Practice of applying functional approach to the design of digital learning aids

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Practice of applying functional approach to the design of digital learning aids

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Abstract. In accordance with its aim, the paper highlights practical aspects and experience of the functional approach applying to the development of contemporary digital learning aids in the progress of project-driven activity of the pre-service IT specialists at their holistic vocational training. Theoretical framework of the work is made by holistic educational paradigm and functional approach to digital learning aids development. The specific examples of such an experience of the functional approach applying to the design of digital learning aids within project-based activity of the pre-service IT-specialists at their holistic vocational training: project activity on the design of (1) English digital tutorial for schoolchildren and (2) e-guide on the cryptography fundamentals for university students, are depicted in details. The analysis of such an activity is provided from the standpoint of the benefits of holistic and functional approaches. The prospects of following up research are covered.

1. Introduction

Discussing the importance of the current research, we would like to focus on some essential and mutually linked factors. On the one hand, necessity of the digital learning aids of new generation which is increased by the urgent needs of contemporary education at all of its level, connected with the current rapid shift to a blended and distant learning. The design of nowadays digital aids should be provided on the base of the progressive approaches which are relevant to the realization of prospective educational paradigms.

On the other hand, the process of preparing of pre-service specialists for life and successful work in contemporary volatile world is a complicated problem that currently needs for modification on the new level. The situation with the process of vocational training in different branches is exaggerated by the unexpected circumstances caused by the global pandemic and urgency of development new forms of teaching and learning. Thus, it is essential to create the upgraded model of the specialists' preperation based on new paradigms.

One of the options seems be the holistic educational paradigm, which is pointed out in a set of normative documents: National Strategy for the Development of Education in Ukraine for 2012-2021, the Law of Ukraine "On the Concept of National Education information programs", the Law of Ukraine "On Education" [1], the Concept of the New Ukrainian School [2], Education for Sustainable Development Goals: Learning Objectives etc. According to the studies on the

problems of holistic education, it is discussed as a paradigm that supplies educators with a complex of principles that can be implemented in practice in different ways [3–5]. The core concept of this pedagogical paradigm is the holistic progress of the intire students' personality both at the mental and emotional levels [4]. It is also underlined in the scientific peapers that such a holistic progress should rest on the tight links between real-life tasks and trainee's personal experience. At the same time, the evidence of educational practice demonstrates that fruitful ideas of the holistic paradigm are taken and implemented in quite a limited way. As a result, the great deal of the essential paradigm facilities (like provision of integrity at the levels of the educational content, aids and forms of its application) are not realized in proper way.

Based on the speculations above, at the elaboration of the upgraded model of the vocational preperation, we tend to implement holistic outlook in the complex of different directions: to build the content of educational, to find out appropriate means of its representation and learning, and to provide potential specialists with professional practice. This concept is specified in the performing and application of (1) generalization and concentration of the said educational content resting on the integrative outlook of the curriculum subjects structuring; (2) multi-code rendering of the learning content focused on the reviving of trainees' cognitive processes; (3) native combining of the students'educational experiences with innovative technologies applications to the solution of real-life problems, which can be reached through project-based learning. It is relevant to emphasize that the said things cause and complement each other at the same time. This enables the holistic idea to obtain comprehensive realizing and deeper implementation into educational reality.

It is also important to mind that the realization of the main principles of the holistic theory demands proper system of the learning aids which are able to provide the cohesive development of the trainees' personality. This fact causes development of digital aids basing on the functional approach as the most advanced approach to their design.

In these lines, special attention should be paid to the training of IT specialists of various directions (including potential IT teachers) as for design, creation and applying of innovative didactic aids built on the basis of analysis of their functions, which enables to implement holistic paradigm to learning various disciplines at different levels of education. Therefore, one of the essential integral parts of the upgraded model of IT-specialists'vocational training rested on the holistic educational paradigm is the students' project-oriented activity on the development of digital learning aids [5, 6].

The aim of the paper is to highlight practical aspects and experience of the functional approach applying to the design of contemporary digital learning aids in the progress of project-based activity of the pre-service IT specialists at their holistic vocational training.

2. Theoretical framework

As a theoretical background, there were applied the complex of theoretical, modelling and empirical techniques. In the context of the said model of the potential IT specialists' training created on the holistic paradigm, their mastering of the development of innovative aids is provided both in the progress of learning of the complex of curriculum subjects (of common and prifessional training) and through the project-driven activity.

The theoretical framework of the research in the field of development of digital learning aids is made by the holistic educational paradigm (covered above) and functional approach to the design of digital learning aids.

The task of determination of didactic functions of tutorials and general functional outlook as for their design have got the focus in the works of researchers and practitioners (such as L. Bilousiva, V. Beilinson, L. Gryzun, D. Zuev, V. Kraevskyi, I. Lerner and many others [6–8]). The functional outlook rests on the analysis of the didactic functions of the learning aids and the ways of their realization by the aid. Such an approach to design of learning aids allows to

determine the functional charge of their structural components and the relations between the fulfillment of their certain functions [7–11]. These concepts are getting increasingly essential in the lines of digital tutorials creation along with increasing their role in contemporary education.

