DEVELOPMENT OF ELECTRONIC MULTIMEDIA INTERACTIVE TEXTBOOK FOR PHYSICS STUDY AT TECHNICAL UNIVERSITIES

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Abstract. The article reveals the problem of creating and improving e-textbooks on the example of development of electronic textbook for physics study at technical universities. The disadvantages of e-textbooks based on standard platforms and templates are considered. The problems of using Web technologies for the improvement of such textbooks are discussed. There are numerous platforms and templates for creating electronic textbooks. However, our analysis and experience with such resources showed their inconvenience and inadequacy for the needs of the engineering specialties education because corresponding texts have a large volume, complex structure, contain multilevel cross-content focused both on understanding the fundamental laws and their technical and technological application during engineering activities. Therefore, students find it difficult to navigate in a large amount of material, many equations, massive evidence base, and large graphic material.

The presented e-book configuration is created by JavaScript direct programming. The e-book significantly expands the visibility of the material (color accented graphics, videos, animation, etc.), improves usability (thoughtful intuitive navigation, one-click equations, tips, etc.) using the capabilities of computer technology. It contains a variety of original demo animation, videos, and color drawings worked out to the smallest detail. Many convenient hyperlinks are available at the click (pop-up equations, tips, help and additional information). The e-book also optimizes the student's independent work (examples of detailed step-by-step solution of problems, questions for self-testing with hidden answers, etc.). The e-book is offered to students of all technical specialties and all forms of university education. The application of this e-book involves acquiring theoretical knowledge and practical skills in physics.

Keywords: e-book on physics, electronic educational resource, open educational resources, direct programming, multimedia interactive textbook.

1 Introduction

Significant changes in the quality and nature of education in the 21st century are related with direct and indirect digitization of forms, methods and tools of learning. The relevant techniques such as online courses, online exams, digital textbooks, educational animation are developed on their basis [1].

Digitization is one of the critical factors in hard competition of universities for the precedence in various rankings. According to the Ukrainian Institute of the Future, higher education should integrate physical and digital spaces by 2030. In particular, it takes place through managing the education content and process through «student-teacher» interaction using online platforms [2].The significance of the development and use of new electronic educational resources and the implementation of digital pedagogy in Ukrainian education is also emphasized in the Concept of a New Ukrainian School [3].

Our analysis has shown that e-textbooks are a kind of electronic educational resource (EER), which is defined «as an electronic version of a printed textbook, which is usually divided into separate subject areas» [4], «an educational or instructional book in digital form» [5], «electronic versions of a text that can be read on a desktop, mobile device, or e-reader device» [6].

In national regulatory documents and sources an e-textbook is defined as «electronic educational publication with systematic presentation of an educational material that corresponds to the educational program, contains digital objects of various formats, and provides interactive communication», which is reflected in the general provisions of the Law of Ukraine «On Education» [7] (Article 1, Paragraph 5) and «Regulations on Educational Electronic Resources» [8]. The government guarantees free provision of textbooks (including electronic ones) and manuals for all pupils and pedagogical workers in accordance with the procedure established by the Cabinet of Ministers of Ukraine [7] (Article 4, Paragraph 3).

International experience sets priorities for the development of e-textbooks and the transition from paper to interactive multimedia tools. Teachers can transform such learning material that gives the opportunity to provide students with an individual educational path. There is a growing number of open educational resources (OER) that refer to openly licensed materials that give users legal permission to save, reuse, revise, remix, and redistribute material [4], [9]. A striking example of the high demand for OER-based training courses is the activity of Coursera, a technology company (https://www.coursera.org/home), offering hundreds of free online courses to users.

