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Utilizing predictive analytics to identify at-risk students in digitalized medical education: a motivational perspective

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Abstract

Digitalization has become an imperative of medical education but, also, it raises the questions of forecasting, determination of the latest educational trends and predict system responsiveness. The results indicate that utilizing predictive analytics is an important aspect for transferring to digitalized learning. The aim of the present research is to assess motivation index among medical students establishing effective models of predictive analytics and to design the multi-component target-oriented algorithm of pedagogical interventions for improvement of digitalized medical education. The findings show that pedagogical interventions affected the educational process positively and slightly increased students' academic outcomes. The growth of motivation index for the experimental dashboard in the successful category was +7,7 % and +5,98 % for the safe category. The number of students facing potential risks decreased by 9,4 % and at-risk students by 4,27 % in the experimental dashboard. We suggest that neglecting early identification of at-risk students brings to low academic performance. This demonstrates that implementing the multi-component target-oriented algorithm of pedagogical interventions contributes to improvement of the educational process in the institutions of higher medical education. To conclude, the detailed description of pedagogical intervention was presented to facilitate the use of the algorithm in digitalized medical education.

Keywords

Predictive analytics; At-risk students; Model; Pedagogical interventions; Motivation; Engagement.

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1. Introduction

Digitalization is driving many radical transformations in different fields like business, industry, management or personal relations; and it provides innovative development of the society. Modern educational institutions are facing fundamental changes related to creation of educational technological environment as the main priorities of education system are transparency, knowledge acceleration, accessibility, changing dynamics of competencies and professional requirements, implementing technological solutions (Alenezi, 2021; Kobernyk et al., 2022; Wojciech et al., 2021), and modifying pedagogical discourse (Sapiński & Ciupka, 2021). This leads to the extensive use of innovative technologies in education and, in consequence, enhances educational environment. According to Jakoet-Salie and Ramalobe (2023), digitalization in higher education deals with the introduction of technological and organizational modifications caused by the advancement of digital technologies within the educational process. In the Ukrainian context, digital transformation of education and science focuses on the improvements of institutional infrastructure, access to specialized databases, availability of the necessary software and support, formation of a unified digital environment (Bader et al., 2022; Filipova & Usheva, 2021), orients individuals towards using new approaches to professional development (Rak-Młynarska, 2022), enhancement of their knowledge, skills and competencies (Rossikhin et al., 2020; Tsekhmister, 2022), and includes recent advances of medical science (Tsekhmister et al., 2022).

Presently, digitalization has become an imperative and critical dimension of medical education since digitalized learning offers unprecedented opportunities for all the participants of educational process (Das et al., 2022) and contributes to the students' development (Althubaiti et al., 2022; Tsekhmister, 2023). The research on digitalized medical education has grown significantly in recent years and the existing findings mostly focus on the effectiveness of digital learning versus traditional learning among medical students. Some literature reports that the use of digital technologies in medical education can help in overcoming some challenges related to delivery and flexible access to learning content (Car et al., 2019), personalized learning (Hernandez Cardenas et al., 2021), improved information processing (Sen & Sahin, 2022), adaptability (Zainal et al., 2022), increased students' engagement (Grant et al., 2021; Kay & Pasarica, 2019; Tsekhmister, 2023), enhancement of academic performance (Althubaiti et al., 2022; Mastour et al.,

2023), predictive learning analytics (Berros et al., 2023; Tsaha & Terhemen, 2023), increased motivation and enjoyment of learning (Jun Xin et al., 2021).

Education of healthcare professionals has to respond efficiently and timely to the rapidly changing scientific and social conditions and to keep up with the pace of technological advances (Berros et al., 2023). And, obviously, it raises the questions of forecasting in management of education process as well as determination of the latest educational trends and predict responsiveness in the system (Chan et al., 2019; Peterson, 2019). As a result, higher institutions of medical education seek for the effective tools to predict students' performance and identification of at-risk students (Mastour et al., 2023) to provide them with opportunity to meet graduation requirements.

