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Evaluation of Effectiveness of Teaching Medical Informatics-Related Courses: the TNMU case

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Abstract: Domination of traditional pedagogical strategies in the area of medical education worldwide and in Ukraine is admitted. Definition of Medical Informatics as an interdisciplinary multi-domain field of studying is given. The importance of assessment, comparing, validation and evaluation of different Medical (Health) Informatics academic courses is underscored. New challenges for high medical education area inferred by global threats like worldwide pandemic and military aggressions are emphasized. The necessity for the widening of implementation of the EMR MIS in the Ukraine healthcare system is noted. Lack of digital literacy as one of the key problem during implementation of the EMR MIS is signed. The significance of the proper education methodology for the teaching of the Medical Informatics is confirmed. The experience of teaching of Medical Informatics-related courses at the I. Ya. Horbachevsky Ternopil National Medical University is shown. Composition of typical Medical Informatics course and its delivery using Moodle LMS is presented. The pedagogical experiment for evaluation of students' theoretical knowledge in the MIS EMR topics during timespan of their education process is conducted. The statistical analysis of the dataset contains results of an assessment of students' knowledge is performed. The significant improvements in theoretical understanding of MIS EMR topics for senior students are proved. This confirms the successfulness of TNMU's Medical (Health) Informatics curriculums development and delivering in enhancing both general digital literacy as well as specific healthcare-related IT skills of students.

Keywords: Medical Education; Distance Education; Medical Informatics; assessment of teaching process; data analysis; Medical Information Systems; Electronic Medical Records; high education in Ukraine; Moodle LMS; Project TransLeader.

Ocena Efektywności Kursu Nauczania z Dziedziny Informatyki Medycznej na Przykładzie TNMU

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Streszczenie: Tradycyjne strategie pedagogiczne nadal dominują w obszarze edukacji medycznej na świecie, w tym w Ukrainie. W artykule przedstawiono definicję informatyki medycznej jako interdyscyplinarnego kierunku studiów. Podkreślono znaczenie oceny, analizy porównawczej i walidacji kursów edukacyjnych z zakresu informatyki medycznej („informatyki zdrowotnej"). Zidentyfikowano nowe wyzwania dla szkolnictwa wyższego w dziedzinie medycyny, wynikające z globalnych zagrożeń, takich jak pandemie czy konflikty zbrojne. Zwrócono uwagę na potrzebę szerszego wdrożenia systemów MIS w systemie opieki zdrowotnej w Ukrainie. Brak umiejętności cyfrowych został wskazany jako jedno z kluczowych wyzwań podczas implementacji MIS EMC. Podkreślono wagę stosowania odpowiedniej metodyki nauczania w trakcie zajęć z informatyki medycznej. Opisano doświadczenia z prowadzenia zajęć z tego zakresu na Tarnopolskim Narodowym Uniwersytecie Medycznym (TNMU). Przedstawiono strukturę typowego kursu „Informatyka medyczna" oraz proces jego realizacji z wykorzystaniem platformy Moodle. Przeprowadzono eksperyment pedagogiczny oceniający wiedzę teoretyczną studentów w zakresie MIS EMC na różnych etapach studiów. Analiza

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statystyczna wyników wykazała istotną poprawę teoretycznego zrozumienia tematów związanych z MIS EMC wśród studentów starszych lat. Wyniki potwierdzają skuteczność opracowywania i prowadzenia programów edukacyjnych z zakresu informatyki medycznej na TNMU, które zwiększają zarówno ogólne kompetencje cyfrowe, jak i specjalistyczne umiejętności informatyczne związane ze zdrowiem.

Słowa kluczowe: Edukacja Medyczna; kształcenie na odległości; Informatyka Medyczna; analiza procesu edukacyjnego; analiza danych; Systemy Informacji Medycznej, Elektroniczna Dokumentacja Medyczna; Szkolnictwo wyższe w Ukrainie; Moodle LMS; Projekt TransLeader.

1. Introduction

The problem statement. The field of medical education has traditionally relied upon the certain level of conservative educational strategies and approaches. Pedagogical methods such as “didactic learning”, “direct instruction”, “repetition” and “case studies” have been regarded as the “gold standard” and the most common methods of traditional teaching in the area of healthcare studies [1], [2], [3]. “Didactic lectures” or “didactic classes” have been the standard and the most common method of traditional teaching approach in the area of medical education for generations [2], [3], [4].