The analysis of the Internet messages showed that the advantages of e-textbooks are their cheapness, comparably to similar printed editions, the ability to use a single device for many e-textbooks. The disadvantages are that this software can take up a lot of memory on the gadget, communication with the instructor/teacher is quite problematic, it is difficult to put the notice in the educational text, etc. On the other hand, it is obvious that the creation of high quality and low-cost digital materials to support student learning is rather difficult process, which requires additional competencies for research and teaching staff and have need of state and universities support [5]. The

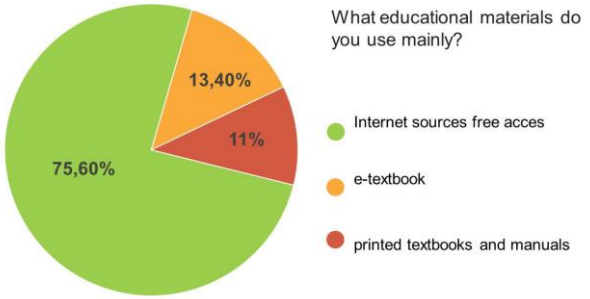
authors of [10] note that the developers of e-textbooks should make the most of digital advantages such as multimedia and collaboration with the teacher in real time. Therefore, their design should focus on usefulness, practice, and motivation. It should be noted that long-term studies of e-textbooks use by students revealed a number of subtle features, which are described in detail in the paper [4]. The following factors can be used for the EER assessment: content, methodology, ergonomic and design, technical and technological factors [8].

Analysis of the situation of e-books creating for the study of technical disciplines showed that the books number is growing annually, and the vast majority of them are similar in structure to the OpenStax OER [11] or the well-known resource «Open Physics 2.6», which contains, among other things, high quality text-based educational material for general physics study [12]. However, more detailed research and experience with similar products have shown that they are inconvenient and unsuitable for the educational needs of future engineers. This revealed a particular problem with the use of WEB-technologies for the development of electronic multimedia interactive textbook for engineering specialties, for example, an e- textbook for general physics study.

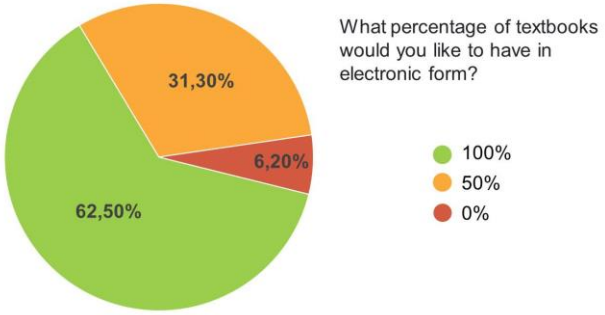
2 Analysis of recent studies and publications

In order to obtain up-to-date survey data on the attitude and use of OER by students in 2019 year, we conducted a survey of 128 first and second year students of the National Aviation University. An analysis of the results obtained using the Google Forms toolkit revealed that respondents actively use electronic data sources during learning (almost 90%), their majority are freely available (Fig. 1a). This confirmed the need for the creation of electronic platforms in departments that would accumulate EER with open or partially restricted access for users. On the other hand, only about 63% would like to have all textbooks electronically (Fig. 1b) and 67% noted that they are very or occasionally tired of using the EER (Fig. 1c). Such data may indicate that students need to use both the paper textbook and its electronic version. In this context, interesting is the research data [4] according to which users (students and postgraduate students of the university) do not indicate the electronic textbook as a more effective tool in forming the required subject skills.

Nowadays in our country the EER is focused on the achievement of complete general secondary education. Multimedia and electronic textbooks and manuals are developed on special electronic platforms of such specialized large publishing houses as «Intellectuals» (http://rozumniki.net), «Morning» (https://www.ranok.com.ua), «Education» (http://osvita-center.com.ua/brands/vydavnychyy_dim_osvita), «Bogdan» (https://bohdan-books.com) under the control of the Ministry of Education and Science of Ukraine (MES of Ukraine) with compliance with state requirements for high quality OER [8].