Predictive analytics promotes the creation of forecasts for the future by analyzing past trends in learning experiences (Sghir et al., 2023). Recently, certain predictive models developed with machine and deep learning have helped discover complex hidden data and achieve reasonable forecast related to the educational process (Bayazit et al., 2022; Sghir et al., 2023). Such models have become powerful instruments that enable detailed monitoring of students' academic performance (Khan et al., 2021), generation of predictions about their learning success (Cui et al., 2019) and design of preventive measures for at-risk students (Herodotou et al., 2020; Mangat & Saini, 2020).

Therefore, it is essential to explore the use of predictive analytics to identify at-risk students in digitalized medical education and to outline the role of analytics tools in increasing learning motivation by creating optimal learning environment. This investigation aims to examine the principles of implementation of predictive analytics within the educational process at the institutions of higher medical education in Ukraine, to identify their advantages in enhancement of engagement of at-risk students, and to observe how predictive analytics is affecting learning motivation among future healthcare professionals.

2. Literature review

2.1 Conceptual framework for describing the at-risk students

The attribute "at-risk" refers to the students who may fail either their final exam or fail to progress in the classroom (Foster & Siddle, 2020). Some scientists claim that an at-risk student is an individual who is in danger of failing to complete learning course and may not achieve a basic level of academic proficiency (Zakharova & Jarke, 2023). The term

may be used to describe students facing a difficult situation or possessing individual characteristics that can hinder them in achieving academic goals or complete course.

In the works of Pedditzi, Fadda, and Lucarelli (2022), Rovai et al. (2020) risk factors, that affect the efficiency of learning and could lead to drop-out, are divided into individual and institution-related factors. Individual risk factors concern students' home environment, social and economic status, cognitive potential, learning behaviors, academic performance, and quality of peer interaction. Institution-related risk factors include infrastructure capabilities, principles of organization of educational process, classroom management, form of training, teacher-student interaction. At the same time, students' motivation and community-related factors are associated with low achievements (Rahmani & Groot, 2023).

For Ukrainian institutions of higher medical education external factors have become decisive due to the ongoing COVID-19 pandemic and military aggression by the Russian federation resulted in the introduction of martial law and forced suspension of educational process for some time (Dobiesz et al., 2022; Khaniukov et al., 2022; Srichawla et al., 2022). This has had a negative impact on medical education and, consequently, many students must adapt to a high degree of threat condition and uncertainty.

According to Bayazit, Apaydin, and Gonullu (2022), identification of at-risk students who are not completing courses can benefit the educational process and lead to better learning outcomes. Moreover, we agree with Wang, Guo, and Shen (2022), who argue that solving the problem of at-risk students in the learning environment may contribute to improvement of education and establish a new pedagogical and educational model oriented towards students' professional development. In this respect, recent research has tried to apply different methods and approaches for learning analysis and prediction to enhance the efficiency of medical education, in particular through innovative digital solutions.

2.2 Predictive analytics is an emerging field of digitalized medical education

Predictive analysis is an interactive process which is based on a dataset and modelling techniques, and it is used to determine risk in prior, opportunities, tendencies, and further develop strategies or appropriate measures for future improvements (Rustagi & Goel, 2022).

Currently, predicting students' academic performance and identifying at-risk students is considered an important research topic since this helps create relevant decision based on data collection (Backhaus et al., 2019; Ranjeeth et al., 2020; Rovai et al., 2020). Predictive analysis focuses on evaluation of learning environment, data description, data verification, summarization, situation visualization, and result generation (Ranjeeth et al., 2020).

The findings show that several models or instruments are applied to carry out predictive analysis and to work out the likelihood of future outcomes. Table 1 describes certain models or instruments and demonstrates their use in digitalized medical education based on literature review.

