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Fundamentals of UX/UI Design in Professional Preparation of the Future Bachelor of Computer Science

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Abstract. The present situation is investigated and the relevance of the stage of prototyping of user interfaces as intermediary of human-machine interaction in the process of software development is substantiated. The necessity of improving the methodology of teaching graphic disciplines and the relevance of studying the technologies of «UX/UI Design» in the process of professional training of future bachelor's in computer science as a perspective direction in view of the demands of the labor market and as a factor that raises the level of motivation of students for professional activity in general and on the formation of graphic competence. The methodical provision of the course is described, the structure and content of the theoretical and practical part of the course are presented, which is focused on the study of the technology of «UX/UI Design». The mathematical modeling of the discipline learning process «UX/UI Design» is described. The use of mathematical modeling to develop a model for training the discipline «UX/UI Design» provided the basis for the creation of a system of scientific-methodical and computer support of pedagogical activities and outlined the perspectives of designing a pedagogical technology for the formation of graphic competence of future Bachelor of Computer Sciences in the course of studying the discipline «UX/UI Design».

Keywords: Mathematical Models for Educational Process, Graphic Competence, User interface, UX/UI Design.

INTRODUCTION

With the onset of the fourth industrial revolution, which gradually and fundamentally changes the labor market, employers require workers to have a greater mix of skills (Schwab, 2017, p. 12-14).

As modern intensive technology development creates new high-quality jobs and reduces the value of other professions, the demand for poly-competence is only increasing. According to recent studies (Chemerys, 2020) the computer graphic and design of the user interface is gaining increasing demand in the labor market, and ranks fifth in the ranking of the most demanded skills that will be relevant in the coming years, according to a study conducted by the (World Economic Forum, 2019). The average salary of a specialist in designing interfaces in the United States is approximately 7,425 USD / month, according to information from 10,591 sources of data collected directly from employees, users, designers from the best design communities, and job vacancy announcements on the Indeed website over the past 12 months. Having analyzed the Ukrainian job search services we conclude that Kyiv has the

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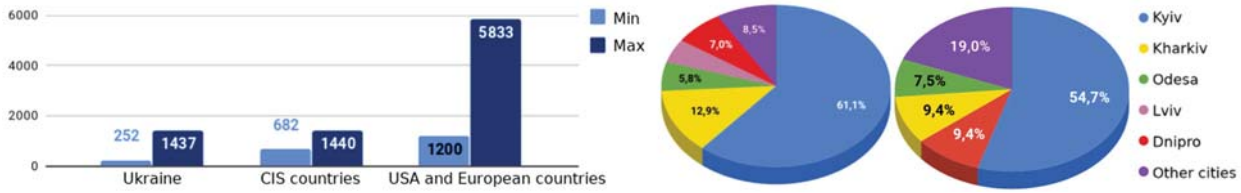
greatest demand for specialists with skills is, followed by Kharkiv and Dnipro, then Odessa, and from other cities there are fewer vacancies. In Ukraine, to apply for an initial position in the developer of interfaces a specialist should have the experience from one year, for CIS countries - from 3 years. In the US and European countries, wages are graded according to the work experience: from 0 to 5 years - from 5 thousand USD / month, from 5 to 10 years - from 6 thousand USD / month, 10 to 20 years - from 7 thousand USD / month (**FIGURE 1**.).



a) b) c)

FIGURE 1. Comparative characteristics of wages in the countries of the CIS, Ukraine, the USA and European countries according to robota.ua (a), characteristics of wages in Ukraine according to robota.ua (b) and work.ua (c)

RESULTS AND DISCUSSION

The visually appealing and user-friendly interface is a key indicator of the quality of the software developed. In conjunction with the competent structure and logical navigation in the sections of the resource interface is important for any software system, and it is an integral part of it, focused, first of all, on the end user. It is through the interface that the user evaluates the application; moreover, a user decides to use an application on a regular basis, considering how easy and understandable the user interface is

