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DEVELOPMENT AND DELIVERY OF PERSONALIZED E-LEARNING CONTENT

ABSTRACT OF PhD THESIS

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The dissertation contains **202** pages, **53** figures, **13** tables and **125** references.

The defense on the dissertation will take place on .... from .... time in hall ....
on block 2 of the ICT-BAS at an open meeting of a scientific jury composed of:

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The materials for the defense are available to those interested in room .... at of
IICT-BAS, "Acad. G. Bonchev", bl. 2.

Author : **Ivaylo Zhivkov Blagoev**

Title : **DEVELOPMENT AND DELIVERY OF PERSONALIZED E-LEARNING
CONTENT**

Introduction

E-learning has completely transformed the way knowledge is imparted and received by learners. Unlike the traditional method of teaching, e-learning makes learning easier and more effective. In an ever-changing, technical and eventful life, lifelong learning becomes a necessity. It can be most adequately satisfied through e-learning.

Nowadays, personalized learning services are a key point in the field of online learning as there is no fixed learning path suitable for all learners. However, traditional learning systems ignore these service requirements and deliver the same learning content to all learners. This approach may not be effective for learners of different backgrounds and abilities. In order to create adaptive learning content, it must be possible to provide learning content according to the specific needs of the learner.

Tools for the creation of e-learning content, and in particular for personalized e-learning, would facilitate the use of a range of learning activities, including visual and verbal activities to increase the effectiveness of learning.

This dissertation analyzes existing models for creating e-learning, already developed software solutions and artificial intelligence technologies. On this basis, methods and models, architecture and system prototype for the development and delivery of personalized e-learning content have also been developed.

Purpose and tasks of the dissertation work

The purpose of the dissertation is formulated from the analytical overview:

To propose a system and tools for the development and delivery of interactive personalized e-learning based on the learners' prior knowledge.

For this purpose, the following tasks are defined:

1. A classification of the functional requirements should be carried out and a methodology developed for the evaluation of e-learning and knowledge management systems;

2. To make a classification of online training courses according to delivery methods and type of training content and to develop a content development approach for e-training courses;

3. To create a method for generating educational content, through generative AI;

4. To develop a model for personalized e-learning based on the competence profile of the learner;

5. To design a tool for creating personalized e-learning content;

6. To develop the architecture and prototype of a web-based platform for the development and delivery of interactive educational content.

Dissertation structure

The dissertation is structured in **four** chapters.

In **the first chapter,** an analytical overview of the theoretical base related to the problem area of the dissertation is made. It includes a brief introduction, relevance of the topic, applications, challenges and existing solutions of scientific research. The need to create and implement new models for personalizing the learning process in an online environment is motivated.

In **the second chapter,** a classification of the functional requirements of the e-learning and knowledge management systems and an assessment of their effectiveness was carried out. A comparative analysis of the e-learning systems and e-learning tools existing on the market was made and their suitability for implementing personalized training based on the competence profile of the learner and his prior knowledge was assessed. A method for evaluating e-learning systems has been developed to reflect the specific needs of different types of organizations using e-learning for different purposes and in different technological contexts. Classification of online training courses according to delivery methods and type of training content was carried out. A content development standard for e-learning courses has also been developed.

The **third chapter** describes the process of developing a system architecture for the development and delivery of customized e-learning content. In the first section of the chapter, the architecture of the complex system is presented. In the second section, a model for personalized e-learning based on the learner's competency profile is developed, and in the third section, the architecture of a tool for creating personalized e-learning content is created, which is the basis for implementing the model of personalization of the learning process.

In **the fourth chapter,** a working prototype of a complex system for the development and delivery of personalized e-learning content is developed, which includes an integrated e-learning system and a tool for the development of interactive personalized learning content.

In the Conclusion, a summary of the obtained results of the development is presented. Directions for future research and development are identified. A list of scientific publications on the topic and noted citations is presented.

The dissertation contains **202** pages, **53** figures, **13** tables and **125** literary sources.

CHAPTER 1 - AN ANALYTICAL REVIEW OF PERSONALIZED E-LEARNING

1.1 Overview of the current state and prospects for the development of e-learning

1.1.1 Development of e-learning

E-learning (E-learning) has completely transformed the way knowledge is delivered to learners. Unlike the traditional teaching method, e-learning makes learning materials easy and efficient. With the rapid acceleration of technological change, lifelong learning is becoming a necessity and can be most adequately addressed through e-learning.

Summarizing all the reviewed definitions, e-learning can be defined as: Using the Internet to access educational materials, to interact with the content, the teaching team and other learners, to obtain support and knowledge in the educational process and, based on the acquired knowledge, to compile own opinion [1].

Nowadays, personalized learning services are a key point in the field of online learning, as there is no fixed learning path suitable for all learners [2]. This approach may not be effective for learners of different backgrounds and abilities. In order to create adaptive learning content, it must be possible to provide learning content according to the specific needs of the learner [3].

