Digital Learning Environment for Mathematical Disciplines at Universities in Times of War

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Abstract. The digital educational environment in the context of martial law in Ukraine ensures continuous self-development and self-realisation of an active and creative student through the organisation and functioning of educational systems with openness, integrity and adaptability through educational websites.
The authors of the article analyse some mathematical websites and present their own, developed on the basis of the WordPress content management system, which has a dynamic structure: e-lectures, e-workshop, workbooks, files with information for students, work programmes and/or syllabuses, author's textbooks in mathematical disciplines, workshops, etc. The use of the site in the educational process allows us to state that it provides students with an effective tool for learning mathematics in an interactive and adaptive environment, and the presentation of educational material in text format and video lectures is appropriate for our country, given the unstable Internet connection in some regions and the constant problems with Ukraine's energy infrastructure due to martial law.
The article investigates the opinion and experience of bachelor students regarding the use of specialised websites for studying mathematical disciplines, and provides a correlation analysis of the results of the questionnaire and academic.

Keywords: Digital Educational Environment of the University, Educational Website, Teacher of Mathematical Disciplines, Content Management System, WordPress.

1 Introduction

In times of pandemic and martial law in Ukraine, the use of the latest technologies and the global Internet in the educational process is becoming an extremely important and necessary condition for ensuring quality education. The development of web technologies is leading to the emergence of websites with advanced features that are becoming convenient both in the professional sphere and in everyday life. Therefore, the skills of

designing and creating functional and user-friendly educational websites are an important aspect of the professional development of a university teacher.

Many teachers believe that creating their own website is only possible for programmers. However, in fact, there are many simple digital tools with ready-made templates that allow you to create educational websites without the need for specialised programming skills.

The purpose of the study is to model and develop a digital educational environment in mathematical disciplines for students of higher education institutions using WordPress; to analyse some profile sites in the international educational space in mathematical disciplines.

2 Materials and Methods

Researches [1, 2, 3, 4, 5, 6, 7] are relevant in the context of the subject of our research.

The article by Alieksieienko et al. [1] identifies the features of the use of modern digital technologies, systemises and forms the main stages of the process of activating and intensifying their use for the development of the educational environment in the system of ensuring sustainable development of the region.

The study by Knoblauch [2] is relevant because it reveals the peculiarities of students' work in a digital project-based learning environment with a view to further implementing the results to improve digital or blended learning in higher education.

The organisation of educational activities in mathematics with the use of information and communication technologies is important for the development of the digital culture of a mathematics student at the university [3]. The theoretical and methodological possibilities of teaching and learning mathematics in the digital era are the central theme of the research by Abar et al [4], Lee et al [5] and Pekkel et al [6]. Raza & Reddy believe that “the major concerns of educators responsible for teaching mathematics and mathematics-related courses are to find effective and innovative ways to deliver mathematical content, to extend the concepts and theories beyond the classroom, to integrate mathematics with important concepts such as gamification, data mining, learning analytics, deep learning, and effective tools such as mobile devices, learning management systems, and digital technology, and to maintain a good record of students’ performances” [7].

The research conducted in our article is a continuation of the authors' previous results on the subject of study [8, 9, 10, 11, 12].

Thus, modern digital technologies and website development are effective and innovative means of teaching mathematics students in higher education institutions.

At the stage of planning and developing an educational website, the teacher determines its goals and objectives that correspond to the curriculum of the discipline at the higher education institution, and takes into account scientific research in the field of digital educational environments [1, 5, 6, 7, 8, 9, 10], which emphasise the provision of convenient access to educational materials, support for interactive learning and opportunities for self-education. The presence of forums, chats, and other communication tools on the website facilitates communication with the teacher, exchange of knowledge

and ideas, and support for each other. Scientific studies confirm that social interaction stimulates a deeper understanding of the material and the development of critical thinking [5, 7].

