Development of a Textbook in the Modern Educational and Scientific Mathematical and Informatics Environment of Higher Education Students

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Abstract: The article deals with the problems of modelling and functioning of a textbook (digital textbook) as an integral part of the educational and scientific mathematical and informatics environment of higher education. It is shown that a high-quality digital textbook ensures the formation of not only the mathematical culture of a future specialist, but also the formation of such basic competencies as the ability and willingness to self-learn, apply knowledge, skills and abilities to work with computer mathematics systems to improve the efficiency of education, self-education and professional activity. The features of a modern digital textbook in mathematical disciplines in the preparation of a bachelor of mathematics are discussed: 1) the theoretical aspect of creating textbooks in the educational space of a bachelor of mathematics in the conditions of blended learning in Ukraine; 2) content of the digital textbook in accordance with the current regulatory framework and practical experience of teachers; 3) techniques of visualisation of educational material in mathematical disciplines and demonstration of some of them in the author's textbooks; 4) the results of the student survey show a strong direct relationship between the rankings of the frequency of use of textbooks in educational activities and their impact on the effective learning process, based on the interpretation of the nine R. Gagné learning events. The developed and implemented author's digital manuals meet the main criteria for their effective functioning: strategic focus, completeness of coverage, intensity, orderliness, coherence and mobility.

1 INTRODUCTION

Creating a textbook is a complex process of preparing, publishing, testing, evaluating, and implementing it in the educational process. The main role and wide range of functions of a textbook in education have always attracted constant attention to the problems of its content, quality, and creation. And this is no accident.

Firstly, a textbook, as a learning book, reflects in detail the content of education, the learning information to be learned. It conveys this information not only in the form of text, but also in illustrations, drawings, diagrams, and graphs. Secondly, an equally important function of a textbook is to manage students' cognitive activity. The apparatus for organizing the learning of educational material consists of two parts: auxiliary knowledge included in the main educational material, and tasks, exercises, questions, etc. that should ensure the process of learning and the formation of skills and abilities. That is why scientists interpret a textbook as an information model of learning, as a kind of scenario of the educational process, which is the embodiment of didactically and methodically developed and systematized educational material. From this point of view, the textbook should reflect the goals and content of learning, determine the system of cognitive actions with the material, organizational forms of learning and methods of control.

Recently, we have observed some intensification in the publication of manuals and workshops in mathematical disciplines for the preparation of a bachelor of mathematics in the specialties 111 Mathematics, 014.04 Secondary Education (Mathematics) and 014.09 Secondary Education (Informatics) [1, 2, 3, 4], as well as publications on

the problems of the content of manuals and workshops for these specialties, taking into account the needs of students with special educational needs [5], expanding the use of digital technologies in the creation of digital manuals and workshops, etc. In our opinion, the relevance of this problem was given by the blended learning of students, which has been operating in Ukraine for a long time for various objective reasons.

The purpose of the article is to analyse the development and transformation of a textbook from a classical to a digital one using the principles of foundation, visualisation of educational content and implementation of nine learning events according to R. Gagné of the sequential transition from one state of student understanding of the educational material to other states; to conduct an experimental study among students to assess the presence and significance of the relationship between the rankings of the frequency of use of textbooks.

2 ANALYSIS OF CURRENT RESEARCH

Mexican scientists M. Pineda Becerril et al. [6] note that "a digital book is a publication based on an electronic file that can be stored on various digital media and allows the inclusion of interactive and multimedia elements". The authors have developed a multimedia tutorial on probability distribution, which is integrated into the relevant virtual environments so that students can immerse themselves in images with interactive subtitles and rotate an object in 3D.

The article [7] discusses the transformation of school teaching materials in the context of the digital society in Latin America and Europe.

Spanish researchers N. Rodríguez-Regueira and J. Rodríguez-Rodríguez [8] analyzed digital textbooks for primary education in Spain (30 digital learning materials). The novelty of their study is the development and testing of a guide for analyzing this type of materials, taking into account their main technological, pedagogical and functional characteristics in connection with the evolution of the digital educational market.