The User Interface (UI) provides a link between the user and the technical means, allows him to achieve the goals, successfully find the solution to the task. The science that is exploring the use of computer systems by the people to solve the set tasks is Human-Computer Interaction (HCI). HCI provides us with knowledge about the computer and the person in order to make the user interface more effective and convenient. The term Human machine interface (HMI) was promulgated by S. Card, A. Newell, and T. Moran in their 1983 founding book (Card, Stuart et al., 2018, p. 44), although the authors first used this term in 1980, and its first use was in 1975 (Carlisle, 1976, p. 613-614). Human Centered Design (ICS : 35.180; ISO 9241-210, 2010) defines usability as the degree of productivity, efficiency and satisfaction with which the user solves specific problems in specific conditions. The Human Centered Design principles are not focused on developing new methodologies, but are oriented towards introducing a human-oriented approach to the existing processes of creating user interfaces. The basic requirements for the development of user interfaces are described in the International Organization for Standardization ISO / IEC JTC 1 / SC 35 User Interfaces (ISO/IEC JTC 1/SC 35), a standardization subcommittee (SC), which is part of the Joint Technical Committee, ISO / IEC JTC 1, the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), which develops standards in the field of user interfaces of the system in information and communication technologies (ICTs). In order to standardize and unify the appearance of user interfaces, a number of Human Interface Guidelines (HIGs) have been developed for software developers by software giants of the software industry: Guide to Flat Design; Guide to Flat Design 2.0; Mac OS X Human Interface Guidelines; Apple - Human Interface Guidelines; iOS Human Interface Guidelines; WinXP Visual Guidelines; Windows Vista User Experience Guidelines; dex of UX guidelines for Windows Store apps; Guidelines - Material Design; Material Design 2.0; Android User Interface Guidelines; KDE Human Interface Guidelines; HIG, used by free development (GNOME Human Interface Guidelines; GNOME Human Interface Guidelines 2.0; OLPC Human Interface Guidelines OLPC); Indie hig; Java Look and Feel Design Guidelines; Java Look and Feel Design Guidelines: Advanced Topics; Eclipse User Interface Guidelines; IRIX® Interactive Desktop User Interface Guidelines and others.

«UX/UI Design» is the most sought after requirement for computer science professionals (Chemerys, 2021). That is why the training of specialists in this direction is an actual problem, which will increase their competitiveness and increase the share of ergonomic and aesthetic software developments in the Ukrainian market. As a result of the analysis of international standards, the experience of the current state and relevance of the design of the user interface as a mediator in human-machine interaction during the software development process and the results of labor market analysis, we note the need to implement the study of «UX/UI Design» in the process of training future Bachelors of Computer Science. Considering that the design of the user interface is a complete design system that requires a future bachelor of computer science to have advanced spatial thinking, the ability to perceive and produce graphic information, this became a prerequisite for the introduction of special requirements for the

professional training of such specialists, in order to overcome their difficulties during the presentation of spatial images and manipulation of these images in the process of solving problems. Such difficulties can be due to psychological peculiarities of visualization of information, perception of space, peculiarities of memorization of images, etc. Since the education of future bachelors in computer science should be subordinated to the requirements of the labor market of the modern post-industrial information society, and based on the study of modern realities and trends in the development of information and communication technologies in education, there is an objective need for the development of a teaching and learning complex, aimed at using prototyping of software interface in the process of forming graphic competence of these specialists. Given the fact that the educational system is a complex system, with a large number of processes and connections taking place in it, and to overcome the contradictions between the vast amounts of knowledge to be mastered and the real conditions for studying disciplines, mathematical modeling is necessary for management of educational and cognitive activity of students.

Application of Mathematical Modeling in the Process of Management of Studying the UX/UI Design

To optimize the system of training «UX/UI Design» is possible by managing individual processes and components. To describe training in view of the processes occurring in the system, we will provide an interpretation of the educational process through mathematical modeling. The urgency of the problem of the application of mathematical methods in pedagogical science is substantiated in the works of V. Zagvyazinsky, L. Itelson, V. Kraievsky and others. Mathematical models are widely used in the scientific and practical activities of people, because they allow to record accurately structural changes in any system and display them in quantitative form. Such models are necessary for the analysis of the efficiency of the functioning of educational systems, forecasting and designing their development. Therefore, for the management of educational and cognitive activities of students during the study of technology of «UX/UI Design», mathematical modeling of the educational process was used (Matsenko, 2014). To develop a mathematical model, the research was based on the creation of a mathematical model of the didactic process (Khlopova, T. P., Viazkova, V. V., Tikhomirova, T. V. & Romanov, 2009), according to which the mathematical model of the learning process for the design of user interfaces should be represented as (**FORMULA 1)**:

$$ML = \{MSA, MEM, MOS, MP\}, \quad (1)$$

where MSA is a model of the subject area of the discipline «UX/UI Design», MEM - model of education management, MOS - model of the object of study (the future bachelor of computer sciences) MP is a model of providing the teaching discipline that is taught. Consider each component.

In the generalized form, the model of the subject field of the discipline «Designing the user interface» can be represented as follows (**FORMULA 2)**:

$$MSF = \{MIC, MAD\}, \quad (2)$$

where MIC is a model of interdisciplinary connections, MAD is a model of academic discipline.

The model of interdisciplinary connections (MIC) of the discipline «UX/UI Design» is presented in **FIGURE 2**. Students learn the basis for studying the discipline «UX/UI Design» in the process of studying the subject «Introduction to a specialty».

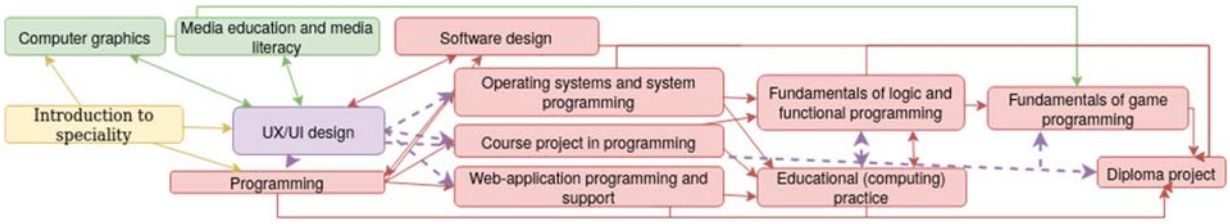


FIGURE 2. Description

Disciplines that have links to the interpenetration of learning material are Computer Graphics, Media Education and Media Literacy, and Software Design. The knowledge, skills and abilities obtained during the study of the discipline «UX/UI Design» students will be able to implement practically in their own projects while studying such disciplines as «Programming», «Programming and Support for Web Applications», «Operating Systems and System

Programming», «Fundamentals of Logic-Functional Programming», «Fundamentals of Game Programming», as well as during production training (computing practice), pre-diploma practice and for writing the graduation qualifications project.

The relationships used in the model of interdisciplinary connections of the discipline «UX/UI Design» can be specified using the **FORMULA 3**:

$$IDC = \{SIC, SF, SB\} \quad (3)$$

where SIC is the set of interconnections between the training material (shown in Figure 3 with two-way arrows), SF is a set of fundamental ties (shown by unidirectional arrows), and SB is the set of bond ties (shown by dashed arrows).

Model of educational discipline (MED) «UX/UI Design» is a clear set of elementary didactic units, which should be learned by the subject of training. The practical significance of the models of educational discipline is that on the basis of them it is possible to design informational educational environments that allow to manage adaptively the educational and cognitive activity of the learner and, therefore, optimize the feedback in teaching. Using a model of educational discipline, the teacher can optimally design a training course, compile a work program and a thematic plan for studying a particular discipline. We visualize a fragment of the model of the discipline «UX/UI Design» in the form of a multi-level oriented graph, in which the vertices reflect the didactic units of the information system, and the number of the vertex layer corresponds to the level of the hierarchy of this subsystem of information. The diagram illustrating the fragment of the model of the discipline «UX/UI Design» with the connections of the set of elementary didactic units is shown in **FIGURE 3**.