The problem of didactic functions analysis has always been quiet complicated and ambiguous. There are a lot of views on their essence and classification. Basing on the learning of number of sources which represent great variety of the functions, we could distinguish certain groups of them that seem to be relevant exactly for the digital aids. In particular, *the first group* includes functions which promote studying motivation; *the second group* contains pure didactic functions that provide efficient representation of the learning content and its successful digestion; *the third group* includes functions of optimization of educational process in the lines of adaptation to the thrainee's learning needs; *the fourth group* is made of so-called meta-functions that encourage trainee's progress and increase their general educational potential which creates a basis for the further successful learning beyond the knowledge domain covered by this exact digital aid. It is important to emphasize that these groups of functions have general character. Depending on the target audience of the digital aid (schoolchildren or students), the type of academic discipline for which the aid is developed, some other factors, the accents and priorities of these groups of functions may be different.

However, anyway, the functional analysis for exact digital learning aid provides specific ways for developing the structure of the aid that should be consequently used as a theoretical fundamental for the process of its projecting. This process comprises establishing the structure of the learning guide which pins up the relations between its components, and determines the mechanism of these relations realization. In addition, this process should base on the comprehensive learning of the aid as an object of the projecting and design. Therefore, it is important to point out that a contemporary digital learning aid has been transformed into the entire tutoring environment that is able to overlay the facilities of the complex of typical learning aids. It became possible thanks to the using advanced technologies in the process of its design.

Besides determining the structure of a digital aid and clarification of the load of each its structural component, the functional approach contributes to the formulation of specific requirements to the aid and to the features of its design. This makes the process of the aid development practically driven, which is really essential for the students' project-oriented activity, as it gives the students clear understanding of the aims of their work, appreciating of its practical importance, increasing their motivation to design high quality aid which meets the requirements, clearly formulated basing on the functional analysis.

The presented theoretical framework may be seen as a base for the functional approach applying to the design of contemporary digital learning aids during the project-based activity of potential IT specialists at their holistic vocational training.

3. Results and discussion

The practical sides and evidence of the said activity are shown below on the examples of the creation of different digital learning aids provided by the students of different specialties within their project-oriented activity in the progress of their holistic training.

In particular, we would like to represent English digital tutorial which was created by the potential teachers of Computer Science and English in the progress of their project-based activity, provided with their preliminary learning of the set of common academic disciplines (English, Pedagogy, Programming, Computer graphics etc.) and professionally-oriented ones (Computer systems of English learning, E-pedagogy, Design of learning aids).

On the initial stage of the project the didactic functions of the digital tutorial were specified and its structure was outlined, according to the challenges of English learning at school. The project participants defined core requirements to the tutorial, revealed its functional facilities

and determined its structure. Thus, it was concluded that in order to ensure the performing of the core functions, the English digital tutorial for 6th grade pupils must provide the set of facilities that are covered below with the reference to the groups of didactic functions (see Theoretical framework).

Firstly, the tutorial has to supply qualitative visualization of learning content and provide enough interactivity with a pupil. It will ensure high-level realization of developing, informational, transformational functions (the second group), functions of feedback and friendly correction (the first group), and the function of control (the third group). It must also garantee that the earning of linguistic competence of the pupils is intensified by the complex implication of the majority of information perception organs, which can ensure the efficient implementation of developing and transformational functions.

In addition, the learning aid has to give opportunity the trainees to work out their different speech skills, which may guarantee realization of consolidation and systematic functions (the second group). The tutorial must provide a reliable feedback with other pupils and a teacher to obtain assistant, consultations, estimation etc. (the second group). It should also realize the cognitive activity management comprising game activity for implementation of developing function and self-learning one (the fourth group).

Finally, the tutorial must to be smoothly integrated with differnet electronic resources, which ensures its coordinative and integrative facilities (the third group of didactic functions).

Based on the above functions and relying on research [6–8, 11, 12], the project participnats could create the structure of the digital tutorial which is able to implement efficiently its didactic facilities. Therefore, the students came to the conclusion that the teaching aid must be built as a complex of integrate parts presented below.

For high level visualization of the educational content, the tutorial should comprise a library of multimedia illustrations which supplies text, images, video, and audio information in integrated way.

In order to facilitate shaping of pupils' language competence through the complex using of many sense organs, the learning aid makes available an interactive video library with didactic provision. On purpose of developing of a variety of skills, the tutorial contains a bank of interactive exercises with an immediate delivery of the results of their fullfillment.

To manage learning activity, the aid provides a special component which includes also various game elements. There is also an appropriate component of the tutorial that holds communication with the teacher and other pupils.

In order to automate the processes of the content retrieval and integration with other e-resources, the aid is supplied with a technological ingredient that ensures its online uploading and the facility of its integration with differnet sources.

Determined didactic functions and structure of the digital tutorial made the basis of its development for the students who participated in the project.

Therefore, at the subsequent stages of the project, the said digital English tutorial for the 6th year pupils was built within Ourboox platform whose embedded facilities were enhanced by the students with some coded supplements.

It is essential to point out that the developed tutorial does not demand installation as it is an online multimedia aid (MultiEnglish). It comprises core themes learnt in the 6th grade at studying English: My family, Shopping, Food, Traveling, Sport, Ukraine, and others (see figure 1).

Every theme is presented in the sections (Let's focus on. . .) that aim at shaping and progress of core language skills: reading, vocabulary, grammar, speaking, listening, and writing (see figure 2). They provide necessary teaching materials, tasks, various exercises, quizzes etc. The demo version of the learning aid which is available on the Internet assumes current modifications of the tasks when it is necessary.

Figure 1. Content of the multimedia tutorial MultiEnglish.

Figure 2. Selected sections of the multimedia tutorial MultiEnglish.

In the progress of the tutorial development according to its didactic facilities and structure, embedded opporunities of the Ourboox environment were significantly enriched by the sudents with the help of HTML programming.