a



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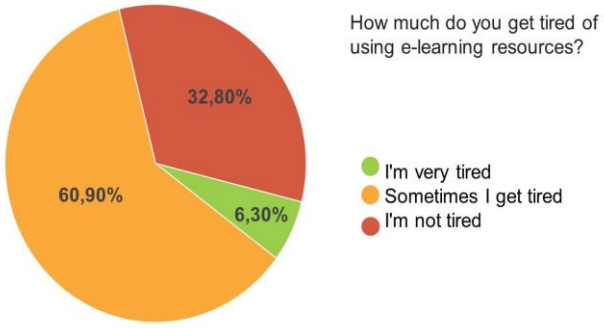

c

Fig. 1. Statistics of students' answers to the questionnaire

Much more complicated is the problem of EER development for higher education institutions, especially technical ones. This is due to the fact that such software products, on the one hand, have a large volume, complex structure, contain multilevel cross-content focused both on understanding the fundamental laws and their technical and technological application during engineering activities; on the other hand, that the creation of high-quality EER requires the involvement of IT professionals, digital content developers and programmers who are not always in the staff of a particular department of the university.

The research has found that there are very few data related to physics e-textbook design among scientific papers including published on the popular Research Gate platform. Obviously, this is due to the complexity of implementing such projects, especially from scratch. The authors [13] have described some features of creation of interactive educational material and visualization of models of the dynamics of rotation of solid body, and also showed the activation of cognitive activity of students as a result of their use [14]. The features of creation and methodology of use of complex EER as a package of physics electronic books for students of the bilingual educational environment senior classes, which include the virtual laboratory environment, students' worksheets and the final test, are described in [15].

Previously, we have already gained practical experience in web-development for physics study and information portal in WordPress designed by Adobe Photoshop and using HTML and CSS site layout [16] as well as an electronic workbook for laboratory work in the form of author's version of flipbook [17].

3 The purpose of the article

The purpose of the article is to highlight the features and problems of the process of creating an e-book for technical disciplines study at universities on the example of the manual «Physics. Module 1. Mechanics».

4 Methods

The most important question that arises when creating an interactive e-textbook is the choice for programming the most suitable environment. The electronic edition we offer has a large amount of information and contains many equations, massive evidence base, and graphic material worked out to the smallest detail. In addition, it implements video, original demo animation, and «pop-up» reference material. Moreover, in accordance with the requirements of the Ministry of Education and Science of Ukraine [8, item III.2], the e-textbook should be adaptive, interactive, cross-platform, and functional. The benchmarking method we have used has shown that now there are a number of platforms and templates for creating EER. The most popular ones are Drupal (https://www.drupal.org/), WordPress (https://www.wordpress.org/), Joomla (https://www.joomla.org/) and others that are written mainly in PHP programming language and have been widely used in creating a wide range of cross-platform web products, from personal blogs to knowledge management systems and business col-

laboration. However, taking into account the above requirements, the features of the known platforms and templates as well as the data obtained by us in the study [16] and [17], the path of direct programming and creation of the software from scratch using JavaScript language was chosen already at the stage of creating the technical task.

5 Results and discussion

The paper version of the manual «Physics. Module 1. Mechanics» (with the stamp of the Ministry of Education and Science of Ukraine) was first published in 2004. It was a new type of publication; its preparation became necessary in connection with the conversion of Ukraine higher education to the credit-module system of teaching [18].

The electronic content of this textbook comprises the basic material necessary for the study of the part of general physics «Mechanics» in higher technical schools, namely:

- theoretical core (topics «Kinematics», «Dynamics», «Laws of conservation», «Fundamentals of special theory of relativity») with comprehensive explanations of all questions and necessary mathematical conclusions of equations;
- examples of solving problems with detailed explanations;
- a significant amount of self-solving tasks;
- laboratory works;
- keywords;
- reference material with all necessary information.