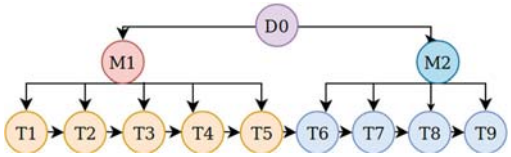


FIGURE 3. Fragment of the model of the discipline «UX/UI Design»

There are horizontal and vertical links between didactic units. Vertical bonds represent the subordination of the lower order of the didactic unit to the higher order module. A didactic unit of zero order (D0) is a discipline. Horizontal connections are semantic connections between didactic units. Didactic unit M1 is the first module of discipline «Pre-design and pre-project preparation». Its components are the following topics: T1 - «Theory of design. Introduction to the design of interfaces and web design», T2 - «Composition as a tool for combining elements of the user interface», T3 - «Prototyping as a method of pre-project research», T4 - «Philosophy of color separation, T5 - «Typography and its features of use in user interfaces». The didactic unit M2 is the second module «Visualization and layout», which includes the following topics: T6 - «Management of content pages. Optical balance. Typographic hierarchy», T7 - «Fundamentals of UX. Design Research», T8 - «Design for Mobile Devices», T9 - «Interaction Animation». Each of the listed didactic units has its own branched hierarchy of subordinate didactic units. We will demonstrate a graph illustrating the hierarchy of the didactic unit T6: «Manage content pages. Optical balance. Typographic hierarchy» **FIGURE 4**.

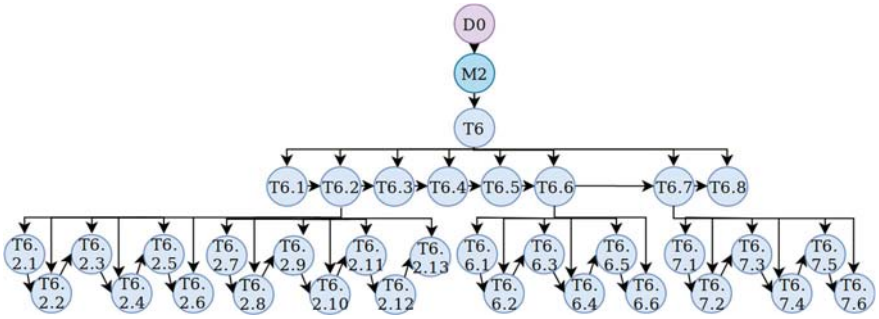


FIGURE 4. The model of interdisciplinary connections of the discipline «UX/UI Design»

The components of the didactic units indicated in the graph are listed in (Example of the didactic unit T6: «Management of content pages. Optical balance. Typographic hierarchy»):

T 6.1. The size of project files and permissions;
T 6.2. The layout is based on a grid;
T 6.3. Hierarchy of content;
T 6.4. Visual balance;
T 6.5. Leveling;
T 6.6. Text hierarchy techniques;
T 6.7. Optical balance in the typography of websites;
T 6.8. Negative impact of content overload;
T 6.2.1. Square modular grid;
T 6.2.2. Columns;
T 6.2.3. Vertical rhythm;
T 6.2.4. On the line;
T 6.2.5. Between the lines;
T 6.2.6. No grid;
T 6.2.7. Combinations of grid systems;
T 6.2.8. Errors in grids;
T 6.2.9 Adjustment and use of grid system;
T 6.2.10. Sensitiveness and flexibility;
T 6.2.11. Alignment and Balance;
T 6.2.12. Uniformity;
T 6.2.13. Paragraphs;
T 6.6.1. Size;
T 6.6.2. Color;
T 6.6.3. Style;
T 6.6.4. Letterspace;
T 6.6.5. Leading;
T 6.6.6. Space;;
T 6.7.1. Alignment in the typography;
T 6.7.2. Uneven distance;
T 6.7.3. Typographic hierarchy;
T 6.7.4. Font size and line spacing;
T 6.7.5. Vertical rhythm;
T 6.7.6. Enhanced contrast.