Intoducing programming instructions allowed to supply the aid with interactive elements of other services, which are unavailable within the standard Ourboox toolkit. In such a way, interactive exercises, posters, video-clips, games, static and dynamic illustrations, links to differnet services, such as Quizlet, YouTube, LearningApps, Google-forms, Jigsaw Planet, Vizia, Gettyimages, ThingLink, ESL Game Plus and others) were integrated into the developed learning aid (see figure 3).

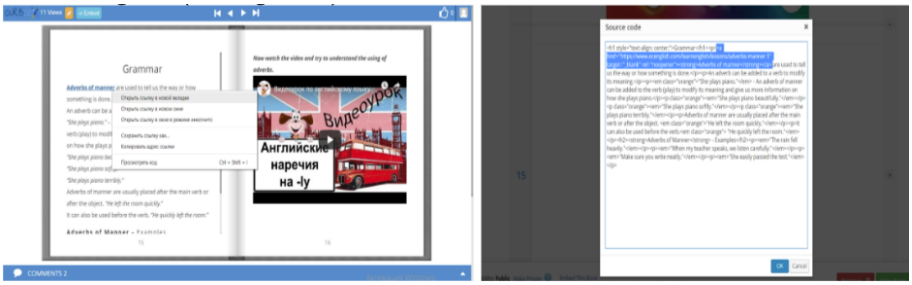

Figure 3. An example of an interactive elements of MultiEnglish embedded with programming.

The media content of the tutorial was created with the help of modification the HTML code of the aid's pages. In particular, the participants of the project were able to combine text, images, and video with the certain hyperlinks. In addition, with the help of programming, it was enhanced Ourboox´s facilities of text formatting: there were prepared instructions in HTML with CSS elements to align text correctly and to build lists. The students also realized integration of interactive didactic provision into the aid, which enables a trainee to watch the video with pauses at the certain places and do interactive exercises to the video story. In such a way, due to introducing of coded elements, the MultiEnglish tutorial became didactically powerful to realize all the didactic functions determined by the students at the first (theoretical) step of the project.

Final stage of the project was devoted to the analysis of the designed learning aid as for revealing and estimation of its didactic facilities.

Analyzing these features of the MultiEnglish tutorial which was created by the potential Informatics and English teachers based on a functional outlook in the progress of their project-dreven activity, it is relevant to underline the following.

The learning aid ensures high-level visualization of the learning content and enables interactive dialogue with the trainee. The rich library of multimedia images as a component of the tutorial represents the relevant elements of the content and maintain immidiate feedback. The library comprises both static and dynamic illustrations of differnet kinds including interactive posters which enable effective boosting trainee's vocabulary, its checking and working out (see figure 4).

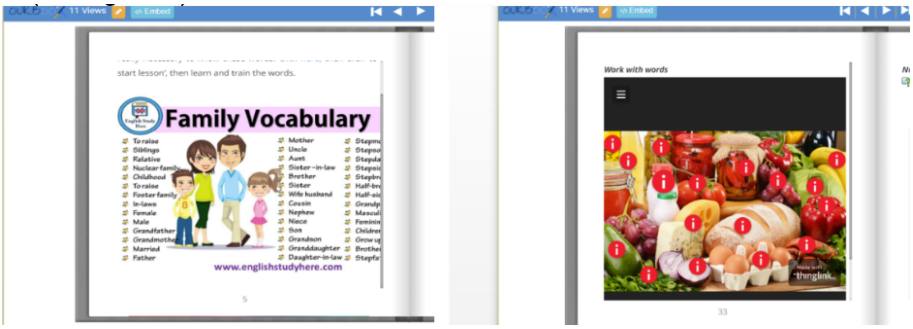

Figure 4. Episodes of work with the library of multimedia images.

The said facility garantees efficient implementation of transformational, informational, and developing didactic functions of the tutorial, and also the functions of self-control, feedback, and correction. In addition, the developed learning aid raises the effectiveness of shaping of language skills via involvement of the pupils' multi-senses activities into their learning practice. In particular, the tutorial enables trainees' work with interactive digital stories for which it has been prepared relevant didactic provision. Therefore, during watching the stories trainees are provided with the assignments developing their listening skills, boosting their vocabulary, stimulating the conscious using of grammar rules (see figure 5).

The developed MultiEnglish tutorial also allows to record trainee's speech aimed at developing their speaking and communication habits (see figure 6), which provides realization of the transformational and developing functions.

The developed digital aid encourages working out of differnet skills, which provides the facility of its using as a simulator. The vast library of interactive tasks offers pupils a variety of exercises of different learning types: matching, puzzle solving, word search, audio and video tasks, interactive texts etc. Thus, the anchoring and systematic functions are performed. Episodes of work upon the exercises of differnet kinds are given in (figure 7-figure 9).