There are generally accepted stages of web product development [19]. We can separate the following main steps of the process of direct programming (frontend and backend development), which we have used in the development of the interactive electronic textbook:

- creating a content tree structure that includes the following main folders: 1 – build; 2 – gulpfile.babel.js; 3 – node_modules [index.html; package.json; .npmrc]; 4 – source [app, assets, content (book / chapters 1, 2 …], [extensions / aviation, personalities];
- processing of the text material (carried out using the Sublime cross-platform text editor): HTML markup and CSS formatting;
- connection of dynamic effects on JavaScript;
- developing graphics that were implemented using Word capabilities;
- create 2D animation based on Photoshop;
- video implementation using Vegas-Pro;
- implementation of the server part of the project using Node.js for compilation;
- code optimization and protection (if possible).

IT capabilities have been widely used at all stages to provide diversity, visual appeal, clearness, aeronautical focus, and usability. In particular, we have declined the standard buttons for switching between the EER sections and topics, as it implemented in

[11] and [12]; the list of the e-textbook «Physics. Module 1. Mechanics» units and items is permanently accessible to the user on the left side of the screen. The looked-for topic can be opened with one click, with the current item highlighted (Fig. 2), which makes it easy to navigate the EER architecture.

An important role in the perception of a figure that reproduces the physical model of a phenomenon, process, or law is played by colors through which the accents in the image can be positioned. That is, the associated color accents of lines and inscriptions allow the user to understand without difficulty the idea of drawing (for example, the red color of the vectors forces $\vec{F}$ and the angular acceleration $\vec{\varepsilon}$ (Fig. 2)).

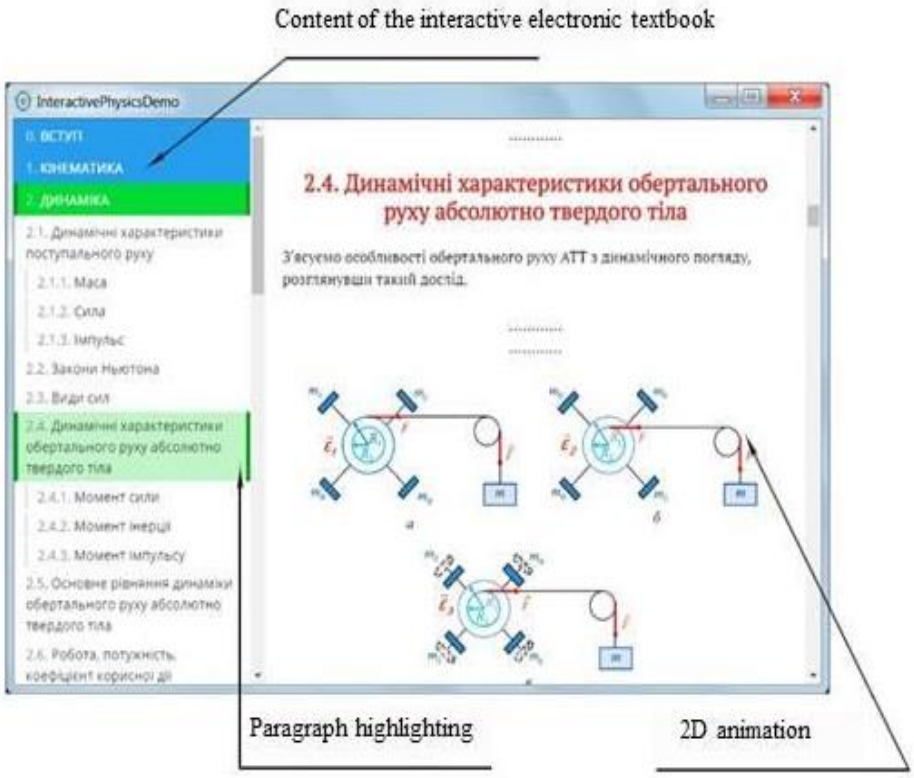

Fig. 2. Features of the page of the interactive electronic textbook «Physics. Module 1. Mechanics» with 2D demonstrations