Fortunately, the rapid development and advances in Information and Communication Technologies (IT/ICT) fields have allowed significant progress in medical education, providing a foundation for modernizing healthcare education. In recent decades, medical students have increased their access to mobile educational tools and online services for learning in contrast to traditional resources such as lectures, textbooks and tutorials [1], [2], [5], [6]. Blended classes, online lecturing and various types of online quiz techniques have become widely introduced in medical educational institutions [3], [4], [5], [6], [7]. Online quiz systems / question banks have also emerged as popular online learning tools being used by students studying for different licensing examinations (“Krok” in Ukraine, “Step” in USA, etc) [1], [3]. Further innovations comes in form of special software solutions for integration of visual assistance techniques like video-conferencing, telepresence (remote participation), Virtual Reality (VR), Digital Patient Simulation (DPS), etc. [4], [5], [6], [7].

Another direction of the innovating of medical education process lays upon wide introduction of the Medical (Health) Informatics courses in the academic curriculums. Medical Informatics (MI), a subset of Health Informatics (HI), is an interdisciplinary field covers understanding of knowledge from different domains, ranging from medical science, through the workflow of health care environments, and up to specific Information Technologies (IT) topics. These IT-specific areas and skills include the designs of Medical (Clinical) Information Systems (MIS), management of healthcare data, and the development and maintenance of Electronic Medical (Health) Record (EMR/EHR) Systems [8], [9].

Analysis of recent studies and publications. The establishment of MI/HI programs in universities worldwide aims to address the increasing demand for trained personnel to manage health information [9]. Modern medical education should prepare future medical professionals to the effective usage of the capabilities and features of contemporary MIS for patients’ data management. To achieve this goal, mentioned above modern learning tools and technologies have to be implemented in higher medical education. [3], [7], [8], [10].

However, as the number of MI/HI educational programs grows, so do the variations in their quality and scope. One example of a challenge for MI/HI curriculum design: students may come from various backgrounds, such as not only medicine, but nursing, computer science, information technology, and even engineering. This underscores the need to investigate, compare, validate and evaluate these programs - a topic scholars are actively exploring [4], [8], [11], [12], [13], [14], [15]. Most common approach on academic program evaluation includes (but not limited to) in addressing the following research questions:

- Exploring the essential components of a MI/HI curriculum in medical school,
- Assess the methods of evaluating the effectiveness of MI/HI education,
- Examine the modes of delivery of a MI/HI-focused curriculums [12], [13], [14], [15].

In addition, recent challenges such as military invasion, (bio)terrorism and global pandemics (like COVID-19) have introduced new demands and requirements for organizing the educational process, particularly in medical education. Higher education institutions must be prepared to transition to fully online and remote educational models with minimal time and adjustments, almost instantaneously [16], [17], [18], [19], [20], [21]. The experience of full-scale Russian

military aggression in Ukraine, coupled with three years of war, has further emphasized the importance of such preparations.

The research goal is to present TNMU's experience in teaching of Medical Informatics through the evaluation of the effectiveness of the educational process using comparative analysis of students' theoretical knowledge of the MIS EMR topics during timespan of their education process.

2. Educational methodology. Teaching the Medical Informatics-related courses at TNMU

The Medical Informatics course at TNMU was introduced in 1997. For decades, the MI course at TNMU was offered to the second-year students of the medical faculty. The number of educational hours, as well as an exact content, was constantly adjusted accordingly to official requirements and experience of faculty teachers. Initially, the MI course was taught in a very classical way, using in-class lecturing, practical trainings, directly instructed by teachers, oral questioning and written examination. In 2006 elements of DE technologies were employed for the first time to assess students' self-preparation to upcoming classes via online quiz (LMS Moodle v1.x was used) [10], [20]. In 2012, a decision was made by TNMU's senate to extending the usage of DE technologies and LMS Moodle capabilities in the learning process.

