EDUCATION AND SCIENCE IN THE PERIOD OF GLOBAL CRISES AND CONFLICTS IN THE 21st CENTURY

COLLECTIVE MONOGRAPH

EDUCATION AND SCIENCE IN THE PERIOD OF GLOBAL CRISES AND CONFLICTS IN THE 21st CENTURY

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The monograph is recommended for publication by the Presidium of the National Academy of Sciences of Higher Education of Ukraine

Education and science in the period of global crises and conflicts in the 21st century : collective monograph / Compiled by V. Shpak; Chairman of the Editorial Board S. Tabachnikov. Sherman Oaks, California : GS Publishing Services, 2023. 331 p.

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PECULIARITIES OF TEACHING THE ELECTIVE COURSE "BASICS OF CHEMICAL METROLOGY": THE DEPARTMENT'S EXPERIENCE

Higher pharmaceutical education undergoes changes in accordance with the needs of the health care system and the requirements of international standards. The main goal of higher pharmaceutical education is to provide highly qualified training of pharmacists capable of critical thinking and making conscious and quality decisions in various practical situations of professional direction. At the same time, the main tasks are the formation of a comprehensively educated person, providing the necessary knowledge, skills, abilities for future professional activity in the conditions of rapid development of technology and science[1,2].

Chemical metrology is an essential aspect of pharmacy education as it ensures the accuracy and reliability of measurements in pharmaceutical analysis. It encompasses the science of measurement and the development of measurement standards, methods, and procedures. In the field of pharmacy, chemical metrology plays a crucial role in various areas, including drug formulation, quality control, and regulatory compliance[3,4]. Thus, the introduction of elective course "Ba-

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1   Anderson, C., & Arakawa, N. (2021). Pharmacy Education Development. *Pharmacy*, *9*(4), 168. https://doi.org/10.3390/pharmacy9040168

2   Papadopoulos, V., Goldman, D., Wang, C., Keller, M., & Chen, S. (2021). Looking ahead to 2030: Survey of evolving needs in pharmacy education. *Pharmacy*, *9*(1), 59. https://doi.org/10.3390/pharmacy9010059

3   Pushkarova, Y., & Zaitseva, G. (2022). Designing an online course for pharmacy students: Case study of basics of chemical metrology. *Anatolian Journal of Education*, *7*(2), 1-10. https://doi.org/10.29333/aje.2022.721a

4   Merone, G. M., Tartaglia, A., Locatelli, M., D'Ovidio, C., Rosato, E., de Grazia, U., Santavenere, F., Rossi, S., & Savini, F. (2020). Analytical Chemistry in the 21st Century: Challenges, Solutions, and Future Perspectives of Complex Matrices Quantitative Analyses in Biological/Clinical Field. *Analytica*, *1*, 44-59. https://doi.org/10.3390/analytica1010006

sics of chemical metrology" into educational process for pharmacy students was logical and necessary.

The process of formation of professional competences in the conditions of martial law does not deny the use of traditional forms of education – lectures, practical and seminar classes, which differ in their content, purpose, tasks and methods of implementation. In the same time, surely, the learning process in the conditions of martial law is impossible without the use of information technologies. The aim of this article is to describe the structure of the new elective course "Basics of chemical metrology" and the experience of its online learning in Bogomolets National Medical University under martial law in Ukraine.

The elective course "Basics of chemical metrology" was designed for pharmacy students of the second year of study at Bogomolets National Medical University and was introduced into the education curriculum for the first time in 2021/2022 academic year.

There were one hundred and forty three students enrolled in this course during 2021/2022 academic year and one hundred students enrolled in this course during 2022-2023 academic year.

The elective course "Basics of chemical metrology" was created on the base of the State Pharmacopoeia of Ukraine, namely according with the requirements to statistical analysis of results of chemical experiments and validation criteria for analytical procedures[5]. The 2.0-credit course consisted of ten lectures (ten hours), five seminar lessons (ten hours) and independent work of students (forty hours). The form of control of academic success is a differential credit. The information about the course topics and distribution of the hours between them is presented in Table 1.

Table 1.

Structure of the discipline «Basics of chemical metrology»

Name of topics	Number of hours			
	total	including		
		lectures	seminar lessons	independent work
1	2	3	4	5
Topic 1. Basics of metrology.	7	1	–	6
Topic 2. Errors of measurements.	10	1	2	7

5   Ukrainian Scientific Pharmacopoeial Center for Quality of Medicines. State Pharmacopoeia of Ukraine. URL: http://sphu.org/en/ukrainian-pharmacopoeia (11.11.2023)

	1	2	3	4	5
Topic 3. Statistical analysis of results of chemical experiments in accordance with the requirements of State Pharmacopoeia of Ukraine.	15	3	4	8
Topic 4. Validation criteria for analytical procedures in accordance with the requirements of State Pharmacopoeia of Ukraine.	10	1	2	7
Topic 5. Mathematical statistics and theory of probability.	10	2	–	8
Topic 6. Chemometrics and chemometric methods in chemistry.	8	2	2	4
Total hours	**60**	**10**	**10**	**40**

Continuation of table 1.