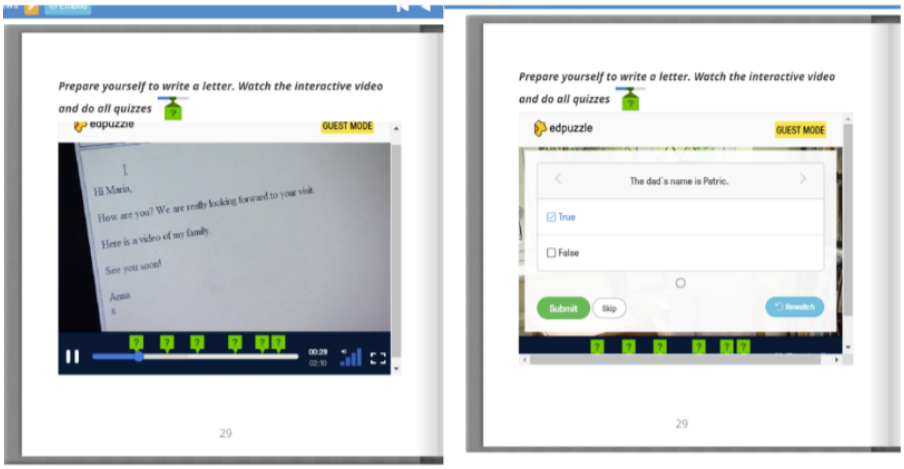

Figure 5. Work with interactive digital video-story "My Family".

Figure 6. A situation of a pupil's voice recording during learning one of the themes.

As it was said above, the facilities of the developed aid also provide the organization of various cognitive activities. Therfore, a pupil has an opportunity to study at their individual pace, under the teacher's guidance or independently. In addition, all of the tasks can be done by trainees as many times as they need, to reach best results. For raising motivation for studying, the tutorial offers trainees game-based activities, such as quests, quizzes, cognitive grammar trips, crosswords and others (see figure 10). These tutorial facilities provide realization of the developing, consolidation, and systematic didactic functions (from the first, second and third groups).

The tutorial allows technologically to be uploaded to other sites and integrated smoothly with other electronic resources (see figure 11), which promotes the implementation of integrating and coordinating functions. It is also essential that the learning aid functions correctly with all browsers (Google Chrome, Opera, Microsoft Edge, Mozila Firefox, Internet Explorer).

In addition, the developed tutorial provides the facility which helps pupils to interact with

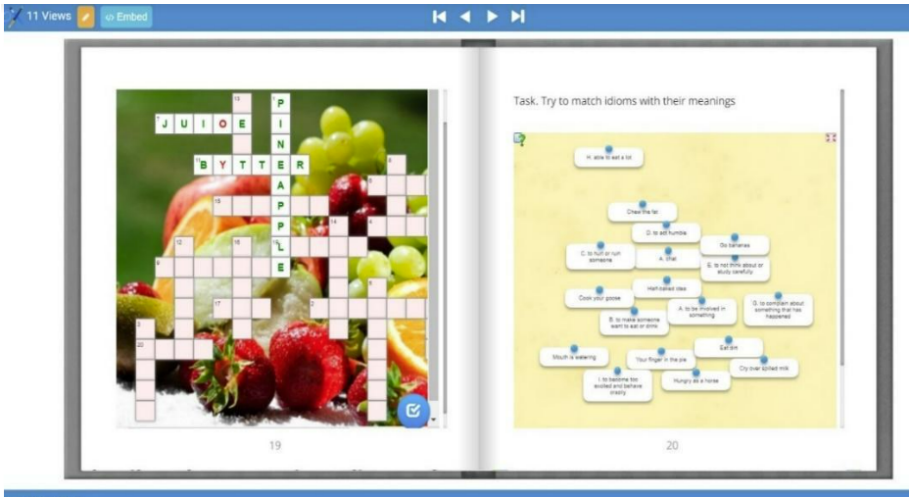

Figure 7. Episodes of work upon interactive crossword puzzles and exercise on matching.

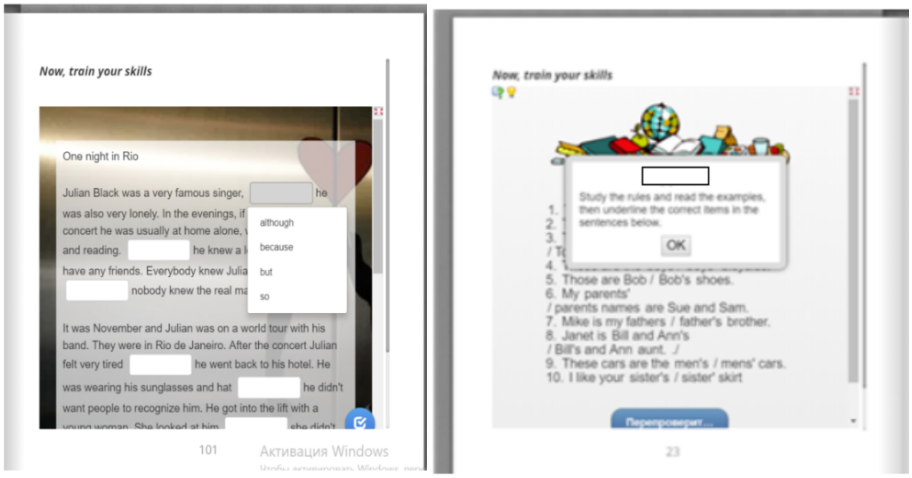

Figure 8. Episode of proceeding an interactive text.

their teacher. For example, comments element of the aid can be used to ask questions while doing an exercise, send a speech record to a teacher, or ask for help from the peers. Therefore, the didactic feedback function is implemented.

Thus, the analysis of the developed multimedia tutorial (done by the students at the final stage of the project) testifies that the tutorial which was developed basing of the functional approach is innovative one, as it provides a trainee with the integral cognitive environment for activity-centred learning. It can be characterized as a platform for pupils' free cognitive activity and for raising their motivation to learning. As a result, it promotes cohesive progress of both the students (project participants) and their potential pupils.