Research by contemporary scholars shows that digital textbooks are particularly difficult to integrate into mathematics teaching [9] and that it is worthwhile to study in more detail how the conditions for teaching mathematics are changing due to modern digital textbooks [10] and textbooks that use artificial intelligence [11] and how learning can be developed with their help.

The use of open textbooks in higher education institutions and the financial benefits to students from this, without reducing their learning outcomes, are emphasized in the article [12, 13]. This should encourage teachers to use high-quality open textbooks in the post-pandemic world to expand digital learning opportunities in the twenty-first century.

3 MAIN RESULTS

3.1 Theoretical Aspects of Creating Textbooks in the Educational Space of Bachelor of Mathematics in the Conditions of Blended Learning in Ukraine

The need to introduce digital technologies into the educational process is demonstrated in studies conducted by the National Training Center in the United States. The results of the research are called the "Learning Pyramid" and show that when using video and audio materials, 20% more material is learned, when using demonstrations, 30% more of the material is learned than when listening to a regular lecture. The largest percentage of knowledge gain during the course of study (work in small groups, work in pairs) and the application of the acquired knowledge immediately after studying ("brainstorming", "aquarium") is 90 % [14].

Our research suggests that in blended learning, student manuals should be consistent:

$$\text{Student} \rightarrow \text{Textbook} \rightarrow \text{Teacher}$$
$$(\text{or Student} \rightarrow \text{Educational and Methodological Complex (Digital EMC)} \rightarrow \text{Teacher}).$$

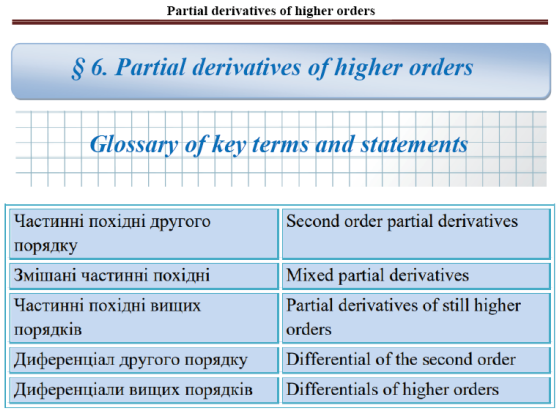
In this case, the role of the teacher is not diminished, but rather enhanced, because it is here that the teacher not only provides ready-made information but also teaches students to search for, analyze, and process new information on their own.

The textbook should be integrated into the teaching technology that the teacher designs and implements. In this case, the logic and structure of the lesson will be an element of the teacher's creativity, and he or she will be able to choose his or her own strategy and teaching methodology, and not just follow the presentation of material proposed by other authors. In a context where the idea of student-centered learning based on teacher innovation is fundamental to education, this approach to textbooks,

in our opinion, is becoming crucial in textbook development.

When creating textbooks, it is necessary to take into account that: textbooks should have a high scientific and methodological level, contain the necessary reference apparatus; textbooks should be written in an accessible form, the educational material should be related to practical tasks, the book should have close interdisciplinary connections [15].

For example, the textbook by M. Kovtoniuk, A. Klimishyn, I. Leonova, and O. Soia contains a glossary of mathematical terms in Ukrainian and their equivalents in English (Fig. 1).


Partial derivatives of higher orders

§ 6. Partial derivatives of higher orders

Glossary of key terms and statements

Частинні похідні другого порядку	Second order partial derivatives
Змішані частинні похідні	Mixed partial derivatives
Частинні похідні вищих порядків	Partial derivatives of still higher orders
Диференціал другого порядку	Differential of the second order
Диференціали вищих порядків	Differentials of higher orders

Figure 1: A fragment of a textbook on higher mathematics[1] [3].