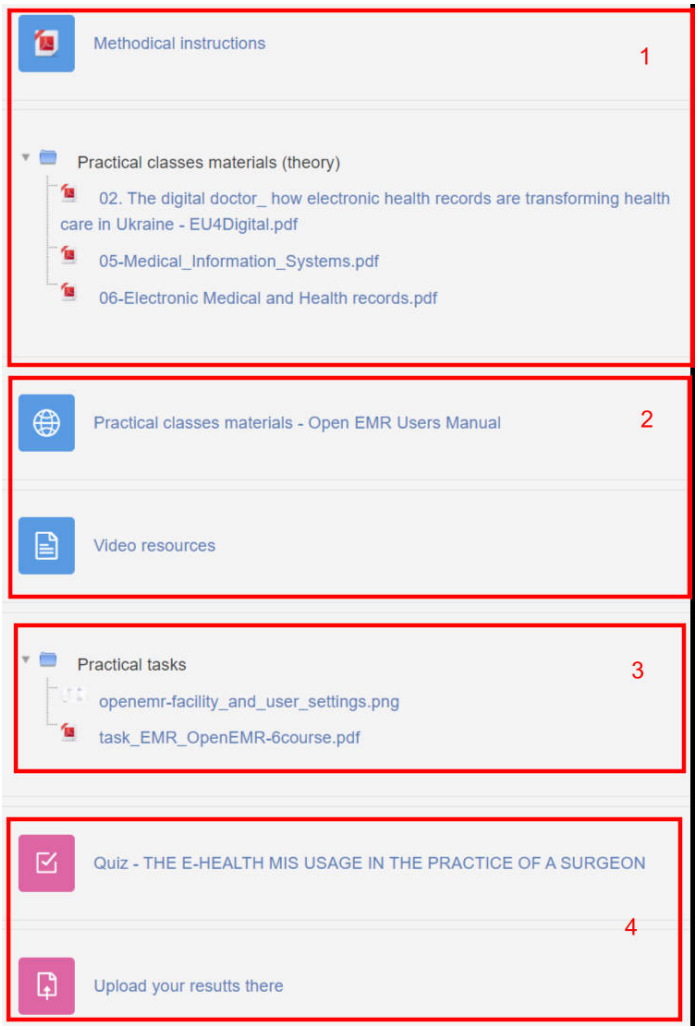


Figure 1. Structure of a topic of typical MI-related course in LMS Moodle (https://moodle.tdmu.edu.ua)

Thus, the existing MI course (https://moodle.tdmu.edu.ua/course/view.php?id=403) was re-designed to implement "blended" educational strategy [20], [21] with selected compulsory online activities. According to internal TNMU methodological recommendations, a topic of the typical MI-related course in LMS Moodle should include the following elements (Figure 1):

1. Required theoretical materials and methodical instructions.
2. List of tasks which must be completed by students (in-class or online).

3. Recommended additional educational materials (UR's. videos, etc.).

Assessment tools. An "assignment" activity allows students to submit results of their practical works. A "quiz" activity is used to perform assessment of theoretical knowledge.

Since 2021, the MI course has been taught to the 1st year students but still includes the same 14 hours of lectures, 32 hours of practical classes and about 60 hours assigned to self-guided work as before. The overall experience of teaching of the MI course in both "blended" as well as fully distance modes was presented early [20], [21]. It is important to note that the course always included a section introducing Medical Information Systems (MIS) and their use to support and maintain Electronic Medical Records (EMR) [22].

In 2022, despite military aggression, further steps in the digital transformation of the healthcare system were announced by the Ministry of Health of Ukraine in cooperation with international organizations such as EU4Digital and USAID [23]. These steps concentrated exactly on extension of application of various MIS to support and maintain of patient's EMR. Digital literacy in the area of MIS EMR usage among practicing physicians was considered a major challenge.

As a response to this increasing demand, a new course on MIS EMR usage was introduced in TNMU under the title "THE E-HEALTH MIS USAGE IN THE PRACTICE OF A PHYSICIAN" (https://moodle.tdmu.edu.ua/course/view.php?id=4950). Currently, the course includes 6 hours of classes fully dedicated to practical interaction with a live "sandbox" of the Ukraine's national eHealth digital system (The Ukrainian Ministry of Health, n.d.) [24], using an educational subscription to the commercial MIS "Helsi" (https://reform.helsi.me/). The first semester of this course has been delivered in 2023/2024 academic year by the authors of this paper to the sixth-year students with confident success and great engagement from the Ukrainian students.

At the same time, the authors recognized additional challenges when presenting this course to foreign students. Since the authors do not have access to respective national digital health information systems (if such even existed), an international version of this course was adjusted to emphasize the role of MIS and EMR solutions in deploying of modern healthcare systems in developing countries (https://moodle.tdmu.edu.ua/course/view.php?id=5228). The free- and open-source general-purpose MIS EMR OpenEMR (https://www.open-emr.org/) and OpenMRS (https://openmrs.org/) were selected for conducting practical trainings as they are widely used in developing countries.