Table 1: *Application of predictive analytics in digitalized medical education*

Usage of predictive analytics	**Model/Instrument**	**Author(s)**
to assess students' performance and predict those at risk	Educational Data Mining model	Sghir et al., 2023
to introduce more intensive interventions to students with the highest risk ratings	"Early alert" system	Bird et al., 2021
to evaluate students' performance in high-stakes tests	Machine Learning model	Mastour et al., 2023
to predict outcomes from observational data	Statistical model	Pearson et al., 2020
to predict each student's future exam scores	"adaptive minimum match" version of the k-nearest neighbors algorithm	Kumar et al., 2023
to predict at-risk students in online learning	Decision tree model	Bayazit et al., 2022
to detect learning difficulties and prevent students from failing the course	Students' learning behavior model	Umer et al., 2023

Investigating applications of predictive analytics in digitalized medical education, we suggest that pedagogical efforts should be focused on the enhancement of students' engagement and motivation as these factors affect the organization of educational process significantly and provide positive learning conditions within the institution of higher medical education.

2.3 Predictive analytics: improving engagement and motivation among medical students

Within digitalized learning in particular, the problem of identifying students' difficulties is even more important than in the classroom where an instructor has a number of tools for early detection and prevention (Avci, 2022; Herodotou et al., 2020). Harnessing the potentials of digitalized medical education, researchers revealed that online learning may bring some frustration, reduce students' engagement and motivation (Liao & Wu, 2023). And this, once again, emphasizes the relationship between motivation and learning effectiveness.

There is a huge amount of research devoted to the problem of motivation in pedagogics and its role within the enhancement of educational process. First, it should be noted that motivation is described as a powerful tool to manage, encourage, and promote goal-oriented behavior among students as well as an essential component of the process of learning and educational achievement (Kong, 2021). A motivated student is able to apply more effective learning strategies, counteract difficulties or failures, and, therefore, he/she achieves a higher level of academic performance and graduate successfully.

In the context of studying of the motivation phenomena necessary for students' development, it is necessary to emphasize the importance of Self-Determination Theory that focuses on the role of three basic psychological needs: autonomy, competence, and relatedness. Developed by R. M. Ryan and E. L. Deci, the theory suggests that these needs are essential for psychological well-being and internal motives. Also, the Self-Determination Theory explains formation of competence and personal development given the situation-dependent or circumstantial factors (Ryan & Deci, 2022). The Self-Determination Theory has been widely applied in educational contexts to understand student motivation and learning outcomes.

It is worth mentioning that Ryan & Deci (2020) distinguish between intrinsic motivation, which comes from within and is driven by internal rewards such as enjoyment, satisfaction, and extrinsic motivation, which comes from external rewards such as money or praise. According to Wu et al. (2023), intrinsic motivation of medical students refers to interest in becoming a doctor or inner desire to solve urgent challenges of medical science while extrinsic motivation, also called outcome-oriented motivation, relates to future benefits that healthcare profession may bring such as praise and approval, respect, promotion, financial gain, or enjoyment.

In addition, Fent et al. (2022) differentiates situational motivation of medical students. It is the motivation of individual experience when individuals are engaged in an activity. In other words, situational motivation deals with self-determination in a specific situation or activity in the classroom and that allows students to act independently and make own decisions in the educational process.

All types of motivation are closely related to students' engagement in learning (Wu et al., 2023) that makes it a crucial aspect in predicting academic performance and identifying at-risk students. Engagement is defined as students' devoting of time, efforts, and energy in learning experiences with expectation of positive result (Kassab et al., 2023). The engagement includes cognitive, affective and behavioral dimensions (Bowden et al., 2021).

Since motivation is a pedagogical category that can be assessed, predictive analytics help to reconsider the educational data on different aspects related to classroom management, students' behavior in the digital learning environment as well as describe students' existing level of motivation and its components, the learning progress and outcomes, confidence, and a range of barriers (Sghir et al., 2023). Further, the output may be used to choose effective teaching methods and create optimal conditions in the classroom to achieve educational objectives.

Thus, we outlined the principles of utilizing predictive analytics to identify at-risk students and further design of the multicomponent pedagogical interventions to improve digitalized medical education through increasing learning motivation among future healthcare professionals. In this study, we developed and evaluated motivation assessment survey with the use of predictive analytics among 234 students of Ukrainian institutions of higher medical education in order to identify at-risk individuals. The results can be used to enhance students' engagement and course completion. Therefore, the *aim* of the study was to assess motivation index among medical students in Ukrainian institutions of higher medical education establishing effective models of predictive analytics and to design the multi-component target-oriented algorithm of pedagogical interventions for improvement of digitalized medical education through increasing learning motivation.