The publication of textbooks and workbooks in Ukraine in the discipline of Mathematical Analysis has been growing over the past 35 years. In particular, students majoring in 111 Mathematics, 014.04 Secondary Education (Mathematics) and 014.09 Secondary Education (Computer Science) use the textbooks by A. Dorogovtsev (1994), I. Liashko, A. Boyarchuk, Y. Gay, A. Kalaida (1979), L. Duzhenkova, A. Kalaida (1979) (Taras Shevchenko National University of Kyiv), L. Duzhenkova, T. Kolesnyk, M. Liashenko, H. Mykhalina, M. Shkil (2003) (Mykhailo Dragomanov Ukrainian State University), N. Shunda, A. Tomusiuk, A. Shunda, A. Tomusiak, M. Kovtoniuk, A. Klimishyna, I. Leonova, O. Soia (2008, 2009, 2011, 2015, 2022, 2023) (Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, 1993), S. Gurgula, V. Moisyshyn, V. Vorobiova (2008) (Ivano-Frankivsk National Technical University of Oil and Gas), B. Kovalchuk, Y. Shipka (2002, 2004, 2006, 2010) (Ivan Franko National University of Lviv), etc.

Designing the content of vocational mathematics education is a necessary key condition for the successful construction of the discipline of the speciality. Particular attention should be paid to the development of the speciality curriculum, work programme, teaching technologies, and quality management. On the basis of these documents, educational and methodological and digital educational and methodological complexes of the discipline are designed and created, which include, in particular, author's educational and methodological developments, manuals included in the teaching technology.

We propose to deepen the theoretical and practical components of the professional education of a bachelor of mathematics on the basis of strengthening the school component of mathematics education with further foundation of knowledge at different levels. The principle of foundation in the process of teaching mathematics is understood as the process of identifying the basic educational elements of school mathematics with their subsequent theoretical generalisation, revealing the integrity, essence, transdisciplinary connections, and aimed at the intellectual development of students. The peculiarity of the foundation principle is the definition of the basis for a spiral scheme for modelling the subject competences of a bachelor of mathematics (the foundation spiral). In each mathematical discipline, it is worth highlighting the basic concepts of school mathematics with further analysis of their foundation. They will form the fundamental core of mathematical disciplines.

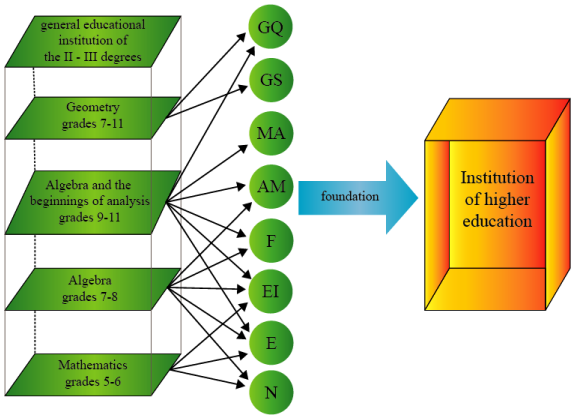


Figure 2: Source objects of funding[2].

Let's analyse this process using several examples. The educational course "Mathematics" in general secondary education is traditionally taught as the following disciplines: algebra, algebra and beginning

[1] https://kovtonyuk.com

[2] author's development

of analysis, geometry. The State Standards of School Mathematics Education define eight content areas of the school mathematics course [16]: 1) Numbers and operations on them [N]; 2) Expressions and their identical transformations [E]; 3) Equations, inequalities and their systems [EI]; 4) Functions, their properties and graphs [F]; 5) Elements of applied mathematics [AM]; 6) Beginnings of mathematical analysis [MA]; 7) Geometric shapes, their elements and properties [GS]; 8) Geometric quantities, their measurement and calculation [GQ].

The definition of content lines allows us to identify the initial objects of funding (Fig. 2).

It is crucial that all fundamental school-level knowledge is incorporated into the list of elements of the academic disciplines of bachelor's degree training in mathematics for the aforementioned specialties and is transferred from the database (formal operations in school mathematics) to the database of subject and professional competencies of the student. For example, for the concept of a derivative, it is necessary to substantiate the transition from the definition of a derivative based on the error of the difference ratio of the increment of a function to the increment of the argument to the definition of the limit transition and the delta-epsilon language and the language of sequences. Filling in these "transitions" between concepts, theorems, methods of proof, and guiding foundations of activity is one of the main tasks of the academic discipline "Mathematical Analysis".

