ріг : Вид. Літерія. 2022. 185 с.
6. Каленик М.В. Роль демонстраційного експерименту у формуванні в учнів природничо-наукової компетентності. *Фізико-математична освіта.* 2020. Вип. 4(26). С. 51–55. DOI 10.31110/2413-1571-2020-026-4-009.
7. Кузьменко О. С. Формування професійної компетентності студентів вищих навчальних закладів з позицій акмеологічного підходу. *Збірник наукових праць Кам'янець-Подільського національного університету імені Івана Огієнка.* 2013. С. 93–95.
8. Мендерецький В. В. Навчальний експеримент в системі підготовки вчителя фізики : монографія. Кам'янець-Подільський: Кам'янець-Поділ. держ. ун-т, ред.-вид. від. 2006. 256 с.
9. Подласов С. О., Матвійчук О. В. Особливості проведення лабораторних робіт з фізики в технічному університеті під час дистанційного навчання. *ITLT.* 2023. Т. 93. Вип. 1. С. 152–162. DOI: 10.33407/itlt.v93i1.4974.
10. Подласов С., Свердліченко Д., Матвійчук О. Експериментальні задачі з фізики в технічному університеті. *Фізико-математична освіта.* 2023. Том 38. No 3. DOI 10.31110/2413-1571-2023-038-3-007.
11. Салтикова А. І., Завражна О. М. «Позитивні та негативні аспекти використання віртуальних лабораторних робіт під час навчання фізики в закладах вищої освіти». Розвиток інтелектуальних умінь і творчих здібностей учнів

та студентів у процесі навчання дисциплін природничо-математичного циклу «ІТМ*плюс – 2020» : матеріали ІІІ Міжнародної дистанційної науково-методичної конференції (квітень – травень 2020 р., м. Суми). Суми, 2020. С. 97–98.

12. Слюсаренко В. В. Експериментальна компетентність та її складові. Наукові записки. Серія Педагогічні науки. 2018. Вип. 168. С. 224–227. https://www.cuspu.edu.ua/ua/arkhiv-publikatsii/356-general-information/naukovi-chasopysy-tsdpu/pedahohichni-nauky/9127-eksperymentalna-kompetentnist-ta-yiyi-skladovi).

13. Стандарт вищої освіти України. Міністерство освіти і науки України : Наказ № 1136 від 19.10.2018 р. https://mon.gov.ua/storage/app/media/vishcha-osvita/zatverdzeni%20standarty/12/21/142-Enerh.mashynobud-bakalavr.21.10.22.pdf.

14. Фіцула М. М. Педагогіка вищої школи : навч. посіб. Київ : «Академвидав», 2006. https://library.udpu.edu.ua/library_files/412096.pdf.

15. Arnold J. C., Kremer K. & Mayer J. Understanding Students' Experiments – What kind of support do they need in inquiry tasks?. *International Journal of Science Education*. 2014. Vol. 36. Issue 16. Pp. 2719–2749. DOI: 10.1080/09500693.2014.930209.

16. Atamanchuk P. S., Bilyk R. N., Menderetsky V. V., Panchuk O. P. Development of experimeental competence student in higher education staff. *Pedagogical scienceеs/"colloquim-journal".* 2019. Nb. 3(27). Pp. 38–41.

17. Bitzenbauer, P., Meyn, J.-P. Fostering experimental competences of prospective physics teachers. *Physics Education.* 2021. Vol.56. Nb. 4. DOI 10.1088/1361-6552/abfd3f.

18. Kurbanbekov, B.A., Turmambekov, T.A., Baizak, U.A., Saidakhmetov, P.A., Abdraimov, R.T., Bekayeva, A.E., Orazbayeva, K.O. Students' experimental research competences in the study of physics. *International Journal of Environmental and Science Education*. 2016. Vol.11(18). Pp. 13069–13078. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85012008387&partnerID=40&md5=0fed3d21d77d173a5d584956198c98.

19. Masril, Hidayati, Y. Darvina Implementation of virtual laboratory through discovery learning to improve student's physics competence in Senior High School Journal of Physics : Conference Series. 2019. Nol.1185 (1). Art. № 012114. https://iopscience.iop.org/article/10.1088/1742-6596/1185/1/012114/pdf DOI: 10.1088/1742-6596/1185/1/012114.

20. Nguyen, V.B., Vylaychit, X. Nguyen, A.T. (2019) Developing of Experimental Competence of Laos Pupils in Science Classroom in Secondary School. *Journal for the Education of Gifted Young Scientists.* Vol. 7(3), 595–608. DOI: http://dx.doi.org/10.17478/jegys.573969.

21. Suhonen S. J. & Tiili J. A. Engineering physics laboratory work during lockdown – how and what? Proceedings – SEFI 49th Annual Conference : Blended Learning in Engineering Education: Challenging, Enlightening – and Lasting? 2021. Pp. 1278–1285. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85122912845&partnerID=40&md5=657d48afab35f25ee8188a046ef2f3b3.