For the page «Dynamic Characteristics of Solid Body Rotational Motion» the code snippet has the following structure:

```
</style><svg style="display: none;"><defs
id="MathJax_SVG_glyphs"></defs></svg><h2 id="p-2.4.">2.4.
Динамічні характеристики обертального руху абсолютно твердо-
го тіла</h2>
```

```
<p> З’ясуємо особливості обертального руху АТТ з динамічного
погляду, розглянувши такий дослід.
</p><figure><figcaption>............</figcaption>
<figcaption>............</figcaption></figure>
<fig-
ure><imgsrc="\content\book\chapter_2\img\part_2.081.png"
class="va-mid" width="1100">
```

As you know, the physics course (as well as various technical disciplines) contains significant mathematical conclusions with numerical references. As students point out, the large number of cascading transitions that are usually used in e-textbooks often leads to a loss of logic in the educational material and misunderstanding. Therefore, all the numerous references to equations in the proposed interactive electronic textbook are pop-up, without cascading transitions. Convenient hidden tips at the one-click «open / hide» were used for self-preparation and self-testing (Fig. 3). The element code of this page looks like this:

```
<li>
<h4> відцентрова сила </h4>
<div> Відцентрова це сила, що виникає в неінерціальних
системах відліку, що обертаються <spandata-formula-
id="2.94a" class="formula TipInsert"> (2.94a) </span>.
(Див. п.2.11).</div>
</li>
```

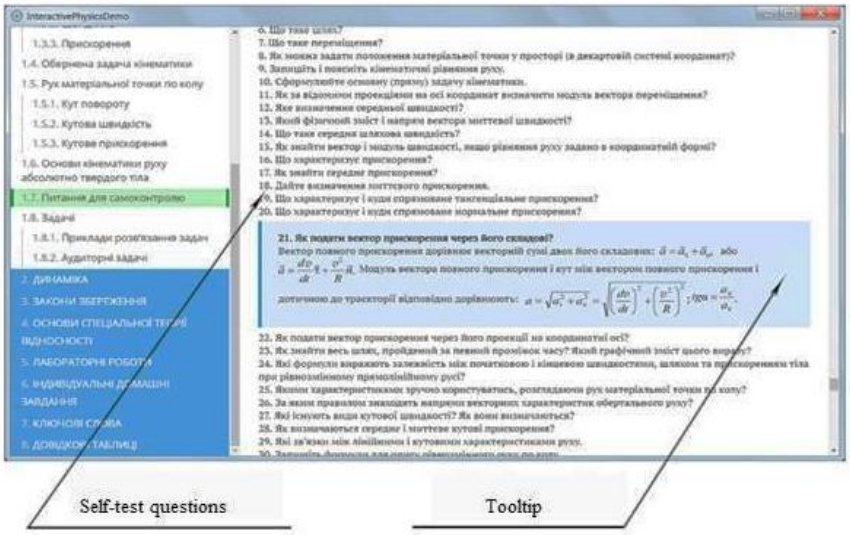

Fig. 3. Self-test questions with tooltips

Particularly interesting from a didactic point of view is the presence in the interactive electronic textbook animated 2D attachments, which demonstrate the dynamics of scientific thoughts. However, the most effective is the implementation of video clips from official sources. Thus, we used a series of documentaries on the Discovery Channel «Airport from within» [20], which allowed us to demonstrate the real work of the laws of mechanics in aviation (Fig. 4).