The concepts of the primitive and definite integral, which are studied in the 11th grade of general secondary education institutions, are gradually generalized through the Riemann definite integral for a function of one variable, multiple integrals (double, triple, surface, curvilinear) for functions of many variables, and, finally, in the course of modern mathematical (functional) analysis, the Lebesgue integral on measurable sets is studied.

Having reached a certain level of abstraction of this concept, students begin to work on the methodological analysis of the concepts of the original and definite integral in the course of methods of teaching mathematics (Fig. 3). The highest level of foundation is provided during the modelling of real processes and phenomena with the help of integrals, when the student applies qualitative mathematical research methods, computer mathematics systems, and develops practical recommendations.

At each level of foundation, special attention should be paid to understanding the essence of each basic concept.

Thus, summarising the above, it can be argued that the information component of creating textbooks for bachelors of mathematics should be formed on the basis of the principle of foundation of mathematical objects.

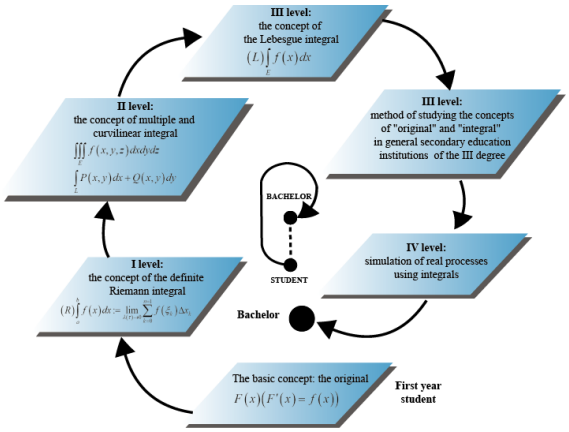


Figure 3: Scheme of foundation of the school concepts of the initial and definite integral[3].

3.2 Visualisation in Mathematics Textbooks

The term "visualisation" comes from the Latin visualis - perceived visually, visual. Visualisation is the process of presenting data in the form of an image for the purpose of maximising the ease of understanding; giving a tangible form to any object, subject, process, etc. However, such an understanding of visualisation involves minimal mental and cognitive activity of students, and visual didactic tools perform only an illustrative function [17].

Visualisation is a visualisation, creating conditions for visual observation [18].

The use of tables, diagrams, and drawings facilitates quick memorisation and comprehension of the material being studied. Taking into account modern technical capabilities, the idea of visualising information in the learning process takes on new features (Fig. 4).

Advantages of visualisation in teaching mathematical disciplines:

- helps students to organise and analyse information correctly;
- charts, diagrams, drawings, memory maps help to assimilate large amounts of information, make it easy to remember and trace the relationship between blocks of educational material;
- develops critical thinking;
- helps students integrate new knowledge;

[3] author's development

- allows you to link the information received into a holistic picture of certain phenomena or objects (Fig. 5).

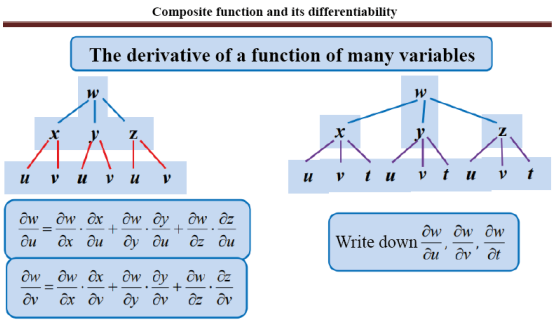


Figure 4: A fragment of a mathematics textbook[4] [3].

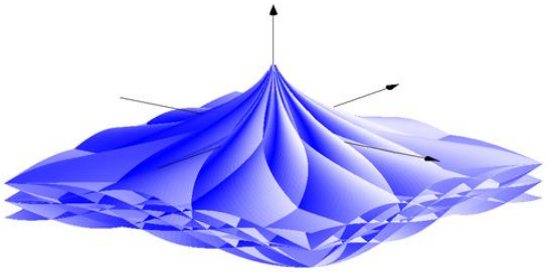


Figure 5: Visualisation of the surface "Snow Avalanche"[5].