Accordingly, the following research questions were formulated:

RQ1: What are the models of predictive analytics to assess engagement and motivation among medical students?

RQ2: What is the rate of at-risk students in the institutions of higher medical education in Ukraine? What is the number of successful and safe students?

RQ3: How to design, and further to apply, the effective multicomponent pedagogical interventions for improvement of digitalized medical education through increasing learning motivation?

3. Methods

3.1 Context

The study was conducted among students of four institutions of higher medical education in Ukraine during first semester of 2022-2023 academic year. The courses selected included the humanities, fundamental sciences, and clinical training. Thirteen instructors, three methodologists, and one head of research and teaching laboratory were involved in the study to collect the data and evaluate learning interactions. The data was collected in the classroom, during video conferencing, through face-to-face discussions, group work, and quizzes weekly. Also, the marks obtained during the test, differentiated test or exams were considered. The data were verified by two educational experts experienced in application of quantitative research methods and modelling of pedagogical patterns.

3.2 Participants

Participants for the study were chosen among four institutions of higher medical education in Ukraine. All of them were undergoing educational program “Medicine” on the second level of higher education (master’s). The program is accredited by the Ministry of Education and Science of Ukraine. The study included 234 second- (68,3 %) and third-year students (31,7 %). All the participants were divided into two groups: experimental dashboard (117 students) and control dashboard (127 students). All of them were informed about the procedure of the study and informed about the research objectives. Besides, the results were assessed objectively and impartially.

Table 2 shows the main descriptive characteristics of educational program “Medicine” used in the study. These characteristics include the following: level of higher education, educational qualification, field of knowledge, specialty, duration of training, orientation and content information, graduation requirements, and assessment techniques.

Table 2: *Main descriptive characteristics of educational program*

Descriptor	**Data**
Level of higher education	Second
Educational qualification	Master of Medicine. Physician
Field of knowledge	22 Healthcare
Specialty	Medicine
Duration of training	5 years and 10 months (360 ECTS credits)
Program orientation	At least 75% of the educational program is aimed at the formation of general and professional competencies
Program content	Humanities – 4,4 %, fundamental sciences – 31,5 %, clinical training – 54,1 %
Graduation requirements	Carrying out complex professional tasks in the field of health care in the relevant position; ability to use special tactics of patient management; awareness of laboratory and instrumental research, medical manipulations; military expertise; ability to act in uncertain conditions and emergencies.
Assessment	Test, differentiated test, exam, complex state examination

All the participants had the possibility to know the results of the research and participate in the design of pedagogical interventions to improve digitalized medical education through improvement of engagement and motivation.

3.3 Instruments

To answer the research questions, we applied quantitative and qualitative research methodology. Firstly, qualitative methods such as analysis of courseware and classroom observations were applied to study the use of predictive analytics models at the Ukrainian institutions of higher medical education and to outline the pedagogical interventions to increase students' learning motivation. Then open-ended questionnaire was developed to obtain students' evaluation on learning objectives, learning, environment, and learning satisfaction. Secondly, motivation assessment scale was applied and it included three blocks of questions related to intrinsic, extrinsic and situational motivation. Each question was discussed within the research team and changed if it was necessary. The questionnaire was conducted online through Google forms anonymously. Thirdly, predictive modelling was introduced through statistical methods and decision tree that helped correlate students' actual and predictive motivation. Face-to-face discussions, personalized feedback interviews, pedagogical observations were used as additional qualitative techniques to make the research more accurately. The discussions and interviews were audio-recorded and then transcribed so that all the experts could study

them thoroughly. The data obtained during the observations were recorded and provided in reports. Also, we considered the marks obtained during the tests, differentiated tests, and exams.

3.4 Data analysis

The study of the use of predictive analytics models and possible pedagogical intervention, the methods of qualitative analysis such as visual analysis and content analysis. They contributed to the organization and interpretation of the findings as well.

To assess students' motivation and identify at-risk students we used applied Motivation Index tool (1) that involved the data on actual motivation (M_a) and predictive motivation (M_p):

$I_m = M_a + M_p$ (1).