Differnt example of functional approach applying to the creation of innovative digital learning aids is the development of the e-guide on the cryptography fundamentals provided by pre-service IT specialists (unlike the first e-tutorial realized within vocational training of pre-service teachers of Computer Science and English), but also within their project-oriented activity in the process of their holistic training. Including this example, we also aimed to demonstrate main features of the approach realization on the samples of e-guides for completely different

Figure 9. Fragment of work with the video content.

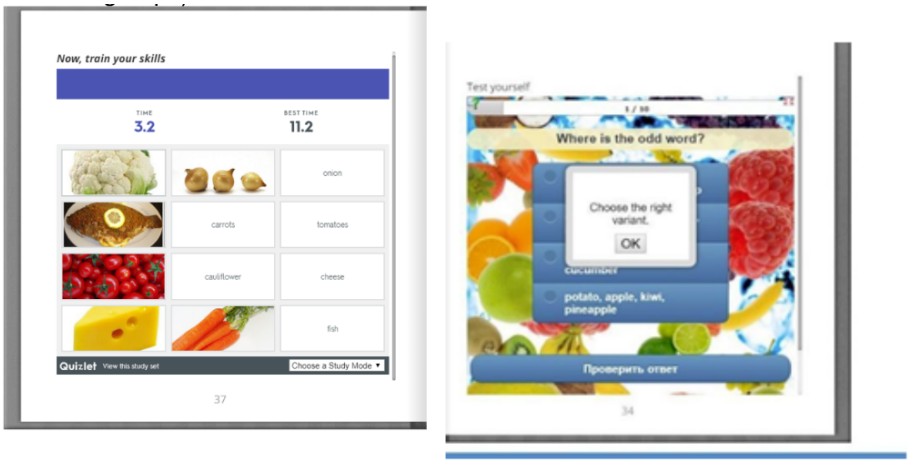

Figure 10. Episodes of the various kinds of game activities.

target audience (schoolchildren and university students), knowledge domain, forms of potential students' activities etc.

At the first stage of the project activity, the didactic functions and structure of the e-guide were determined due to problems of the course "Information security", which is a basic one for lots of vocations.

In such a way, resting on the theoretical background on the functional approach (covered above), the students defined proper structural components of the learning aid. In particular, it was determined that the e-guide must contain the textual component organized in hypertext form which presents systematized and didactically processed learning material according to the syllabus of the academic discipline. Here the place of the cryptography fundamentals in the course was determined, and the necessity of coverage in the aid of encryption as one of the means of information protection was established. The learning material was selected and structured on the basis of a number of sources on the basics of cryptography and modern computer encryption systems [10, 13–15].

It was also determined that the textual component has to provide transition to non- textual structural components: Illustrative material and Apparatus of the acquisition arrangement.

Illustrative material should contain the static illustrations (technical charts, schemes, photos,

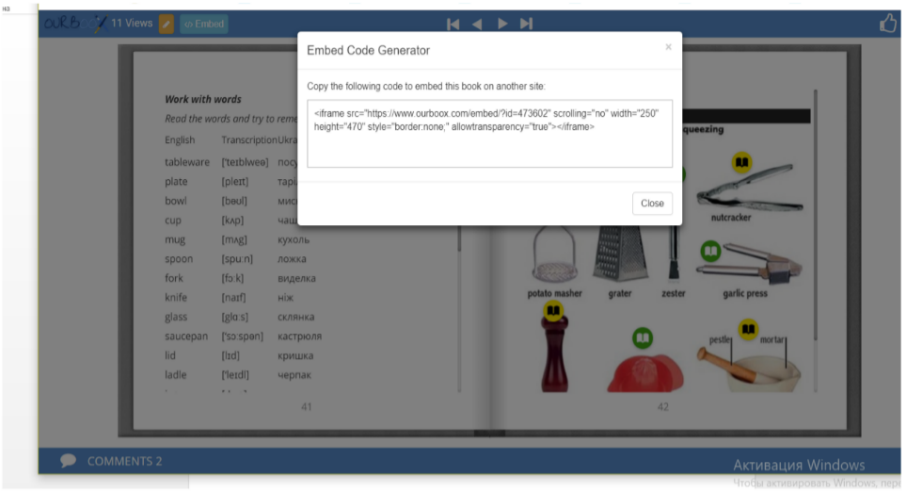

Figure 11. Embedding the tutorial into different site.

pictures etc.) and dynamic ones (animated or video illustrations that demonstrate different methods of information encrypting).

Apparatus of the acquisition arrangement should be represented by a library of learning tasks of different types and a system of self-checking. Among the learning tasks of the e- guide should be distinguished three basic types of the tasks: teaching, training and cognitive- search ones.

At the next stage of the students'project-oriented activity, the e-guide whose functions and structure were specified at the previous stage was developed in the environment of MS Learning Content Development System using its tools and facilities. The developed learning aid covers the following topics on the basics of cryptography: "Basic concepts of information security", "Cryptology as a science", "Classical encryption algorithms", "Computer encryption systems".

As it was planned, the e-guide contains a textual component organized in the form of hypertext, which allows to find quickly necessary learning material on the course, navigate easily the topics and sections, work with illustrations and tasks, refer to external links for other information resources (see figure 12).