Presentation of educational material using modern visualisation techniques is an integral part of a mathematics textbook for students of higher education institutions. With the help of visualisation, the teacher demonstrates complex abstract mathematical concepts, which helps to develop the student's imagination and memory and helps to dive deeply into the learning material.

The experimental study confirmed that the educational material presented in the textbooks sufficiently ensures the implementation of the nine learning events according to R. Gagné, a sequential transition from one state of student understanding of the educational material to other states.

4 DISCUSSION

The study considers the results of a survey of students of the Faculty of Mathematics, Physics and Computer Science of Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Ukraine.

The results of the first stage of the study showed which digital resources students use during their studies (multiple choice): textbooks (78.9 %), lecture notes (92.1 %), teachers' workbooks for laboratory and practical classes (55.3 %), individual materials of teachers for laboratory or practical classes (68.4 %), search engines (78.9 %), other open sources of information (5.2 %).

The research aims to find out whether the learning material presented in the textbooks sufficiently ensures the implementation of the nine learning events according by R. Gagné, who believed that a student should move sequentially from one state to other states of understanding the learning material. The first learning event is drawing attention to the learning material and motivating students. The ninth and final stage is the use of the acquired knowledge, skills and abilities in practice. The teacher helps the student to go through this process. Analysing a textbook according by R. Gagné makes it possible to understand how effectively the educational content is prepared, whether students have achieved the expected learning outcomes, acquired relevant knowledge, skills, mastered different ways of thinking, acquired scientific views and values that determine the ability of students to successfully socialise and conduct further professional activities [19].

The second stage of the study was conducted among students in order to assess the presence and significance of the relationship between the rankings of the frequency of using textbooks in educational activities (variable X) and their impact on the effective learning process according to the interpretation of the nine learning events by R. Gagné (variables Y_j, $j = \overline{1,9}$). The sample consisted of N=76 students aged 18-21 years (57 % girls). Parental consent was not required, as all students were of legal age at the time of the survey. The research was conducted with the permission of the faculty administration in compliance with ethical standards and with maximum respect for the privacy and confidentiality of students. The authors of the article conscientiously adhered to the ethical standards of the American Psychological Association (APA) and the recommendations of the Ethical Code of the Scientist of Ukraine [20].

The questions of the questionnaire are based on the nine events of Gagné's learning. Students ranked their answers on a scale where a score of 10 means absolute agreement – "Yes", and a score of 1 means absolute disagreement – "No". If necessary, intermediate values were also used.

Step 1. Attract attention.

(Y_1) Do study guides contribute to your interest in learning e.g. [6]?

[4] https://kovtonyuk.com

[5] author's development

[6] https://press.vntu.edu.ua/index.php/vntu/catalog/book/812?fbclid=IwAR3sdYLfk60WmS5HFzbRJtBwRisptz8AxUSxuz1YKLVsGSw7AgorYA1aPzo

Step 2. Informing students about the purpose and objectives of learning.

(Y_2) Does the use of study guides help students to understand the purpose and objectives of the learning?

Step 3. Stimulate the repetition of previous learning material.

(Y_3) Do you pay attention to the presence of revision materials, examples or questions in the textbooks to test your previous knowledge?

Step 4. Presentation of learning material.

(X) How often do you use textbooks (manuals) in your learning activities?

Step 5. Tasks, learning support, instructions for students.

(Y_4) In your opinion, are there enough practical examples in the textbooks to explain the theoretical material?

Step 6. Practice.

(Y_5) In your opinion, are there enough practical examples in the textbooks to reinforce the material?

Step 7. Feedback.

(Y_6) Do you get answers to your educational questions with the help of textbooks?

(Y_7) Is it enough for you to interact with the teacher through the tutorials?

Step 8. Assessment of learning outcomes.