Next, you determine the tentative design and the necessary functionality of the website – what, where and how it will be placed. The next step is to purchase hosting and a domain, after which the site is ready for publication on the Internet. Content management systems and website builders with online editors are the most commonly used tools for website development. 45% of all websites in the world (more than 31 million sites) are created and maintained by the WordPress content management system, which was decisive in choosing a content management system for an educational website on mathematics [13].

Installing the MasterStudy LMS plugin for WordPress [14] gives teachers the ability to create and customise their own online learning environment, taking into account the specific needs of each student. Installing the Elementor page editor plugin simplifies the creation and editing of content on the site without the need for programming, which is especially useful for teachers. The WP Mail SMTP plugin is also installed, which improves the reliability of email delivery and ensures effective communication with users [9]. To monitor the site's activity, a statistics control plugin is installed, which generates various information about the preferences of site users.

3 Experiments

An example of an educational web resource is the website 'I Learn Mathematical Analysis and Differential Equations by Myself' by Mariana Kovtoniuk, Professor of the Department of Mathematics and Informatics at Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (www.kovtonyuk.inf.ua), which has been operating for over 12 years.

The digital educational environment of Professor Mariana Kovtoniuk is being modernised using CMS WordPress (https://Kovtonyuk.com) [15]. The site is designed for further expansion and has a dynamic structure: e-lectures, e-workshops, workbooks, files with information for students, work programmes and/or syllabuses, author's textbooks in the mathematical disciplines Mathematical Analysis, Functional Analysis, Differential Equations (the textbook contains about 100 lectures) and workshops, information about the popular science almanac Mathematics and Informatics Around Us and the international conference Mathematics and Informatics in Science and Education: Challenges of the Present. The educational materials take into account modern trends in the development of mathematics, use elements of modern mathematical symbols and present mathematical terminology in accordance with international standards. The most complex proofs are divided into specific content parts, illustrated with diagrams, graphs, examples, etc.

Students have access to practice problems with answers for self-study, which allows them to test their knowledge and consolidate their skills. In addition, the site offers resources for further study of the topic, including links to literature and other useful materials. Up-to-date information about classes and events is provided through news

and announcements, which ensures constant communication with students. It is planned to post video lectures from the teacher's YouTube channel on the website [9].

To compare Professor Mariana Kovtoniuk's website with other websites in mathematical disciplines, we selected three author's educational courses in mathematics on the non-formal education platform Coursera, namely: the course 'Introduction to Calculus' [16], the course 'Introduction to Mathematical Thinking' [17] and the course 'Introduction to Complex Analysis' [18].

The Introduction to Calculus course, taught by David Easdown, Associate Professor at The University of Sydney, offers video lectures lasting from 7 to 17 minutes with detailed explanations of key concepts and methods. The lecturer uses a graphic tablet to explain the material. The course also contains short notes in the form of pdf files and test tasks for students.

The Introduction to Mathematical Thinking course by Dr Keith Devlin, Co-founder and Executive Director of Stanford University, includes interactive video lectures lasting from 4 to 28 minutes with embedded questions. The instructor uses live writing and hand-drawing to explain the concepts of mathematical thinking, as well as quizzes to practice these concepts. After completing a test task, students have access to a video lecture explaining how to complete the test tasks correctly.

The course 'Introduction to Complex Analysis' by Former Professor of Mathematics at Wesleyan University and Professor of Engineering at Thayer School of Engineering at Dartmouth Dr Petra Bonfert-Taylor offers video lectures based on a presentation with textual description, formulas, graphs, and additional examples written by the lecturer on the presentation slide. At the beginning of the course, there is an archive for downloading these presentations in pdf format.

The comparison shows that each of the sites has its own features and advantages. The website of Professor Mariana Kovtoniuk focuses on providing materials for self-study and self-development, which complement or completely replace the lecture material delivered to students in the classroom (or in a remote format) and are suitable for students who want to dive deeper into the topic of mathematical analysis and differential equations. The presentation of mathematical material in text format is appropriate for our country, given the unstable Internet connection in some regions and the ongoing problems with Ukraine's energy infrastructure due to martial law. Courses on Coursera, on the other hand, offer interactive learning and the possibility of obtaining a certificate, which may be attractive to those who value informal education.