At the same time M_a (2) was estimated as the total score of intrinsic motivation (MS_I), extrinsic motivation (MS_E) and situations motivation (MS_S). Also, we considered the engagement score (ES). So, the formula to estimate M_a looks like this:

$M_a = MS_I + MS_S + MS_E + ES$ (2).

M_p (3) requires the analysis of predictive modelling data (PMD) and students' performance analysis:

$M_p = PMD + P$ (3).

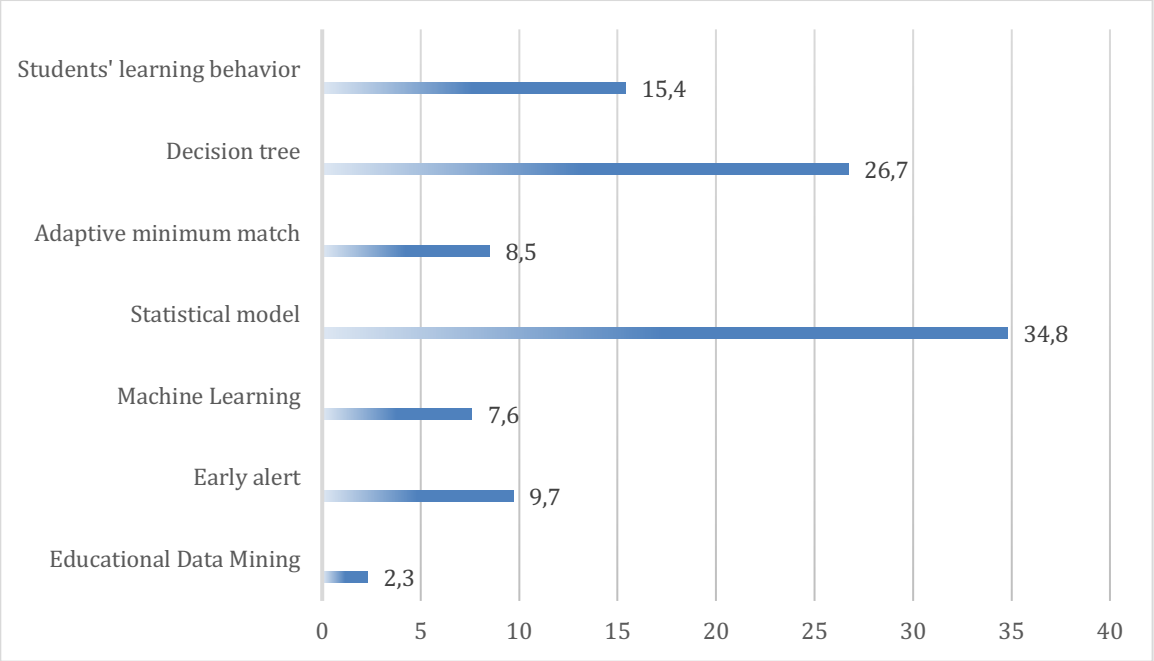
The findings allowed us to divide the participants into categories based on points they obtained and identify at-risk students. The maximum score that can be obtained is 100. The score above 90 means that a student is successful and is not facing the risk of drop-out or failing. 89-70 points mean that a student belongs to safe category and his/her academic performance is good or satisfactory. He/she is able to perform most of the tasks in team or individually and his motivation is at a sufficient level. 69-55 points indicate that a student is facing the potential risk, and his/her engagement needs some modification through teaching methods, learning content or assessment tools. If motivation index is less than 55 points it means that a student is at risk and does not meet course requirements. This situation requires effective pedagogical interventions.

4. Results

To identify the models of predictive analytics used to assess engagement and motivation among medical students, the qualitative techniques like analysis of courseware and

classroom observations. The results showed that predictive analytics is now extensively used within the educational process at the Ukrainian institution. Two models – statistical model (34,8 %) and decision tree (26,7 %) – were the most common ones. At the same time, adaptive minimum match, educational data mining, and Machine Learning model are used sporadically only by instructors since their application requires advanced training and specific digital skills. Figure 1 shows the use of predictive analytics models in medical education in Ukraine.