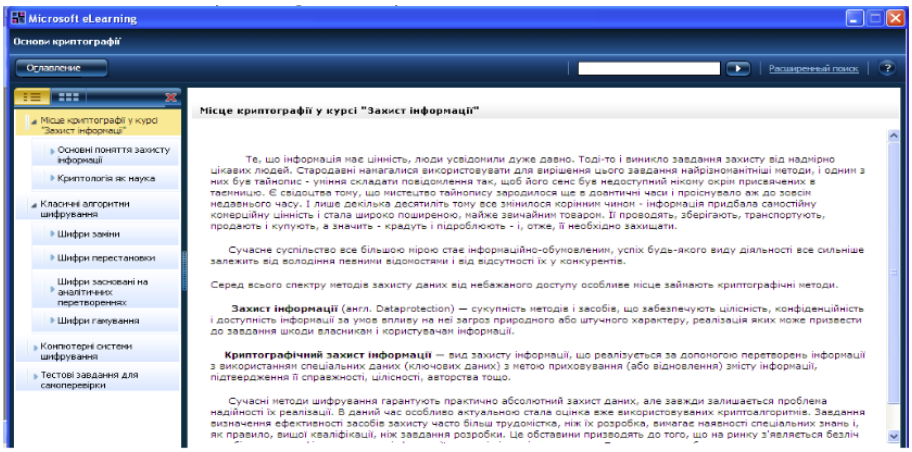

Figure 12. Episodes of work with the hypertextual component of the e-guide.

The textual component is supported by the Illustrative material component which provides

a trainee with two types of illustrations. The first type includes static illustrations, such as generalized schemes of computer cryptosystems, the visualization of which facilitates the understanding of educational content (see figure 13), contributes to the transformational function and function of visual method use.

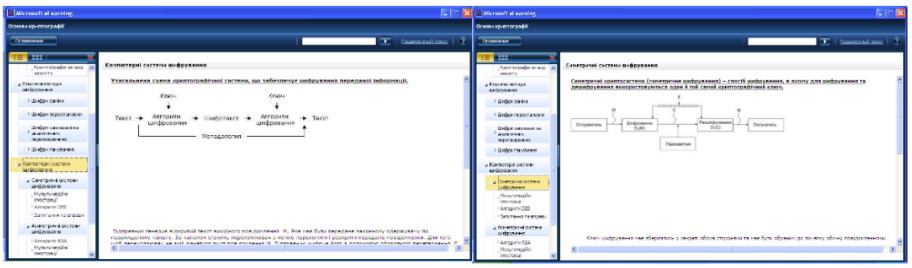

Figure 13. Work with static illustrations on the topics "Computer encryption systems".

The second type of illustrations are dynamic ones which demonstrate the process of data encrypting based on various encryption algorithms; processes that reproduce the sequence of actions in the operation of encryption algorithms, historical information, the essence of some abstract concepts, and so on. This component gives for potentical trainees the opportunity to observe these processes, review them at different speeds and check the assimilation of the content, answering a number of questions to the reviewed dynamic illustrations offered by the e-guide.

Thus, the work provided by the e-guide with its hypertextual component supported by static and dynamic illustrations promotes implementation of informational, transformational and systematizing functions (the second group of functions depicted in the Theoretical framework above).

Apparatus of the acquisition arrangement of the e-guide, as it was planned, is represented by a library of learning tasks of different types that are forcused on the mastering of theoretical content, and a system of self-checking.

The teaching tasks of the developed aid are ready-made programs (realized in different programming environments) that implement a certain encryption algorithm. The e-guide encourages a trainee to work with the program, to find out its purpose and functions, and to analyze the program code. In particular, the teaching tasks allow data encrypting and decrypting based on some classic encryption algorithms. The solution of the teaching task expects trainee's processing, according to a certain scheme proposed by the library of teaching tasks (or by the teacher). Trainees have the opportunity to run them, analyze the operation of algorithms and make conclusions by answering questions. In addition, it is possible to copy fragments of program code and use them to develop trainees'own programs (see figure 14-figure 15).

Training tasks include tasks similar to teaching ones, but students solve them independently, based on theoretical content and program implementation of teaching tasks. For example, working with the code of the learning task, a trainee masters the encryption of a certain algorithm, and then he is offered a training task to implement a decryption program by the same algorithm. Some of the training tasks are focused on working out the skills of using various encryption algorithms via the set of exercises. For example, for the topic "Replacement encryptions" and "Substitution encryptions", the e-guiede offers the set of exercises given at the (figure 16-figure 17).

Cognitive-search tasks presented by the Apparatus of the acquisition arrangement are aimed at applying knowledge at the creative level. Trainees are offered a number of tasks on each topic: tasks that require significantly transformed knowledge; tasks for independent application of different types of encryption algorithms; research tasks and comparative analysis of different