Duration of the course was five weeks: one seminar (two hours) and two lectures (two hours) per week. In 2021/2022 academic year course was studied during April-May, in 2022/2023 academic year – during January-February.

All students studied the course "Basics of chemical metrology" online in 2021/2022 academic year. During the 2022/2023 academic year it was implemented blended form of education in Bogomolets National Medical University. All lectures were online and for practical and seminar classes students chose the form of education (online or offline) themselves. Twenty one students from one hundred chose offline form of education.

It was created educational-methodical complex for teaching discipline "Basics of chemical metrology" on Ukrainian (for domestic students) and English (for foreign students) languages. It included academic curriculum, syllabus, presentations of lectures and recorded video lectures, methodical instructions for seminar classes, problems and cases for discussions during the seminars, student notebook, cards for assessment the knowledge of students.

Bogomolets National Medical University has implemented the platform LIKAR_NMU on the basis of Learning Management Systems Moodle for distance education[6].

The using portal LIKAR_NMU allows creating a well-structured teacher-student interaction[7]. Educational-methodical complex for teaching discipline

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6   Kuchyn, I., Vlasenko, I., Gashenko, I., Mykytenko, P., & Kucherenko, I. (2021). Creating the informational and educational environment of the University based on the distance learning platform LIKAR_NMU. *Archives of Pharmacy Practice, 12*(2), 66-74. https://doi.org/10.51847/5zZerOAbwA

7   Pushkarova, Y., Chkhalo, O., Reva, T., Zaitseva, G., & Bolotnikova, A. (2021). Using Information Technology in Teaching of the Course "Analytical Chemistry" in Bogomolets National Medical University. Archives of Pharmacy Practice, 12(3), 89-93. https://doi.org/10.51847/dvMCSbO1SE

"Basics of chemical metrology" were posted on a web-based learning platform LIKAR_NMU and available for students whole time (ID of course 6841).

The full-scale war worsened access to education. There are some main reasons to explain this fact:

1. Frequent air raid sirens.

2. Blackouts and problems with internet connection.

Each lecture was occurred like videoconference via Zoom. Seminar classes were occurred via Zoom or offline in compliance with the students choosing. For the fast communication between the teacher and students outside the class was used chat in Telegram.

We proposed the recorded video lectures for students who couldn't join the lecture via Zoom due to good reasons (air raid sirens, lack of light or internet connection, sickness). Students could found them on distance platform Likar_NMU or open the video lecture with QR code (Table 2). QR codes were sent to students in Telegram chat.

Table 2.

Topic of lectures and QR codes for recorded video lectures

Week	Topic	QR code
1	Metrology as a science of measurement. General concepts and basic terminology. The main stages of evolution of metrology. Legal metrology.	
	Errors of measurement, general concepts. Classification of errors. Errors in chemical analysis.	
2	Population and sample. Mean value, standard deviation and confidence limits.	
	Checking of the sample homogeneity. Assessment the equality of variances.	
3	Comparison of the results of quantitative analysis of the sample by two methods.	
	Validation of analytical procedures and tests.	
4	Basic concepts of probability theory.	
	Probability distributions for discrete and continuous random variables.	

5	Correlation analysis. Regression analysis.	
	Chemometrics as an interdisciplinary scientific discipline. Review of chemometrics tasks and main chemometric methods.	

Table 3 shows the information about lecture attendance in 2022/2023 academic year. As we can see QR code was also an effective and popular technology for sharing education materials for students as well as distance platform LIKAR_NMU.

Results of our communication with students showed that the student's choice in favor of a platform LIKAR_NMU or QR code depended on the device used (phone, tablet, laptop) and the strength of the Internet connection.

Table 3.

Lecture attendance in 2022/2023 academic year

Week	Number of students who joined the lecture via Zoom	Number of students who couldn't join the lecture via Zoom and studied the recorded video lecture via LIKAR_NMU	Number of students who couldn't join the lecture via Zoom and studied the recorded video lecture via QR code
1	62	17	21
2	53	25	22
3	65	14	21
4	58	23	19
5	64	21	15

Out-class activity of the students (independent work) included reading of recommended literature and articles, performing the tasks according to the curriculum of discipline, studying the lectures' material.