Figure 1: *The use of predictive analytics models*



The findings show that in the beginning of the semester most students belonged to safe category. Thus, there were 49 safe students in the experimental dashboard and 53 students in the control dashboard. Successful category included 38 students for the experimental dashboard and 42 students for the control dashboard respectively. At the same time, there were 24 students who faced potential risk in the experimental dashboard and 28 students – in the control dashboards. 6 students faced risk of drop-out in the experimental dashboard and 4 students – in the control dashboard. It is necessary to admit that the results were largely the same for all the categories in the beginning of the semester.

But utilizing predictive analytics enabled us to develop multi-component target-oriented algorithm that included pedagogical interventions oriented towards enhancement

of engagement and motivation. Table 3 shows the data comparison on motivation index in the beginning and in the end of the semester when appropriate pedagogical interventions were implemented.

The findings shows that the algorithm was effective and we observed the increase of students in successful and safe categories for the experimental dashboard. It indicated that early identification of at-risk students and assessment of their motivation index contributed to improvement of educational process in the institutions of higher medical education. It also enabled the selection of effective digital tools to promote students' interest in professional development.

Table 3 analyses the study results in the experimental and control dashboards in the beginning and in the end of the semester.

Table 3: *The analysis of study results*

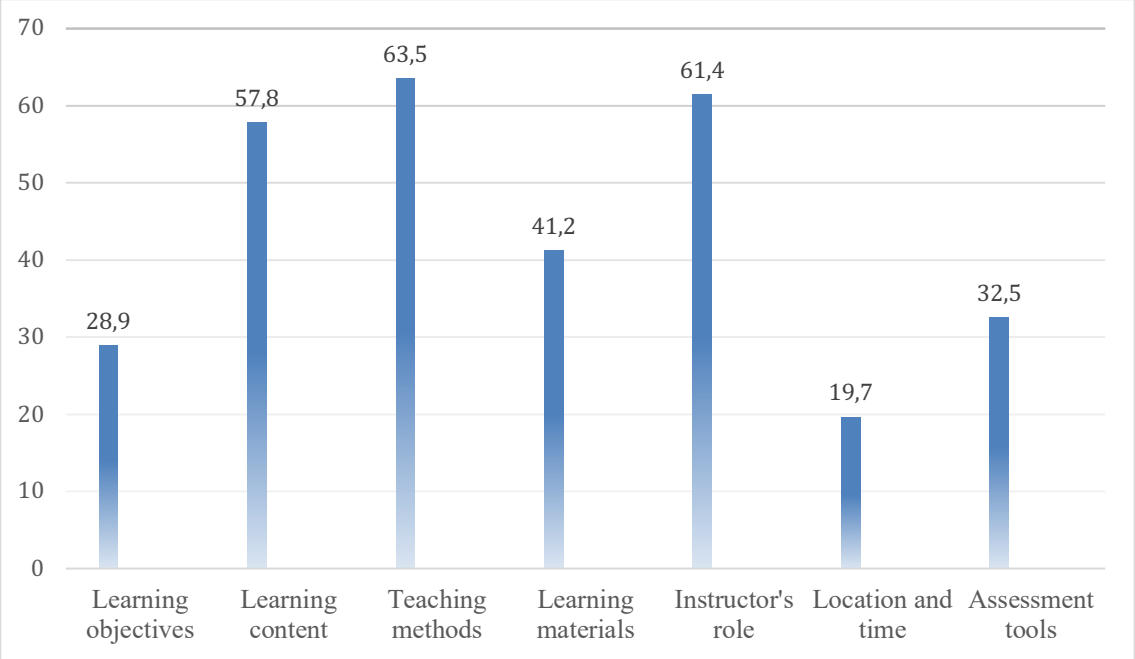
Categories	**Beginning of the semester**		**End of the semester**	
	Experimental dashboard	**Control dashboard**	**Experimental dashboard**	**Control dashboard**
Successful	38	42	47 (+7,7 %)	40 (-1,57 %)
Safe	49	53	56 (+5,98 %)	58 (+3,94 %)
Potential risk	24	28	13 (-9,4 %)	27 (-0,79 %)
At risk of drop-out	6	4	1 (-4,27 %)	2 (+1,57 %)