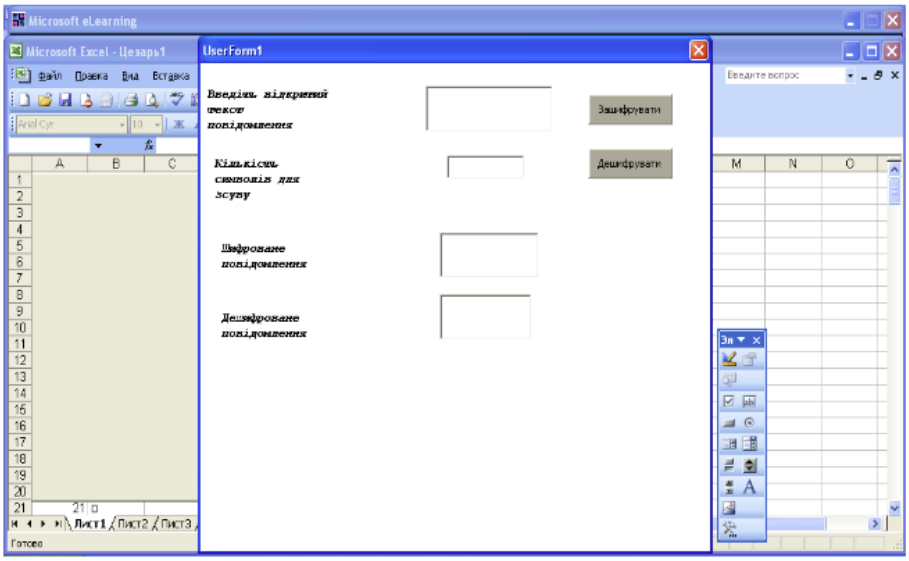

Figure 14. Teaching task for the implementation of the Caesar encryption algorithm.

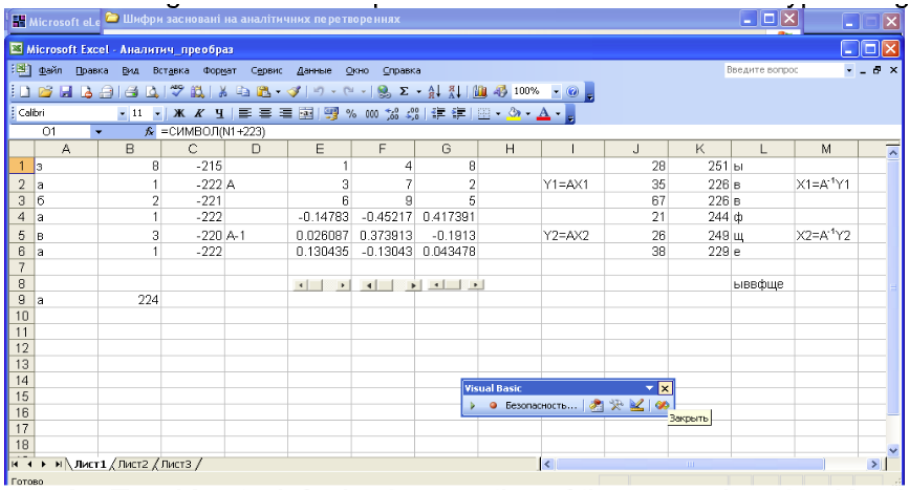

Figure 15. Teaching task for implementation of the encryption algorithm based on analytical transformations.

information encryption systems; complex tasks on the composition and those that involve gradual complication etc. Each task has instructions and answer, as well as the references to relevant theoretical material or to the teaching tasks of the manual.

Thus, the developed and filled library of the learning tasks allows to realize at a higher level the functions of consolidation (the second group of functions) and development (the fourth group of functions).

The self-checking system presented in the e-guide is realized with the help of Google Forms(see figure 18). The system includes a set of generalized test tasks to check the level of mastery of educational material. The form is connected to the Google spreadsheet and the answers of the respondents are automatically stored in it, which in turn allows the teacher to analyze the trainees'achievements. Thus, the implemented system of self-checking contributes to the implementation of such didactic functions as the functions of correction and contro (the third

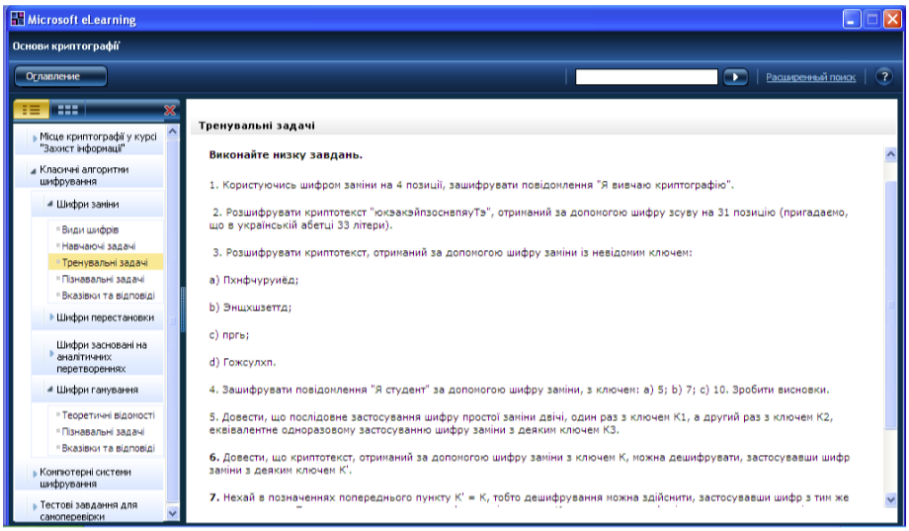

Figure 16. Fragment of work with training tasks on the topic "Replacement encryption".