(Y_8) In your opinion, how does the use of study guides contribute to self-analysis of your educational activities?

Step 9. Consolidating and applying the acquired knowledge, skills and abilities in practice.

(Y_9) In your opinion, how does the use of study guides form your ability to self-educate?

To identify the existence and significance of relationships, we chose Spearman's rank correlation coefficient r_s, which is used to determine the closeness of relationships between quantitative and qualitative attributes if their values are ranked. The rank correlation coefficient r_s is calculated by the [21]:

$$r_s = 1 - \frac{6\sum_{i=1}^{n}(x_i - y_i)^2}{n \cdot (n^2 - 1)},$$

where n – is the volume of the set of objects; $(x_i - y_i)$ – is the rank difference of the i-th object. The coefficient r_s takes values in the range from – 1 to + 1.

The sampling distribution r_s, which characterises zero correlation between two groups of ranks, is associated with the Student's t-distribution. If the value of r_s is 0 and $n > 10$, the empirical criterion for degrees of freedom $(n - 2)$ is determined by the

$$t_{emp} = \frac{r_s}{\sqrt{(1 - r_s^2)/(n - 2)}}.$$

The null hypothesis of no correlation is rejected for the significance level α at $t_{emp} > t_\alpha$.

The results of the study are presented in Table 1 for $\alpha = 0.01$ ($t_\alpha = t_{0.01}$).

Table 1. Calculations of the existence and significance of the relationship between the rankings of the frequency of using textbooks in educational activities (variable X) and their impact on the effective learning process according to the interpretation of the nine R. Gagné learning steps (variables Y_j, $j = \overline{1,9}$).

Rank correlation coefficient r_s, t-distribution	(X, Y_1)	(X, Y_2)	(X, Y_3)	(X, Y_4)	(X, Y_5)	(X, Y_6)	(X, Y_7)	(X, Y_8)	(X, Y_9)
r_s	0.994	0.997	0.997	0.994	0.997	0.997	0.997	0.998	0.998
t_{emp}	80.512	109.670	111.175	78.076	112.214	105.057	103.782	123.785	121.054
$t_{0,01}$	2.894								

Thus, since all $t_{emp} > t_\alpha$ for the significance level $\alpha = 0.01$, the null hypothesis of no correlation is rejected at the 0.01 level. The numerical value of $r_s > 0.99$ indicates a strong direct relationship between the rankings of the frequency of using textbooks in educational activities (variable X) and their impact on the effective learning process as interpreted by the nine R. Gagné learning events (variables Y_j, $j = \overline{1,9}$).

5 CONCLUSIONS

The article deals with the problems of development and transformation of a textbook (digital textbook) as an integral part of the educational and scientific mathematical and informatics environment of higher education. It is shown that a high-quality digital textbook ensures the formation of not only the mathematical culture of a future specialist, but also the formation of such basic competencies as the ability and willingness to self-learn, apply

knowledge, skills and abilities to work with computer mathematics systems to improve the efficiency of education, self-education and professional activity. The use of a digital textbook integrated into the learning technology designed and implemented by the teacher allows him or her to choose their own creative strategy and methodology for teaching students.

The features of a modern digital textbook in mathematical disciplines in the preparation of a bachelor of mathematics are discussed:

1) the theoretical aspect of creating textbooks in the educational space of a bachelor of mathematics using the principles of foundation, spiral and continuity in the context of blended learning in Ukraine;
2) content of the digital textbook in accordance with the current regulatory framework and practical experience of teachers;
3) techniques of visualisation of educational material in mathematical disciplines and demonstration of some of them in the author's textbooks;
4) the results of the student survey show a strong direct relationship between the rankings of the frequency of use of textbooks in educational activities and their impact on the effective learning process, based on the interpretation of the nine R. Gagné learning events.

The developed and implemented author's digital manuals meet the main criteria for their effective functioning: strategic focus, completeness of coverage, intensity, orderliness, coherence and mobility.

In the future, we aim to investigate the impact of using a digital textbook on the formation of mathematical, informatics and pedagogical culture of a higher education student.

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