Student notebook and methodological instructions were used for student's out-class activity. Methodological instructions include actuality of the topic, general aims of the seminar class, key questions, list of main terms, content of the topic (theory), questions and tasks for self-control and recommended literature.

Student notebook it's a short form of methodological instructions. It contains the necessary information for successful preparing for seminars and allows students to keep their written records.

Students had the methodological instructions and student notebook in PDF and DOC/DOCX formats.

Figure 1 demonstrates the screen of the page of student notebook for topic "Calculation of the basic metrological characteristics of analysis methods. Presentation of the results of quantitative analysis».

Figure 1. Screen of the page of student notebook

Organizational structure of each seminar is presented in Table 4[3].

Table 4.

Organizational structure of the seminar

Stages of the seminar	Time distribution	In-class activity
Preparatory stage	**15 min.**	
Organizational issues	5 min.	
Formation of motivation	5 min.	Discussion the actuality of the topic
Control of the initial level of students' knowledge	5 min.	Five test questions or oral interview
Main stage	45 min.	
Study of the topic		Discussion the key questions according to the topic of seminar, answering the students' questions, consideration of calculated and situational problems (cases)
Final stage	**30 min.**	
Control of the final level of students' knowledge	20 min.	Solving the problems (cases)
Overall results. Summaries. Assigning marks	10 min.	

Students who couldn't join the seminar in Zoom, studied the topic independently. Also for these students were additional consultations at a time convenient for them. The majority of such consultations were spontaneous.

For students who couldn't solve the tasks via platform LIKAR_NMU due to the failed connection, we used the alternative way of communication via messenger Telegram.

Topics of the seminar lessons, general aims and key questions for them are shown in Table 5.

Table 5.

Topics of seminar lessons, general aims and key questions for them

№	Topic	General aims	Key questions
1	Rounding of the measurements results. Estimation of the presence of outliers in results.	✓ to know rules for determining the number of significant figures; ✓ to know the scientific notation of very large or very small numbers; ✓ to know rules for rounding of data in a computation; ✓ to know what are outliers; ✓ to know the Rule of the Huge Error; ✓ to know the Dixon Test (Q-test); ✓ to know the Grubbs Test.	1. Significant figures. 2. Rounding of data in a computation. 3. Outliers. 4. Procedures for a statistically supported decision with respect to rejection or retention of a suspected outlier.
2	Calculation of the basic metrological characteristics of analysis methods. Presentation of the results of quantitative analysis.	✓ to know examples of application of statistical methods in chemistry; ✓ to know difference between sample and population; ✓ to know formulas for calculation the basic metrological characteristics (mean, standard deviation, variance, coefficient of variation, relative standard deviation, standard deviation of the mean (standard error of mean), degrees of freedom, confidence interval (confidence limits)).	1. Application of statistical methods in chemical experiments. 2. Basic metrological (statistical) characteristics. 3. Presenting data.
3	Comparison of two methods by reproducibility analysis. Comparison of the mean values of two samples.	✓ to know algorithm for comparison of standard deviations; ✓ to know algorithm for comparison of two experimental means if the standard deviations do not differ significantly; ✓ to know algorithm for comparison of two experimental means if the standard deviations differ significantly.	1. F-test for the comparison of standard deviations. 2. Comparison of two experimental means. 2.1. Case I. The standard deviations do not differ significantly. 2.2. Case II. The standard deviations differ significantly.

4	Estimation of the repeatability of results. Estimation of the accuracy of measurements.	✓ to know the difference between precision, bias and accuracy; ✓ to know the difference between repeatability and reproducibility; ✓ to know how estimate systematic error; ✓ to know how estimate repeatability; ✓ to know how compare an experimental mean with a known value.	1. Precision, bias and accuracy. 2. Repeatability and reproducibility. 3. Comparison of an experimental mean with a known value.
5	Calculation and statistical evaluation of linear dependence parameters. Estimation of the limit of detection.	✓ to know algorithm for calculation the product-moment correlation coefficient; ✓ to know algorithm for calculation the slope of regression line; ✓ to know algorithm for calculation the intercept of regression line; ✓ to know algorithm for calculation the errors in the slope and intercept of the regression line; ✓ to know algorithm for calculation the limit of detection.	1. The product-moment correlation coefficient. 2. The line of regression of y on x. 3. Errors in the slope and intercept of the regression line. 4. Limit of detection.

Case studies are effective instructional method for teaching short elective courses[3]. That is why case studies are an integral part of lectures and seminar lessons during the study chemical metrology.