3. Research methodology. MIS EMR Knowledge Evaluation Experiment Design

Due to the introduction of the new MIS EMR-oriented course, the authors were provided with a quite special opportunity to measure students' performance directly and conduct a cross-evaluation of their knowledge over time of their education:

- In the 2019/2020 academic year, during their second year of study, foreign students were introduced to the theoretical background of MIS and EMR along with basic practice of using of the OpenEMR;
- In the 2023/2024 academic year, during their sixth year of study, the same cohort of foreign students extended their theoretical knowledge in the area of MIS and EMR, with more comprehensive practice of using of the OpenEMR.

The authors were aware that OpenEMR MIS had significantly evolved between 2019 and 2024: the major version had been upgraded from 5.x to 7.x with multiple new features had added and significant changes to the User Interface (UI) had made. In contrast, the general theoretical background for MIS EMR remained based on the same key principles, definitions, classifications and core standards [25], [26]. Therefore, validating the students' theoretical knowledge was an obvious choice. Consequently, the aim of this paper is to present TNMU's experience in MI education based on the evaluation of the effectiveness of the educational process through a comparative analysis of students' knowledge of the MIS EMR topic during timespan of their education process.

In the 2019/2020 academic year, after MIS EMR topic were completed, students were given a quiz to assess their theoretical knowledge. The quiz was composed of 24 questions randomly selected from a question bank of size about 150 multiple-choice questions, each with one correct answer and four distractors. The quiz was conducted using Moodle LMS, with two attempts allowed and a time limit of 24 minutes per attempt. The final grade was calculated as the average score from both attempts by the Moodle quiz module (https://moodle.tdmu.edu.ua/mod/quiz/view.php?id=79187).

To ensure reliable knowledge evaluation in the 2023/2024 academic year, the authors decided to repeat the same assessment from 2019/2020 academic year. A special quiz activity was created in the new course and question bank was reused with only minor changes (https://moodle.tdmu.edu.ua/mod/quiz/view.php?id=312106). About 10% of the questions were removed as they were no longer relevant, but none were added to maintain question bank's consistency with the 2019/2020 version. During the 2023/2024 classes, students were informed that the theoretical background for

the MIS EMR course is solely the same as it was 2019/2020 period, with additional emphasis on new as well as irrelevant concepts. Finally, all students were obligated to complete the new quiz in Moodle LMS without being directly informed that the question bank had been reused.

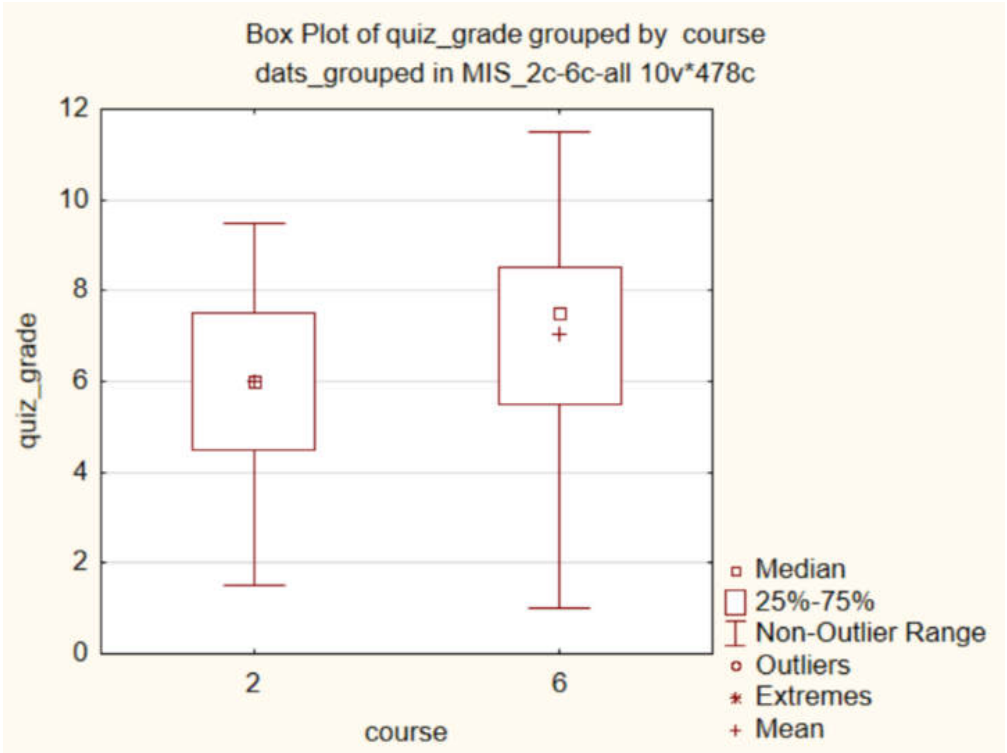
It is important to note that in both academic years (2019/2020 and 2023/2024) the corresponding classes were delivered in a fully distance education mode using Moodle LMS for managing education materials and activities and MS Teams for interactive collaboration. The DE format was caused by COVID pandemic in the 2019/2020 and in the 2023/2024 it was a result of military invasion to Ukraine.