The findings demonstrate that pedagogical interventions affected the educational process positively and slightly increased students' academic outcomes. The growth of motivation index for the experimental dashboard in the successful category was +7,7 %. For the control dashboard this number was -1,57 %. Safe category also showed gradual growth during the 10-15 weeks and the absolute increase was +5,98 % for the experimental dashboard and +3,94 % for the control dashboard. The data obtained in potential risk and at-risk of drop-out categories indicates the effectiveness of pedagogical interventions during the educational process. Thus, the number of students facing potential risks decreased by 9,4 % in the experimental dashboard. To compare, the number of students facing risk of drop-out decreased by 4,27 % through the experiment. The data about the students in the control dashboard shows that neglecting early identification of at-risk students may bring to low academic performance in the institutions of higher medical education.

Designing the multicomponent pedagogical interventions for improvement of digitalized medical education through increasing learning motivation was based on the

results of empirical research. The questionnaire among the students and instructors of the institutions of higher medical education showed that pedagogical interventions are related to learning objectives, learning content, teaching methods, learning materials and resources, instructor's role, location and time, and assessment tools. Importantly, respondents admitted that implementation of relevant teaching method (63,5 %) and appropriate learning content (57,8 %) are important conditions for increasing students' learning motivation. Figure 2 shows the efficiency of each component increasing students' learning motivation according to the respondents' responses.

Figure 2: *Pedagogical interventions to increase learning motivation*.



Furthermore, it is required to develop the multi-component target-oriented algorithm considering the use of pedagogical interventions.

5. Discussions

The study results proved that utilizing predictive analytics to identify at-risk students enhances digitalized medical education through introduction of effective pedagogical interventions within the educational process. These findings may help the instructors in the institutions of higher medical education create positive learning environment for meeting graduation requirements, increase their learning motivation and facilitate students' professional development.

It was found that the multi-component target-oriented algorithm includes several pedagogical interventions for enhancement of engagement and motivation among medical students in digitalized learning environment, particularly learning objectives, learning content, teaching methods, learning materials and resources, instructor's role, location, time, and assessment tools. The combination of these components ensures realization of effective pedagogical interventions.

Learning objectives concern clear and concise statements that determine the expected results of the educational process. They are considered through the educational program, curriculum, course, lectures or practical training and oriented towards formation of professional competencies among medical students. In the context of medical education, learning objectives are closely connected with the graduation requirements. We found that at-risk students do not realize learning objectives clearly and, therefore, they focus their learning efforts on the completely different aspects of the educational process and it results in educational errors and failures.

Learning content refers to the topics, concepts, facts that are grouped within the subjects of the educational program and are expected to be learned. Learning content forms knowledge, skills, attitudes, values, and…..? becomes the foundation for professional competencies of medical students. Since medical education is going rapidly digitalized, it is very important to build effective content strategy for learning platforms the institutions of higher medical education apply and provide students with actual learning content considering the recent advances in medical science. Also, it is necessary to consider that, according to the requirement of the Ministry of Education and Science of Ukraine, at least 75% of the educational program is aimed at the formation of general and professional competencies.

Teaching methods means pedagogical techniques used to help students achieve their learning outcomes. Improving students' engagement and motivation requires using various teaching methods oriented towards the assistance of at-risk students. They include the following: adaptive learning platforms, simulation-based learning, online tutoring, and interactive technologies including game-based learning, problem-based learning, collaborative work, situated learning, video-based learning, flipped classroom. We found that these teaching methods enhance the students' engagement significantly, and contribute to increase of situational and intrinsic motivation. As a result, students facing potential risk or who are at risk of drop-out promote the interest within the educational process and become more motivated in professional development.

Learning materials and resources are the materials that instructors use to provide instruction and facilitate the educational process towards achievement of pedagogical intentions. Digitalized medical education requires implementation of conventional learning materials and resources like textbooks, manuals, dictionaries, e-books, worksheets, etc. But the main attention should be paid to the use of digital learning materials and resources like applications, software, programs, learning platform, multimedia presentation, or specialty websites.