Let us demonstrate the some case study examples from our lectures and seminar classes[8,9,10]:

1) A set of data was taken to calibrate a measuring instrument. In the course of a preliminary manual plot of the data (eye estimate), it was noticed that one point appeared to be much farther from the line than the others, so it was ignored for the moment. The analyst was tempted to reject it because he feared (and rightly so) that its inclusion (if it were an outlier) would falsify his least squares fit. The average deviation of the plotted points from the line (observed – curve) was 0,012. The deviation of the suspected point from the line was 0,06. Use the Huge Error Rule for statistically supported decision with respect to rejection or retention of a suspected outlier.

2) Assume that an analyst used a certain method to determine the amount of lead in a water sample and estimated $s = 2,5$ µg/L based on 7 measurements. At a later date, she analyzed another water sample for its lead content, using the same

8   Miller, J., & Miller, J. C. (2018). *Statistics and chemometrics for analytical chemistry*. Pearson education.

9   Taylor, J. K., & Cihon, C. (2004). *Statistical techniques for data analysis*. CRC Press.

10   Crowder, S., Delker, C., Forrest, E., & Martin, N. (2020). *Introduction to Statistics in Metrology*. Cham, Switzerland: Springer.

method, and obtained $s = 3{,}3$ µg/L based on 10 measurements. Were both sets of measurements equally precise with 95 % confidence?

3) The absorbance scale of a spectrometer is tested at a particular wavelength with a standard solution which has an absorbance given as 0,470. Ten measurements of the absorbance with the spectrometer give = 0,461, and $s = 0{,}003$. Find the 95 % confidence interval for the mean absorbance as measured by the spectrometer, and hence decide whether a systematic error is present. Make conclusion about accuracy of results.

Students got the mark for each seminar class. Figure 2 demonstrates the distribution the marks according with the topics during 2022/2023 academic year.

Unexpectedly, it turned out that the most difficult topic was topic 1. It can be explain by that fact that there is not enough time for detailed consideration rounding of data in a computation and estimation of the presence of outliers. Therefore, we will ask to increase the number of hours for studying this course and divide above two points into separate seminar lessons.
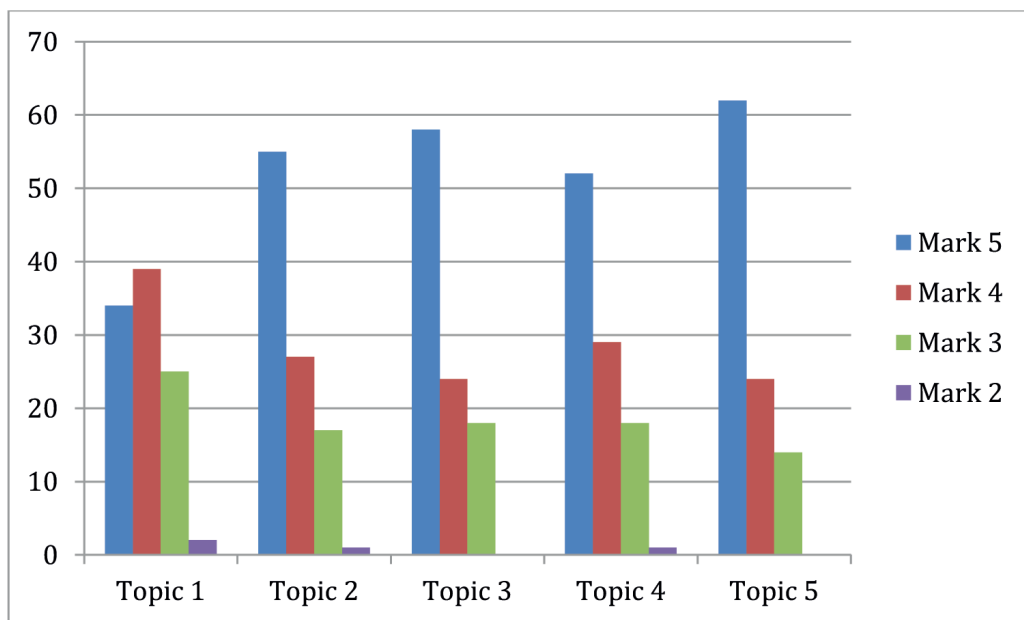

Figure 2. Distribution the marks according with the topics during 2022/2023 academic year

So, learning outcomes for discipline can be described as:

– students should know: subject and tasks of chemical metrology; general metrological characteristics of chemical analysis; classification of errors in chemical analysis and the reasons for their occurrence; basics

of validation of analytical methods and tests; basics of mathematical statistics and probability theory; subjects and tasks of chemometrics, application of its main methods for processing the results of chemical experiment;

– students should be able to: perform calculations of the main metrological parameters of the chemical analysis; estimate the presence of outliers in results; estimate the repeatability of results; estimate the accuracy of measurements; to compare two methods by reproducibility analysis; to compare the mean values of two samples; to determine the parameters of linear dependence; to determine the limit of detection; to interpret the results of metrological processing of measurement results.