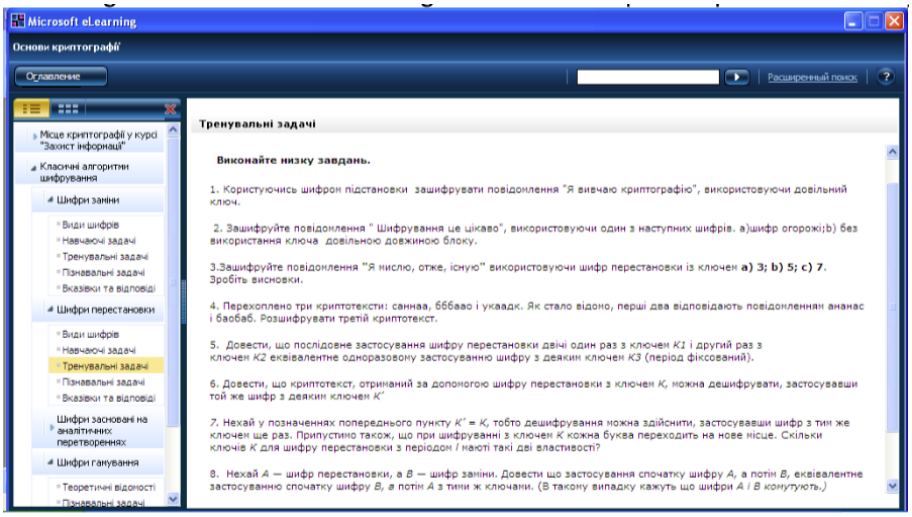

Figure 17. Fragment of work with training tasks on the topic "Substitution encryptions".

group of functions), consolidation (the second group), and developing and educational function (the fourth group).

Thus, the digital learning aid, designed by the students based on the functional approach, makes a whole learning environment suitable for use in the educational process of IT specialists training within the course "Information Security" providing its holistic learning.

At the final stage of the students' project-oriented activity the developed e-guide was tested and elaborated. In addition, there were offered some methodical recommendations as for its using at the educational process of the university in its different forms.

Summing up the depicted experience and specific examples, we would emphasize the following. The functional approach which was applyied by the students to the design of the digital learning aids demonstrated its great benefits as for the quality of the aids as the results of the students'project-oriented actvity. In particular, the functional approach enabled the students (1) to specify the doals of development; (2) to determine the aid's structure components, their

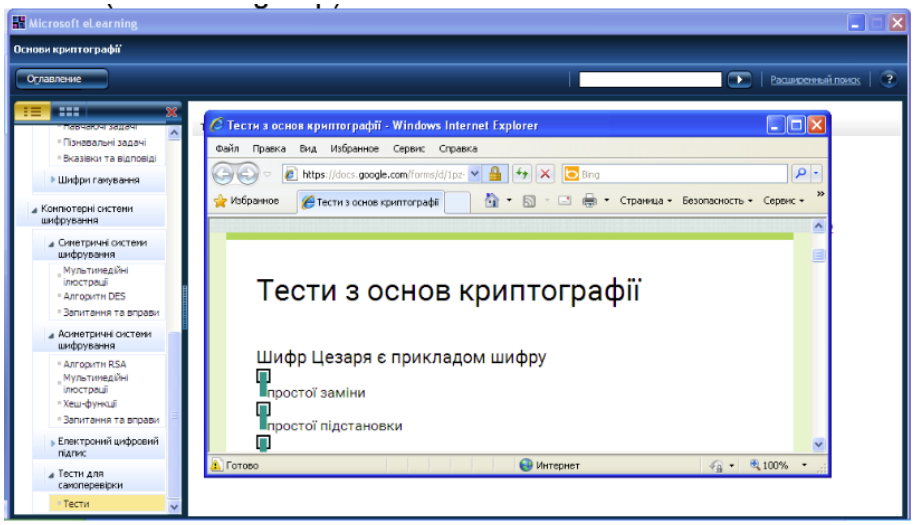

Figure 18. The fragment of work in self-checking system of the e-guide on the fundamentals of cryptography.

purposes, and their mutual connections; (3) to clarify the choice of the fulcrums for the purposes achievement; to control the process of the aid development; (4) to provide objective estimation of the results; (5) to promote the demand and practical application of the created digital learning aid. Here, it is important to point out that the result of the academic project-oriented activity had not only learning value, but also obtained essential practical application. Th elaborated digital learning aids were approved in the real educational processes at school and at university during various kinds of practices. The results of the work were also presented during the students conferences and workshops.

It is also worth underlying, that on condition of such an interdisciplinary preparation and project activity, pre-service IT specialists obtain meta-skills on the design of innovative digital learning aids. In the process of this kind of training, potential pre-service IT specialists obtain full understanding and capability for practical embodiment of core ideas of holistic educational approach via their personal experience of development of the learning aids. In addition, the application of the fuctional approach made students' project activity more practically-driven and motivational.

Thus, we could anticipate the positive impact of such professional training on the shaping of students' holistic system of their knowledge and skills. Elaboration of the methodology of its diagnosing may be a prospect of following up research.

4. Conclusions

In accordance with its goal, the paper covers practical aspects and experience of the functional approach applying to the development of contemporary digital learning aids in the process of project-based activity of the pre-service IT specialists at their holistic vocational training.

Theoretical background of the research includes holistic educational approach and functional basics of digital didactic aids development. The specific examples of such an experience of the functional approach applying to the design of digital learning aids within project-based activity of the pre-service specialists of different branches of their preparation at their holistic vocational training are depicted in details. In particular, there are examples of students' project activity on the design of (1) English multimedia tutorial for schoolchildren (done by the pre-service teachers of Computer Science and English) and (2) e-guide on the cryptography fundamentals

for university students (done by the pre-service IT specialists).

The analysis of such an activity is provided from the standpoint of the benefits of holistic and functional approaches.

The prospects of further research are outlined. It is planned to investigate the influence of this kind of training on the forming of the students' holistic system of professional knowledge and skills. On this purpose, it is assumed to elaborate proper methodology of its diagnosing and estimation, which is a prospect of our following up research.

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