The authors must admit that, despite butch of modern IT/ICT technologies being involved, the overall pedagogical approach to teaching these courses remained based on traditional strategies such as "didactic learning", "direct instruction", "repetition" and "case studies" [1], [2], [3], [4]. This is due to the relatively strict regulations in the area of medical education in Ukraine that being enforcing by the Ministry of Health of Ukraine. On the other hand, the assessment of the theoretical knowledge, obtained by students from the specific topics of MI-related courses in form of online quizzes using Moodle LMS, has been widely adopted to use in the MI-related courses for many years. Thus, this kind of "formative assessment" pedagogical strategy has demonstrated its reliability and effectiveness in teaching of Medical Informatics-related courses at the MI department of TNMU.

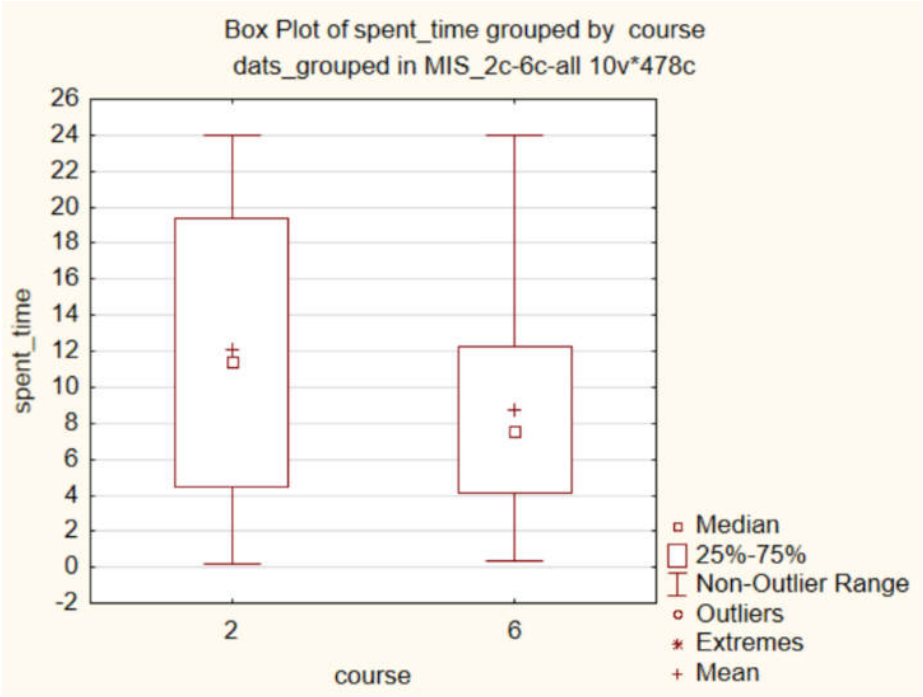
4. Results and discussion

The reports with students' grades and the time they spent on quizzes were downloaded from both Moodle courses as the dataset for analysis. The dataset was filtered to include only students who had completed both quizzes, resulting in 239 matched records. Finally, two samples were formed: ("quiz_grade" and "spent_time" with general statistical characteristic as shown in Figure. 2.

First, the distribution plots (Figure 3) were drawn. Obtained charts clearly suggested potential improvements in students' grades by the sixth year of study compared to their second year, as well as reduction in the time spent answering the quizzes.