4 Results

The study is based on digital educational environments of mathematical disciplines' teaching materials developed, tested and implemented in the educational process of students majoring in 014 Secondary Education (Computer Science. Mathematics) and 111 Mathematics at the Faculty of Mathematics, Physics and Informatics of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University (Ukraine). The sample included 56 first- to fourth-year undergraduate students (approximately 18-20 years old). The survey was conducted online using the Google Form tool. The survey was conducted

with maximum respect for the privacy of students, in compliance with ethical standards, ensuring the safety and well-being of participants. The faculty administration was informed and gave permission to conduct the study. Parental consent was not required as all students were over 18 years old. Throughout the study, the researchers adhered to the ethical standards of the American Psychological Association (APA) and the recommendations of the Ethical Code of the Scientist of Ukraine [19].

The online survey of students was conducted to establish correlations between students' academic performance and their use of websites for studying mathematical disciplines, and to analyse the use of such websites in the study of higher mathematics. The dataset of students' academic performance and the results of the survey was imported into the STATISTICA 12 software application to calculate the correlation between academic performance and the use of websites in higher mathematics. Spearman's rank correlation coefficient was calculated to determine the strength and direction of correlations.

For example, let the sample objects have qualitative attributes and the sample of size n contains independent objects that will be ranked in order of deterioration (or improvement) in quality. Let's assume that the ranks *x1, x2, x3, ..., xn* are the values of the random variable *X*, and the ranks *y1, y2, y3, ..., yn* are the values of the random variable *Y*. Then the sample Spearman's rank correlation coefficient (1) is determined by the formula [20]:

$$r_s^* = 1 - \frac{6\sum_{i=1}^{n} d_i^2 + T_x + T_y}{(n-1)n(n+1)}, \qquad (1)$$

where $d_i = x_i - y_i$, $i = \overline{1, n}$ $\quad (-1 \le r_s^* \le 1)$,

T_x, T_y – corrections related to the same ranks are calculated using the following formulas: $T_x = \frac{\sum_{i=1}^{l_x}(T_{xi}^3 - T_{xi})}{12}$, $T_y = \frac{\sum_{i=1}^{l_y}(T_{yi}^3 - T_{yi})}{12}$, де l_x, l_y – the number of links (groups of the same rank); T_{xi}, T_{yi} – sizes $i-th$ those links (the number of elements in them).

The strength of the correlation does not depend on its direction and is determined by the absolute value of the correlation coefficient $|r_s^*| = r_s$.

Using an online questionnaire, we analysed students' opinions and experiences about the frequency and usefulness of using educational websites for studying mathematics, non-formal education platforms, mathematical disciplines they study with the help of these websites, and the content of the websites with aspects of educational material.

5 Discussion

Analysing the results of the online survey, it can be concluded that 82.1% of respondents use educational websites in their studies. Among the non-formal education platforms used by students are: Khan Academy (15.6%), Coursera (22.2%), Prometheus (44.4%), EdX (11.1%), YouTube (91.1%), Mathway (44.4%), EdEra (31.1%). The respondents use specialised websites when studying the following mathematical disci-

plines: mathematical analysis (86%), linear algebra (65.1%), geometry (48.8%), differential equations (46.5%), discrete mathematics (44.2%), mathematical statistics (34.9%), computing methods (23.3%), mathematical modelling (20.9%), functional analysis (16.3%), and complex analysis (14%). The higher the percentage of websites used by students in a particular mathematical discipline, the higher their average academic performance (see Fig. 1).