22. Usman M., Suyanta, Huda K. (2021) Virtual lab as distance learning media to enhance student's science process skill during the COVID-19 pandemic". *Journal of Physics : Conference Series.* Vol. 1882. Pp. 1–8. https://iopscience.iop.org/article/10.1088/1742-6596/1882/1/012126/pdf.

23. Vorholzer A., Hägele J. J., von Aufschnaiter C. (2020) Construction of coherent instruction and investigation of competence development: Approaches and challenges exemplified with experiment related competence. *Unterrichtswissenschaft*. Vol. 48 (1). Pp. 61–89. DOI: 10.1007/s42010-019-00064-5.

REFERENCES

1. Halatiuk, M. Yu. (2010) Formuvannia eksperymentalnoi kompetentnosti u konteksti rozvytku navchalno-piznavalnoi kompetentnosti starshoklasnykiv. [The formation of experimental competence in the context of the development of educational and cognitive competence of high school students]. Zbirnyk naukovykh prats Kamianets-Podilskoho natsionalnoho universytetu imeni Ivana Ohiienka [Collection of scientific studies of Kam'yanets-Podilsky National University named after Ivan Ogienko] nb. 16, pp. 143–145. [in Ukrainian].

2. Holovan, M. S. & Yatsenko V. V. (2012). Sutnist ta zmist poniattia "doslidnytska kompetentnist" [The essence and content of the concept of "research competence"]. Teoriia ta metodyka navchannia fundamentalnykh dystsyplin u vyshchii shkoli: zbirnyk naukovykh prats [Theory and teaching methods of fundamental disciplines in higher education: a collection of scientific papers]. Issue VII, Kryvyi Rih. pp. 55–62. [in Ukrainian].

3. Isychko, L. V. (2012). Vykorystannia matematychnoho modeliuvannia u navchanni fizyky studentiv vyshchykh navchalnykh zakladiv [The use of mathematical modeling in teaching physics to students of higher educational institutions]. [Avtoreferat dysertatsii na zdobuttia naukovoho stupenia kandydata pedahohichnykh nauk. Kirovohrad], [Dissertation abstract for obtaining the scientific degree of Candidate of Pedagogical Sciences. Kirovohrad]. http://repository.pdmu.edu.ua/handle/123456789/11019. [in Ukrainian].

4. Zabolotnyi V. F., Demkova V. O. (2015) Eksperymentalna kompetentnist yak skladova profesiinoi pidhotovky studentiv. [Experimental competence as a component of professional training of students] Visnyk Chernihivskoho natsionalnoho pedahohichnoho universytetu. «Seriia: Pedahohichni nauky». [Bulletin of Chernihiv National Pedagogical University. "Series: Pedagogical Sciences]. issue 127. Pp. 49 – 52. [in Ukrainian].

5. Zdeshchyts V. M., Zdeshchyts, A. V. (2022) Vykorystannia tekhnolohii BYOD v osvitnomu protsesi v umovakh dystantsiinoho navchannia studentiv-fizykiv: navch. posibnyk [The use of BYOD technology in the educational process in the conditions of distance learning of physics students: education. manual]. Kryvyi Rih, Literiia. [in Ukrainian].

6. Kalenik, M. V. (2020). Rol demonstratsiinoho eksperymentu u formuvanni v uchniv pryrodnycho-naukovoi kompetentnosti [The role of demonstration experiment in the formation of natural science competence in students]. Physical and Mathematical Education. Issue 4 (26). Pp. 51–55. DOI 10.31110/2413-1571-2020-026-4-009. [in Ukrainian].

7. Kuzmenko O. S. (2013) Formuvannia profesiinoi kompetentnosti studentiv vyshchykh navchalnykh zakladiv z pozytsii akmeolohichnoho pidkhodu. [Formation of professional competence of students of higher educational institutions from the standpoint of acmeological approach] Zbirnyk naukovykh prats Kamianets-Podilskoho natsionalnoho universytetu imeni Ivana Ohiienka [Collection of scientific studies of Kam'yanets-Podilsky National University named after Ivan Ogienko]. Pp. 93–95. [in Ukrainian].

8. Menderetskyi V. V. (2006) Navchalnyi eksperyment v systemi pidhotovky vchytelia fizyky [The initial experiment in the system of training teacher of physics]. Kamianets-Podil.derzh.un-t, red.-vyd.vid. [Kamianets-Podil State University, editorial and publishing department]. [in Ukrainian].

9. Podlasov, S. O., Matviichuk O. V. (2022) Osoblyvosti provedennia laboratornykh robit z fizyky v tekhnichnomu universyteti pid chas dystantsiinoho navchannia [Particularities of physics laboratory work conducting at the technical university during distance learning]. ITLT. Vol. 93(1). Pp. 152–162. DOI: 10.33407/itlt.v93i1.4974. [in Ukrainian].

10. Podlasov, S., Sverdlichenko, D., Matviichuk O. (2023) Eksperymentalni zadachi z fizyky v tekhnichnomu universyteti [The experimental physics problems the technical university]. Fizyko-matematychna osvita [Physical and Mathematical Education]. Vol. 38. Nb.3. Pp. 50'56. DOI 10.31110/2413-1571-2023-038-3-007. [in Ukrainian].