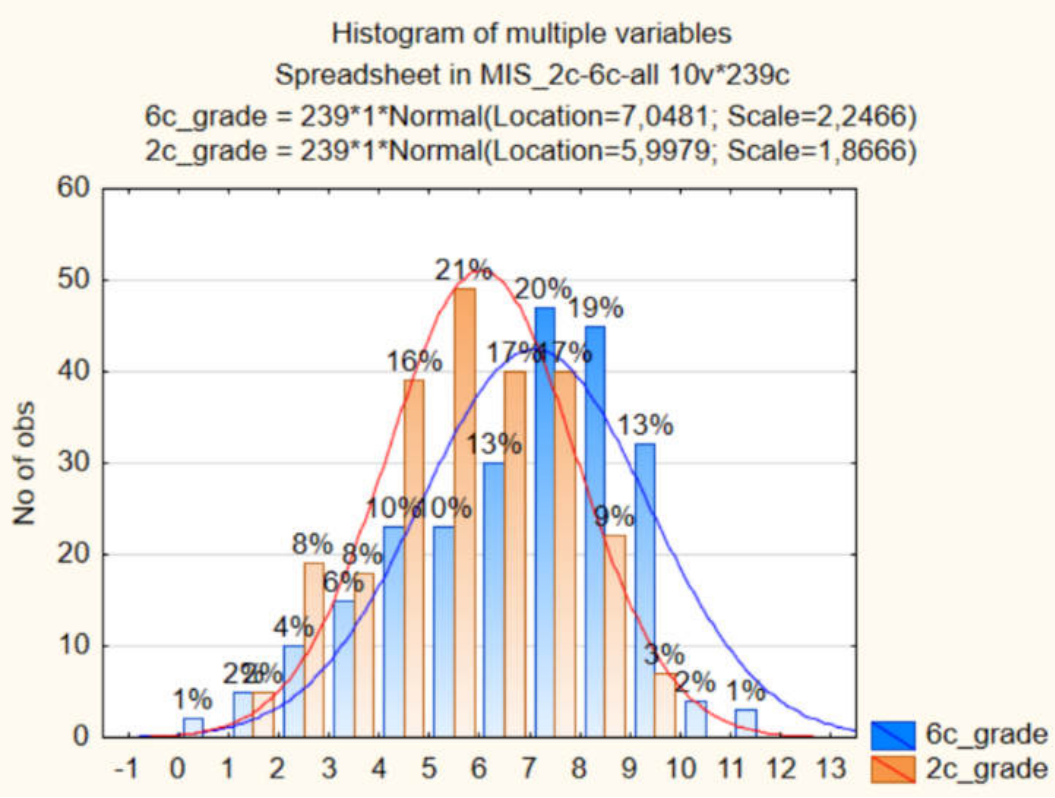


a)