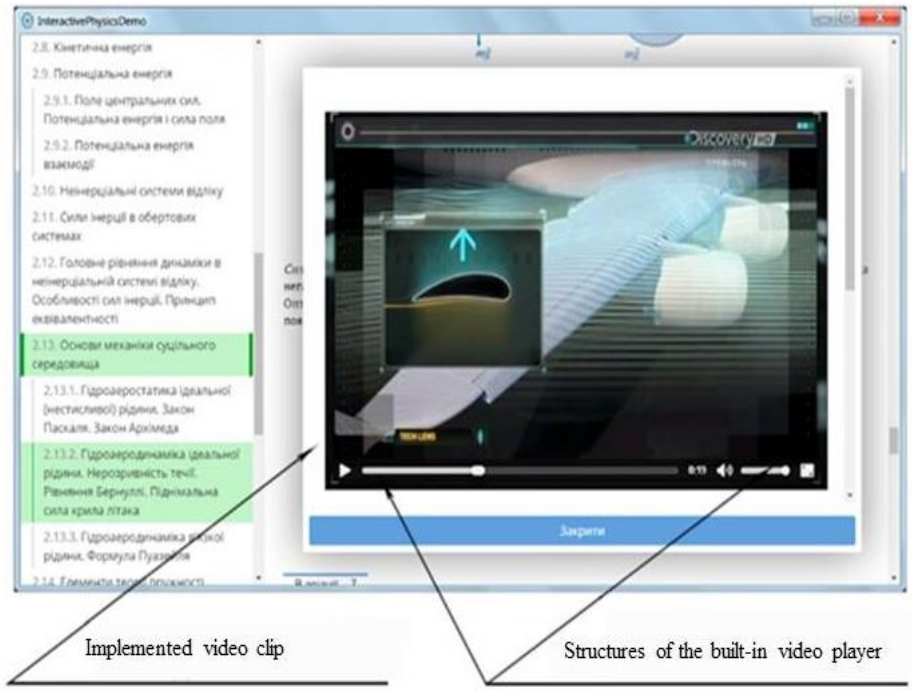

Fig. 4. Aviation-themed video clip in the built-in video player

As noted above, physics training material contains significant mathematical calculations, which often make it difficult for the user to perceive the required data. As students point out, the large number of cascaded transitions that are typically presented in EER often leads to a loss of logic in learning material and confusion. Therefore, large quantity of references to equations in the e-book «Physics. Module 1. Mechanics» are pop-up, without cascading transitions. For example, for the convenience of finding the definition of physics terms, the unit «Keywords» is made in such a way that all the necessary links are opened / closed with one click (Fig. 5).