Instructor's role is still considered to be a crucial in digitalized medical education despite radical changes in functions. Currently, as learning gets student-centered and collaborative, an instructor performs as a designer, facilitator, observer, adviser, course leader, assistant, and mentor. In addition, Learning Management Systems enable instructors to deliver and organize the course more efficiently and optimize their activities before and in the classroom. The study indicated that choice of relevant instructor's role affects students' performance positively, and at-risk students in particular.

Location and time depend on the format of learning process whether it is synchronous or asynchronous. The study resulted in conclusion that the best option is to combine different format, if it is possible and differentiate learning activities to promote students' interest.

Assessment tools refer to instruments that are designed to evaluate students' performance. Digital assessment solutions include online quizzes, essay questions, online interviews, simulations, game-based activities, peer evaluations, written reviews, projects and presentations.

Due to utilizing predictive analytics it is possible to identify at-risk students and, therefore, introduce preventive pedagogical interventions to promote their interest, enhance engagement and increase learning motivation. The relevant use of multi-component target-oriented algorithm of pedagogical interventions may contribute to improvement of digitalized learning in Ukrainian institutions of higher medical education.

6. Conclusion

The study explores the use of predictive analytics to identify at-risk students in digitalized medical education and outlines the role of analytics tools in increasing engagement and learning motivation. The findings show that at-risk students are those who may fail either

their final exam or fail to progress in the classroom. This may occur because of a number of risk factors including individual, institution-related and external or community factors. Identification of at-risk students can benefit the educational process and lead to better learning outcomes. Moreover, we found that solving the problem of at-risk students may contribute to improvement of education and establish new pedagogical and educational model for students' professional development.

The study indicates that predictive analysis is an interactive process which is based on a dataset and modelling techniques and that is used to determine risk in prior, opportunities, tendencies, and further develop strategies or appropriate measures for future improvements. Predictive analysis focuses on evaluation of learning environment, data description, data verification, summarization, situation visualization, and result generation.

The results demonstrated that several models or instruments are applied to carry out predictive analysis and to develop the further recommendations on educational process improvements. They include educational Data Mining model, "early alert" system, Machine Learning model, statistical model, "adaptive minimum match" version of the k-nearest neighbors' algorithm, decision tree, and students' learning behavior model. We concluded that within digitalized learning in particular, the problem of identifying students' difficulties is even more important since online learning may bring some frustration, reduce students' engagement and motivation.

As for medical students, motivation can be classified into intrinsic, extrinsic, and situational. We found that all types of motivation are closely related to students' engagement in learning, and it becomes a crucial aspect in predicting academic performance and identifying at-risk students. Since motivation is a pedagogical category that can be assessed, predictive analytics helps to reconsider the educational data and improve the educational process, for at-risk students, in particular.

In this study, we developed and evaluated the survey with the use of predictive analytics among 234 students of four Ukrainian institutions of higher medical education to identify at-risk individuals during first semester of academic year 2022-2023. To assess students' motivation and identify at-risk students we used applied Motivation Index tool that involved the data on actual motivation and predictive motivation. The findings allowed us to divide the participants into four categories (successful, safe, potential risk, and at risk of drop-out) and identify at-risk students.

Utilizing predictive analytics enabled us to develop multi-component target-oriented algorithm that included pedagogical interventions oriented towards enhancement of engagement and motivation. The findings shows that the algorithm was effective and we observed the increase of students in successful and safe categories for the experimental dashboard. It indicated that early identification of at-risk students and assessment of their motivation index contributed to improvement of educational process and enabled to select effective digital to promote students' interest.

7. Study limitations

Our study still contains some limitations that should be clarified and considered in further investigations. Hence, the study was conducted in the first semester of 2022-2023 academic year in the Ukrainian institutions of higher medical education that means the education process was organized during the full-fledged war. Of course, this could not but affect the number of at-risk students. We assume that the number of successful and safe students may increase in the peacetime. But it does not mean that this fact diminishes the positive role of predictive analytics and multi-component target-oriented algorithm of pedagogical interventions in digitalized medical education.

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