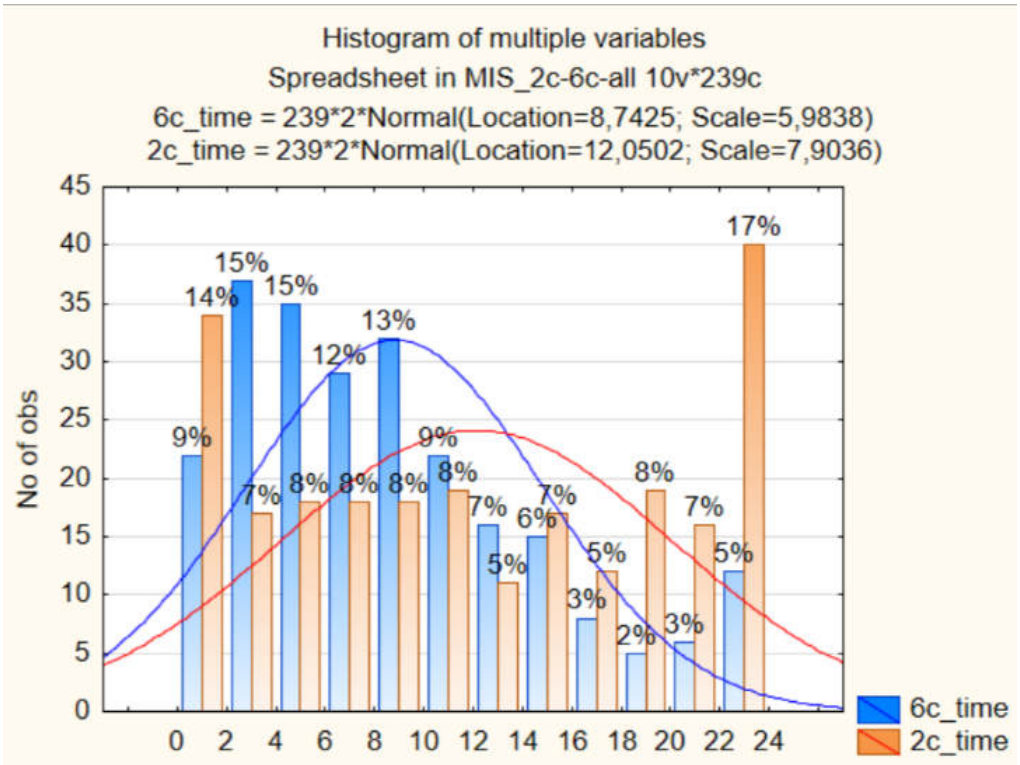


b)

Figure 2. Descriptive statistic for the "quiz_grade" (a) and the "spent_time" (b) samples of students' scores.



a)



b)

Figure 3. Comparison of distributions of the "quiz_grade" (a) and the "spent_time" (b) samples of students' scores.

Then, statistical hypothesis testing was employed to confirm that the suggested improvements were significant. Non-parametric statistical methods were used because the "quiz_grade" sample represented an ordinal variable and the "spent_time" sample did not match the normal distribution (b on Fig. 2). The authors decided to use both the Sign (Table 1) and the Wilcoxon Matched Pairs Test (Table 2) at the same time to ensure more reliable results.

Table 1. Results of the Sign test for statistical hypothesis

Pair of Variables	**2c_grade & 6c_grade**	**2c_time & 6c_time**
No. of (Non-ties)	223	237
% (v < V)	67,2646	37,5527
Z	5,0893	3,7675
p-value	0,000000*	0,000165*

Table 2. Results of the Wilcoxon Matched Pairs test for statistical hypothesis

Pair of Variables	**2c_grade & 6c_grade**	**2c_time & 6c_time**
No. of (Non-ties)	223	237
T	6929,5	8461
Z	5,7628	5,3384
p-value	0,000000*	0,000000*

The values of Z-scores from all tests were used to make a conclusion. The obtained Z-values were greated than critical value Zc = 1,65 for both methods, leading to the rejection of H0 (states of no difference between the samples' means) in

favor of H1, indicating presence of significant differences between the samples' means. All tests were significant with p-values well below 0,05.

Therefore, the authors concluded that sixth-year student demonstrated significantly better theoretical knowledge in the area of MIS EMR than during their second year of study. The simultaneous reduction in quiz time indicates that students retained a good level of permanent knowledge. In the authors' opinion, these results clearly demonstrate the effectiveness and quality of the learning methods and approaches used by faculties of TNMU's MI department in teaching foreign students on topics related to MIS EMR usage. This outcome also confirms an overall effectiveness of TNMU's curriculum for medical students. The results also indicate not only students' progress in digital literacy but also their development in healthcare-related IT skills. This is because many medical and clinical courses in TNMU were taught with significant emphasis on digital solutions in healthcare [10], [22].

5. Conclusions

Medical Informatics is an interdisciplinary field, integrating health sciences, computer science, information science, and cognitive science to assist health information management, analysis, and utilization. This study highlights the evolution of teaching Medical Informatics-related courses at I. Ya. Horbachevsky Ternopil National Medical University over two decades, with a focus on integrating digital solutions such as Medical Information Systems and Electronic Medical Records. The adoption of blended and fully online learning methodologies has proven essential, especially in light of global challenges such as the COVID-19 pandemic and the ongoing military conflict in Ukraine. The study's findings indicate that the educational process at TNMU is effective in improving students' theoretical knowledge and practical skills in the area of MIS EMR usage.

Through a longitudinal assessment conducted with the same cohort of students in the 2019/2020 and 2023/2024 academic years, a significant improvement in students' knowledge was observed. Statistical analyses, including the Sign and Wilcoxon Matched Pairs tests, confirmed that students demonstrated higher quiz scores and reduced time spent on assessments in their sixth year compared to their second year. These results suggest not only the effectiveness of TNMU's curriculum but also the retention of knowledge over time.

The successful implementation of MI courses at TNMU demonstrates the importance of incorporating modern educational tools and technologies to prepare future healthcare professionals for the digital transformation of healthcare systems. This study further emphasizes the need for digital literacy in healthcare, particularly in the usage of MIS EMR, and underscores the global relevance of adapting medical education to rapidly evolving technological environments.

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Disclaimer

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