To increase the interest of students to the personalities of famous physicists, we have replaced standard biographies of the scientists, which can be easily found using Internet, by short texts with wise aphorisms of these scientists (and not about physics only) that appear against the backdrop windows that are opened with the portrait (Fig. 6). The code snippet for such a page looks like:

```
<imgsrc="\content\extentions\personalities\galiley\img\ph
oto.png" height="210px" alt="photo">
<fig caption> ГАЛІЛЕО Галілей (1564 – 1642) </fig caption>
</figure>
<p align="center"> Італійський мислитель епохи Відродження,
засновник класичної механіки, фізик, астроном, математик,
поет. </p>
<p> <em>" Всі істини легко зрозуміти, тільки-но вони будуть
виявлені. Але проблема в тому, що їх складно виявити."
</em> </p>
<p> <em>" Немає більшої ненависті в світі, ніж ненависть
невігласів до знання." </em> </p>
<p> <em>" Істинне знання - знання причин." </em> </p>
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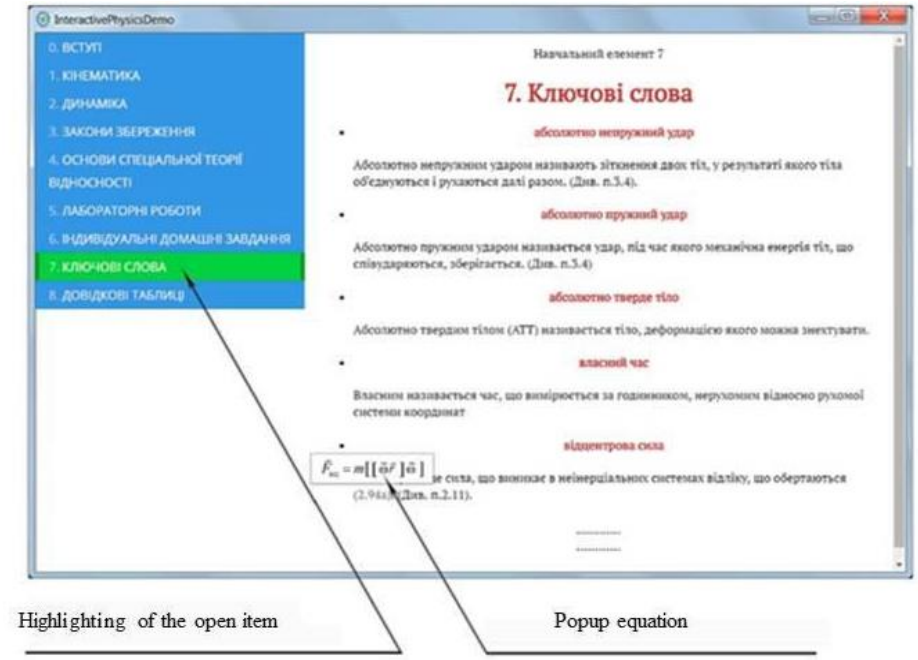

Fig. 5. Features of the Keywords page

In the current conditions of functioning of the domestic universities, the creation of EER has more and more become a problem for the specific departments that work on this issue separately. And this, in addition to creating high-quality scientific content, implies that they have to get additional competencies such as knowledge of JavaScript syntax, HTML, CSS, site building rules, graphics editors, the basics of animation and video processing; this requires a lot of time.

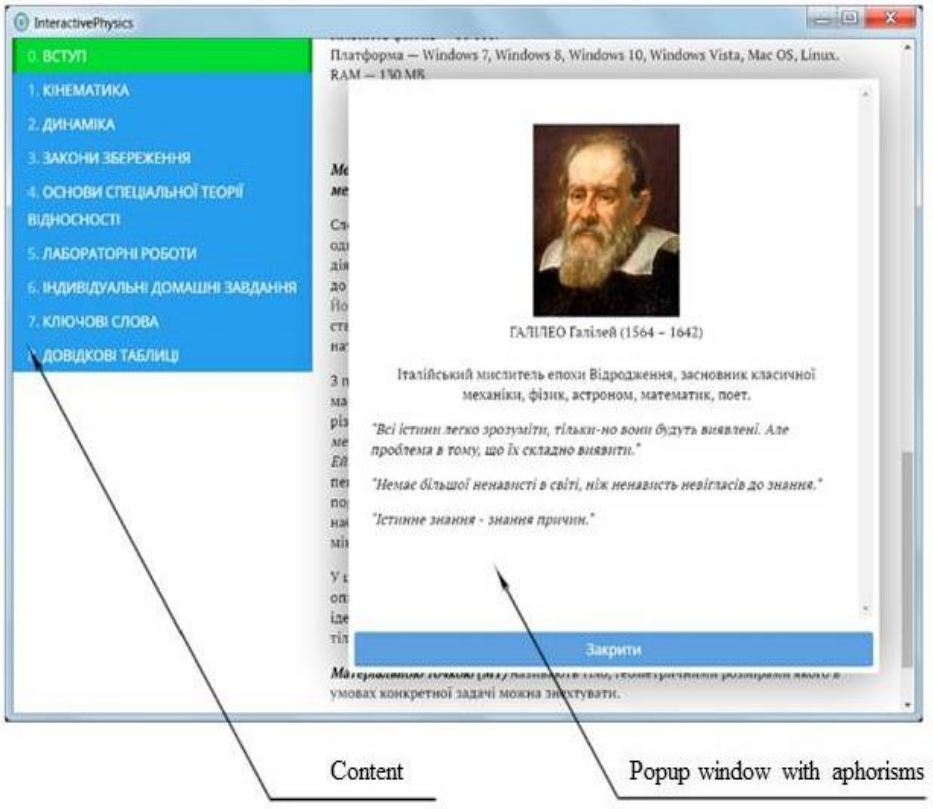

Fig. 6. A window dedicated to outstanding physicist with some of his aphorisms.

Development of the e-textbook «Physics. Module 1. Mechanics» lasted more than a year; this EER contains 270 Mb of digital information representing 220 pages of significant educational text, over 80 drawings and animations, over 500 equations with conclusions and cross-references, videos, a thematic dictionary with pop-up definitions. This volume of material, variety and specificity of works for the creation of such edition requires joint concerted activity of scientific and pedagogical workers such as content authors and a group of engineers-developers (web designer, layout engineer, graphic artist, animator, video content specialist, as well as back-end developers). It should be noted that in our case students acted at different stages of product creation.

6 Conclusions

In our opinion, direct JavaScript programming is the most promising and convenient technology for developing interactive e-books for universities engineering specialties. This technology greatly extends the space for developers to create schemes and draw-

ings with appropriate technical features. We offer color-based graphic data that can be maintained in color accents and processed to the smallest detail. Use the animation and video made the physics course visual and deepen the clearness of the material. Direct programming has been implemented in the process of creating the physics e-textbook «Physics. Module 1.Mechanics» and made it possible to develop from scratch a unique multimedia interactive cross-browser EER with easy-to-use navigation. We have used for this purpose JavaScript programming, the HTML5 hypertext markup language, cascading CSS3 style sheets, Adobe Photoshop, and VEGAS Pro software. The Node.js platform was used to build and implement the server side of the project. Intuitive navigation, one-click viewing, pop-ups hyperlinks, pop-ups equations and tips have made the study material easy to use in the learning process. In our opinion, this combination of software products is now most convenient for the development of sophisticated EER architecture for technical disciplines. Note that an important advantage of our technology is that it does not require additional installation of various applications and plug-ins on users' devices.