Thus, at each level of the hierarchy, the model of educational information (MEI) can be represented as the **FORMULA 4:**

$$MEI = \{KNII, VZ, GZ\}, \quad (4)$$

where the CEI - the set of components of educational information, VL - the set of vertical links between the information components, GL - the set of horizontal links. From the system-functional point of view, the model of educational information can be represented as the **FORMULA 5**:

$$MEI = D \cup F \cup T \cup SGI \cup DGI, \quad (5)$$

where D - the set of definitions of the subject area of the discipline «UX/UI Design», F - the set of verbal formulations and laws, T - the set of educational tasks, SGI - the set of elements of static graphic information, DGI - a set of elements of dynamic graphical information. To construct the model of the training course, we give a fragment of the matrix, the rows of which are the modules of the discipline «UX/UI Design», columns - the types of elements of educational information (**FIGURE 5.**):

		D	F	A	SG	DG
M1	T1	1	1	0	1	0
	T2	1	1	1	1	0
	T3	1	1	1	1	1
	T4	1	1	1	1	0
	T5	1	1	1	1	0
M2	T6	0	1	1	1	0
	T7	1	1	1	1	1
	T8	1	1	1	1	1
	T9	1	1	1	1	1

FIGURE 5. Matrix of the educational information model of the discipline «UX/UI Design»

The model of the object of study (MOS), as part of our study of the future bachelor of computer science, is given below **FORMULA 6:**

$$MOS = \{BC, LP, PE, MOR, PLO\}, \quad (6)$$

where BC - basic competencies of the student, LP - learning parameters, PE - the parameters of education, MOR - model of the relationship between student's learning and student's education, PLO - program learning outcomes.

Educational parameters are quantitative and qualitative indicators reflecting the social and professional competence of a future specialist (Khlopova, T. P., Viazkova, V. V., Tikhomirova, T. V. & Romanov, 2009; Vjazkova, V. V., Mausheva, Z. A. & Romanova, 2010) As the basic competencies to be mastered by the future bachelor of computer sciences, for the successful mastering of the discipline «UX/UI Design» we have identified the ability to generate new solutions, creative thinking and creative approach that gives impetus to the birth of design innovations. In particular, the list of basic skills needs to be expanded with basic mathematical knowledge, since any interface requires careful calculation of the parameters of the future product, the basics of programming, which are laid down in the course of studying the discipline «Introduction to the specialty» and during the parallel study of the subject «Programming». The basis for studying the discipline «UX/UI Design» will also be the skills of work in

graphic editors acquired by the future bachelor of computer sciences in the process of mastering the discipline «Computer Graphics».

As a result of the application of the described method, the requirements for «UX/UI Design» according to international standards were compared, and the following basic competencies were distinguished: the ability to enter and process text, graphical and multimedia information in the design process; the ability to apply computer methods for constructing two- and three-dimensional images and graphic presentation of visual material, model materials and technologies for their processing; the ability, on the basis of regularities, methods and principles of designing objects, to design an image and the spatial structure of design objects of graphic design (printing products, media, space media, etc.) and environment objects (physical bodies, objects, interiors of structures, etc.). Professional competence is the result of studying the discipline, which is specified in the tasks: expanding the students ideas about the purpose and possibilities of programs for processing and creating computer graphics; providing students with the necessary knowledge about creating and using prototypes and layouts of the user interface; acquaintance of students with the basics of graphic editor, prototyping of vireframes, prototypes and layouts of user interfaces and design of websites; the formation of skills and abilities of students for the creation and application of computer graphics and animation on examples of designing the user interface and web design; demonstration of practical significance and orientation of the existing knowledge and skills for further independent development of more complex techniques and methods of work in professional graphics processing programs and in the programming of software and web programming. Model of discipline provision (MP) we provide in the form of the **FORMULA 7:**

$$MP = \{RMS, LS, IS\}, \tag{7}$$

where RMS - a model of regulatory and methodological support, LS - logistical and IS - information support.

Normative-methodological provision of the discipline «UX/UI Design» includes the documentation that regulates the educational process, namely: the work program of the discipline, the curriculum, the basic abstracts of lectures, the methodical recommendations on laboratory work, the training manual «UX/UI Design», a set of test and control tasks for the thematic (modular) evaluation of student achievements, the means of final control (a set of printed tasks for final control). Teaching of the discipline is provided by modern technical means, which are based on the latest information and communication technologies (multimedia computer, multimedia projector, EdPro Interactive Intelligent Panel, copyrighted multimedia). At the classes and during independent work of students methodical recommendations are used.