11. Saltykova, A. I., Zavrazhna, O. M. (2020) Pozytyvni ta nehatyvni aspekty vykorystannia virtualnykh laboratornykh robit pid chas navchannia fizyky v zakladakh vyshchoi osvity [Positive and Negative Aspects of Using Virtual Laboratory Work while Teaching Physics in Higher Education Institutions]. Rozvytok intelektualnykh umin i tvorchykh zdibnostei uchniv ta studentiv u protsesi navchannia dystsyplin pryrodnycho-matematychnoho tsyklu «ITM*plius – 2020»: materialy III Mizhnarodnoi dystantsiinoi naukovo-metodychnoi konferentsii [Development of intellectual skills and creative abilities of pupils and students in the process of learning the disciplines of the natural and mathematical cycle "ITM*plus – 2020": materials of the 3rd International Distance Scientific and Methodological Conference]. Sumy. Pp. 97-98. https://repository.sspu.edu.ua/handle/123456789/9342. [in Ukrainian].

12. Sliusarenko V. V. (2018). Eksperymentalna kompetentnist ta yii skladovi. [Experimental competence and its components] Naukovi zapysky. Seriia Pedahohichni nauky. [Scientific notes. Series Pedagogical sciences]. Issue 168. Pp. 224–227. https://www.cuspu.edu.ua/ua/arkhiv-publikatsii/356-general-information/naukovi-chasopysy-tsdpu/pedahohichni-nauky/9127-eksperymentalna-kompetentnist-ta-yiyi-skladovi).

13. Standart vyshchoi osvity Ukrainy. Ministerstvo osvity i nauky Ukrainy : Nakaz № 1136 vid 19.10.2018 [Standard of higher education of Ukraine. Ministry of Education and Science of Ukraine. Order No. 1136 of October 19, 2018] [in Ukrainian].

14. Fitsula, M. M. (2006). Pedahohika vyshchoi shkoly. Navchalnyi posibnyk [Pedagogy of high school. Tutorial]. Kyiv : «Akademvydav». https://library.udpu.edu.ua/library_files/412096.pdf. [in Ukrainian].

15. Arnold J. C., Kremer K. Mayer J. (2014) Understanding Students' Experiments – What kind of support do they need in inquiry tasks?, International Journal of Science Education. Vol. 36. Issue16. Pp. 2719–2749, DOI: 10.1080/09500693.2014.930209

16. Atamanchuk P. S., Bilyk R. N., Menderetsky V. V., Panchuk O. P. (2019) Development of experimeental competence student in higher education staff. Pedagogical sciencees/"colloquim-journal". Nb3(27). Pp. 38–41.

17. Bitzenbauer, P., Meyn, J.-P. (2021) Fostering experimental competences of prospective physics teachers. Physics Education. Vol. 56. Nb. 4 DOI 10.1088/1361-6552/abfd3f

18. Kurbanbekov, B.A., Turmambekov, T.A., Baizak, U.A., Saidakhmetov, P.A., Abdraimov, R.T., Bekayeva, A.E., Orazbayeva, K.O. (2016) Students' experimental research competences in the study of physics. International Journal of Environmental and Science Education. Vol. 11(18). Pp. 13069–13078. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85012008387&partnerID=40&md5=0fed3d21d77d173a5d584956198c98

19. Masril, Hidayati, Y. Darvina. (2019) Implementation of virtual laboratory through discovery learning to improve student's physics competence in Senior High School. Journal of Physics : Conference Series. Vol. 1185(1). Art.№ 012114, https://iopscience.iop.org/article/10.1088/1742-6596/1185/1/012114/pdf DOI: 10.1088/1742-6596/1185/1/012114

20. Nguyen, V.B., Vylaychit, X., Nguyen, A.T. (2019). Developing of Experimental Competence of Laos Pupils in Science Classroom in Secondary School. Journal for the Education of Gifted Young Scientists. 7(3), 595–608. DOI: http://dx.doi.org/10.17478/jegys.573969

21. Suhonen S. J. Tiili J. A. (2021) «Engineering physics laboratory work during lockdown – how and what?» Proceedings – SEFI 49th Annual Conference: Blended Learning in Engineering Education: Challenging, Enlightening – and Lasting? Pp. 1278–1285. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85122912845&partnerID=40&md5=657d48afab35f25ee8188a046ef2f3b3.

22. Usman M., Suyanta, Huda K. (2021) Virtual lab as distance learning media to enhance student's science process skill during the COVID-19 pandemic". Journal of Physics : Conference Series, Vol.1882. 2021. 2021. Pp. 1 – 8. https://iopscience.iop.org/article/10.1088/1742-6596/1882/1/012126/pdf.

23. Vorholzer A., Hägele J. J., von Aufschnaiter C. (2020) Construction of coherent instruction and investigation of competence development: Approaches and challenges exemplified with experiment related competence. Unterrichtswissenschaft. 48 (1). Pp. 61–89. DOI: 10.1007/s42010-019-00064-5.