Application of direct programming significantly optimizes the student's independent work (examples of detailed step-by-step problem solving, self-test questions with hidden answers, comprehensive information for preparation of laboratory works, etc.). Due to cross-browser compatibility and cross-platform performance any modern web browser and any operating system (Windows, MacOS, Linux) can be used.

An important area of development of e-textbook «Physics. Module 1. Mechanics» is the implementation of tests and interactive instructions for laboratory work fulfillment on the basis of a physics field experiment. Such EER can be submitted in the form of the flipbook that we have proposed in [17]. In addition to multimedia presentation of theoretical material and practical instructions the EER also contain hyperlinks to experimental data processing programs (Excel, MatLab, MicroCal Origin, etc.); besides, it can provide controlled-consulting interaction and feedback between students and teacher.

We believe it would be very helpful to set up an inter-departmental interdisciplinary IT laboratory in the technical university, one of the important activities of which would be the creation of digital educational resources (EER, digital demonstrations, various specialized multimedia, etc.) for use during the study of engineering and mathematical disciplines. The activities of such centers, which should be carried out with the involvement of scientific-pedagogical, engineering workers, students of the technical universities, and structures of the external environment (for example, employers in the field of IT). Moreover, focusing of EER improvement on general educational disciplines such as physics at a technical university should have the greatest impact on the development of the e-textbook creation culture.

All abovementioned would significantly contribute to the motivation to fundamental disciplines study, acquisition of comprehensive awareness of the scientific and technological picture of the world, increasing the quality of interdisciplinary education of future specialists.

Unexpected circumstances of the pandemic have actualized the revision of higher education technologies, which are now becoming increasingly mixed and individualized. In this context, an important role is played by adequate teaching aids, in particu-

lar, e-textbooks. They should match the specifics of teaching various natural and technical disciplines at university departments.

The proposed article reveals the authentic pedagogical experience in designing a digital textbook, in particular, the selection of effective software tools (this explains the conciseness of the description of both the structure of the e-book and the technological features of JavaScript and Node.js).

The organization of exclusively distance learning in the pandemic has accelerated and expanded the implementation of the developed e-book «Physics. Module 1. Mechanics». The analysis of the results of this pedagogical experiment is one of the areas of further research.

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