For the information provision of the discipline, the methodical instructions are posted on the website of distance learning, consisting of lecture material, accompanying presentation and illustrative computer teaching material, computer testing tools for students' academic achievements. As a result of mathematical modeling, a teaching-methodical complex on discipline «UX/UI Design» was developed, which includes theoretical and practical modules, the structure of which is shown in **FIGURE 6.**

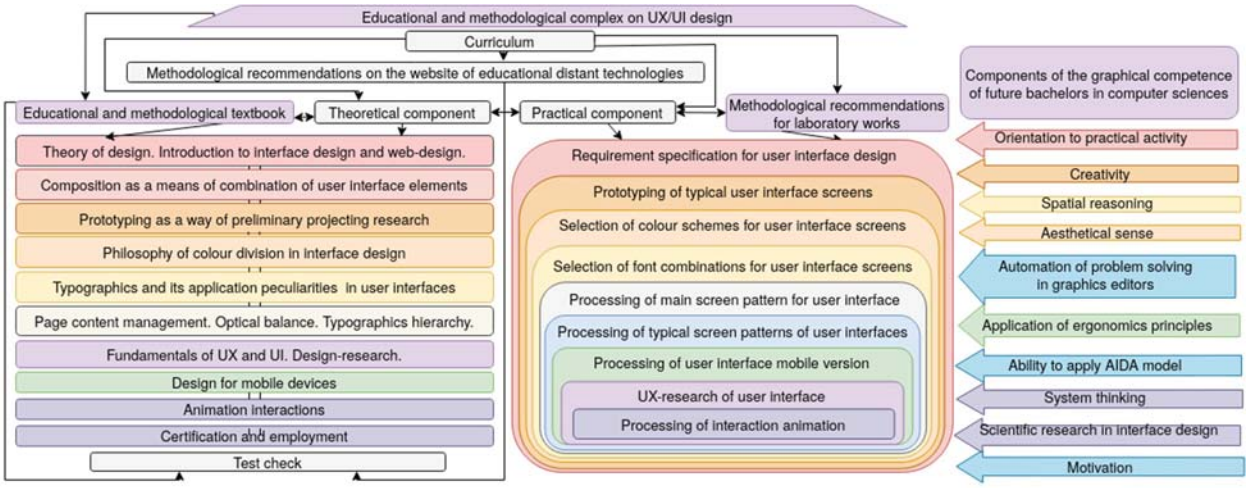


FIGURE 6. Structure and content of the teaching-methodical complex «UX/UI Design»

Lecture material and tasks for a practical module are based on active educational and project-oriented activities of students, integrating fundamental knowledge and practical skills. During the development of a series of laboratory

works on designing the user interface, a gradual transition from low-accuracy prototyping to interactive and high-level prototyping. Such a gradual transition from prototyping with low precision to high accuracy implements the principle of a flexible methodology for developing design tasks in an educational process (Agile-methodology) as a series of iterations (work cycles), where each iteration has the form of a program project in a thumbnail and includes all the tasks necessary for obtaining an increase in functionality (Chemerys, 2020). Laboratory works are semantically connected with each other, therefore, for these tasks, the probability of a solution to the next depends on the probability of the solution of the previous one. Applying the gained knowledge in practice, the students get the foundations of the technology of «UX/UI Design», and as a consequence, the motivation increases to the study of disciplines of professional orientation. The purpose of studying the discipline «UX/UI Design» is the formation of skills for operating graphical information in the design of the user interface, a deep and thorough study by students the complex design and engineering solutions for the development of user interfaces.

CONCLUSIONS

The article presents the mathematical model of teaching the discipline «UX/UI Design». The diagrams of processes taking place in the system of education with indication of its separate components and interconnections between them are given. The basis of the mathematical model is the functional diagram of the learning process, input and output elements of each block of the scheme are defined. This approach to the description of the learning process has allowed to identify the elements the management of which will improve the quality of the educational process in the distance or e-learning discipline «UX/UI Design». The use of mathematical modeling to develop a model for training the discipline «UX/UI Design» provided the basis for the creation of a system of scientific-methodical and computer support of pedagogical activities and outlined the perspectives of designing a pedagogical technology for the formation of graphic competence of future bachelors of computer sciences in the course of studying the discipline «UX/UI Design».

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