Number of students who received grades of A, B, C, D and E in the online elective course during 2021/2022 academic year and in the blended form of education during 2022/2023 academic year are shown in Table 6. The most students earned grades A, B and C.

Note that the majority of students chose online form of education during 2022/2023 academic year. Analysis of students' performance during two academic years show that proposed structure and organization of online course "Basics of chemical metrology" are effective and allow students to achieve necessary learning outcomes.

Table 6.

Number of students who received different grades during 2021/2022 and 2022/2023 academic years

Academic year	A (%)	B (%)	C (%)	D (%)	E (%)	Average mark
2021-2022 (143 students)	90 (62,9 %)	28 (19,6 %)	9 (6,3 %)	10 (7,0 %)	6 (4,2 %)	4,52
2022-2023 (100 students)	62 (62,0 %)	14 (14,0 %)	16 (16,0 %)	5 (5,0 %)	3 (3,0 %)	4,54

Table 7 shows the students' performance independently for online and offline students during the 2022/2023 academic year. One can see, that online form of education was not worse than offline form of education. This may also suggest that the online course study was well organized using different information technologies.

Table 7.

**Comparison of the online and offline education
forms during 2022/2023 academic year
(number of students who received different grades)**

Form of education	A (%)	B (%)	C (%)	D (%)	E (%)	Average mark
Offline (18 students)	7 (38,9 %)	2 (11,0 %)	7 (38,9 %)	1 (5,6 %)	1 (5,6 %)	4,3
Online (82 students)	55 (67,1 %)	12 (14,6 %)	9 (11,0 %)	4 (4,9 %)	2 (2,4 %)	4,6

Table 8 shows the students' performance for online students during the 2022/2023 academic year in accordance with their attendance of the seminar classes. We can observe a direct relationship between student's academic performance and their attendance at seminar lessons. This allows us to conclude that the main role in online education is played by the teacher, joint discussion and explanations of the key questions, answering the students' questions, consideration of calculated and situational problems (cases). By itself educational-methodical complex can't provide the students with high level of knowledge.

Table 8.

**Comparison of the online students' performance
in accordance with their attendance
of the seminar classes**

Attendance of seminar classes	A	B	C	D	E	Average mark
Students, who attended all seminar classes (total 65 students)	54	11	–	–	–	4,8
Students, who attended 3-4 seminar classes (total 10 students)	1	1	7	1	–	4,0
Students, who attended 1-2 seminar classes (total 7 students)	–	–	2	3	2	3,3

Eighty seven students (2022/2023 academic year) completed the anonymous voluntary 6-question post-course survey. The 5-point scale survey was used, where 5 was means "Strongly agree", 4 – "Agree", 3 – "Neither agree nor disagree", 2 – "Disagree" and 1 – "Strongly disagree". Results are shown in Table 9. Students highly rated the quality of the course and its significance for the future profession of a pharmacist.

Table 9.

Course evaluation

Statement	Average point
Course is useful for better understanding the future pharmacists work	4,1
Lectures are informative	3,9
The seminars are interactive	4,0
Methodical instructions are informative and sufficient for understanding the topics	3,9
Student notebook is useful and comfortable way for keeping the information about the course	3,7
I would recommend this elective course to other students	4,2

Living conditions during martial law pose new challenges to teachers of Ukraine. They require professionalism, quick adaptation and a creative approach to the sharing of educational material among students. But even in such difficult conditions it is possible to acquire knowledge and professional competencies. The online elective course "Basics of chemical metrology" was successfully implemented under martial law during 2021/2022 and 2022/2023 academic years for pharmacy students of the second year of study at Bogomolets National Medical University.

Learning the course "Basics of chemical metrology" enabled Ukrainian students to form the knowledge and skills regarding the assessment of metrological characteristics of chemical analysis methods, validation of analytical methods and tests; and to acquire of statistical processing skills and presentation of measurements results. The responses to survey questions revealed an overall positive attitude of students to the organizing the course and its quality.

The practice of distance learning has demonstrated that this approach can be equally effective as face-to-face education. The possibilities of modern digital technologies make it possible to quickly establish both the informational component of education and the control of students' knowledge.