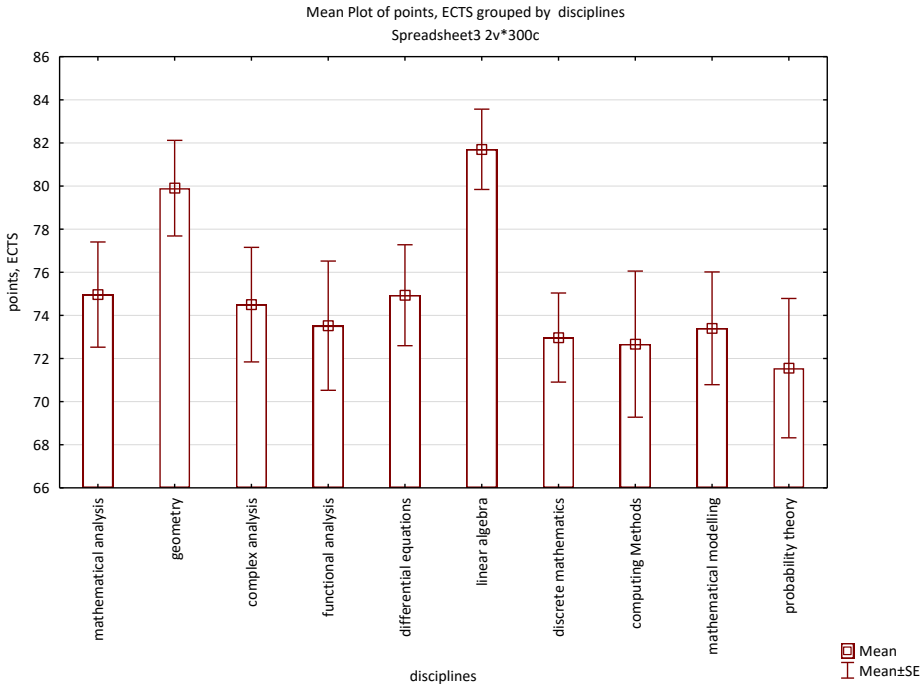

Fig. 1. Window of the Box Plots module of STATISTICA 12 on students' academic performance in mathematical disciplines.

To establish correlations between students' academic performance and the frequency of their use of websites for studying mathematical disciplines, Spearman's rank correlation coefficient was calculated. Statistical conclusions were drawn based on the significance level of $p<0.05$. Based on the results of the calculations, a correlation matrix of the above relationship was constructed (see Table 1).

Table 1 suggests that there is a strong direct correlation between the frequency of website use and students' academic performance in mathematics (r_s=0.81), and a moderate direct correlation between the frequency of use of educational websites and academic performance in computer science (r_s=0.41).

The results of our study correlate with the results of other researchers and confirm their relevance. For comparison, we considered related studies on the issue of considering students' work in the digital educational environment of mathematics learning

materials in the context of university education and how these results can be constructively implemented to improve digital or blended learning in the higher education segment in the future [1, 2, 6].

Table 1. Rank correlation between students' academic performance and frequency of using websites for studying mathematics.

Correlation matrix	Frequency of use of websites	Frequency of use of websites Mathematical disciplines, points	Computer disciplines, points
Frequency of use of websites	1.00	0.81	0.41
Mathematical disciplines, points	0.81	1.00	0.62
Computer science disciplines, score	0.41	0.62	1.00

6 Conclusions

Creating an educational website is a complex, multi-stage process that requires creative and analytical skills from the developer. It should be ergonomic and informative. In the context of distance learning, when access to traditional education may be limited due to the martial law in Ukraine, digital technologies provide an opportunity to continue learning and develop students' mathematical skills. Proper optimisation and up-to-date educational content increase the effectiveness of an educational website, which affects the ranking of a higher education institution in the modern digital educational environment and attracts future applicants. The authors of the article analyse some mathematical websites and present their own, developed on the basis of the WordPress content management system, which has a dynamic structure: e-lectures, e-workshops, workbooks, files with information for students, work programmes and/or syllabuses, author's textbooks on mathematical disciplines, workshops, etc.

The survey we conducted allowed us to find out students' opinions and experience of using specialised educational websites to study mathematics. Thus, almost 82% of students use non-formal education platforms, among which the most popular are: YouTube (91.1%), Prometheus (44.4%), Mathway (44.4%). The correlation analysis shows a strong direct correlation between the frequency of use of websites, students‘opinion on the usefulness of websites and students’ academic performance in mathematics.

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