One of the modern methods of training both pupils and students, as well as company employees and adults, is precisely through online courses and online training materials [4].

Historical development of e-learning

With the development of personal computers in the 1980s and 1990s, computer-based learning began to be applied in a wider range of educational and corporate settings. Multimedia elements such as text, audio and video are integrated into the training programs, thereby improving the effectiveness of the training. This lays the foundation for subsequent development of Internet-based learning [5]. During this period, the first learning management systems (LMS) appeared [6], which provided a structured platform for organizing, delivering and tracking the learning process.

In the first decade of the 21st century, e-learning continued to evolve with the emergence of massive open online courses (MOOCs) [7].

COVID-19 has led to the widespread use of virtual classroom systems to conduct real-time synchronous learning sessions. Synchronous learning platforms have become a major channel for communication and collaboration between teachers and students [8].

The pandemic has also highlighted the need to develop interactive and adaptive content to meet the diverse needs of learners.

Technological components to ensure the learning process

The development of electronic learning (e- learning) would not be possible without the availability of modern technological solutions that ensure flexibility, interactivity and accessibility of the learning process. This section outlines the main technology components essential to creating an effective e-learning system, such as learning management systems (LMS) [6], interactive content development tools, and synchronous and asynchronous learning platforms.

The technological implementation of the electronic learning process requires three key software solutions that must be provided to ensure quality organization, conduct and follow-up of the learning process. First of all, an LMS e-learning system is needed to ensure user management, setting access rights, providing access to e-learning content, and mandatory tracking and reporting of learners' progress and acquired competencies. In second place are systems for synchronous video and audio training of the "virtual classroom" type [9], which are the closest analogy to classroom training. However, the main advantage of e-learning comes from the ability to reuse and quickly update training resources, which requires organizations to have specific tools for developing digital training content - Authoring Tools [10].

1.1.2 Models for creating eLearning content

The effectiveness of e-learning content depends not only on the quality and development of technology. The preliminary analysis of the situation and the learners, the correct determination of the training objectives, the selection of strategies and means of delivery, as well as the evaluation of the training results are essential. Specialists in training development (Instructional Development , ID).

Using classic approaches to designing eLearning materials is critical to your success, at least in the beginning. The modern scientific approach to instructional design was established during World War II, when many (literally hundreds of thousands) of people had to be trained on specific tasks in a very short time [11].

The following models were analyzed:

- Meryl's First Principles of Learning

- Nine Learning Events of Robert M. Gagne

- Bloom's taxonomy

- ADDIE Model

1.1.3   Learning Management Systems

LMS are specialized training systems based on modern internet and web technologies [6]. On the other hand, it is believed that LMSs arise due to the need to provide organizational, administrative and educational elements, as well as the inclusion of various technological components [12]. LMSs offer services that meet specific training and automation needs, where they perform four main tasks through an easy-to-use and unified user interface [13].

The main functions of the LMS system include:

o   Content management;

o   Track progress;

o   Interactivity and evaluation;

o   Communication and collaboration;

1.1.4   Tools for creating interactive trainings

Interactive learning creation tools play a key role in modern e-learning by providing personalized learning experiences based on learners' prior knowledge [14]. These tools allow educators and course developers to create device-responsive [15] and interactive learning materials [16].

The main purpose of the tools for creating interactive trainings is to ensure increased engagement and effectiveness of the learning process through the use of interactive and multimedia elements [17].

Interactive learning creation tools play a central role in personalized learning that builds on learners' prior knowledge and skills. They allow the creation of courses that adapt the content in real time, depending on the performance of the learners and their individual needs.

1.1.5   Microlearning and its role in personalizing the learning process

Microlearning is a relatively new approach in the field of e-learning, which is gaining more and more popularity due to its flexibility, short duration and high efficiency [18]. This approach breaks learning material into small, digestible units that can be quickly consumed and applied by

learners. This section presents the concept of microlearning, their characteristics, their benefits, as well as their role in personalizing the learning process.

One of the most important roles of microlearning is to personalize the learning process. They provide an opportunity to adapt the learning materials to the needs, interests and pace of the individual learner. This is especially valuable in the context of modern e-learning, where an individualized approach is considered a key success factor [19].

1.1.6 Personalization of eLearning

Nowadays, personalized learning services are a key point in the field of online learning as there is no fixed learning path that suits all learners. However, traditional learning systems ignore these service requirements and deliver the same learning content to all learners. This approach may not be effective for learners of different backgrounds and abilities. To design adaptive learning content, we need to enable the delivery of learning content according to the needs of the particular learner [3]. Much of today's research and development focuses on the creation and reuse of learning objects (LOs) [20].

Prior knowledge influences future understanding. By recording learner performance, a set of parameters can be compared and used in formative or summative assessments. Prior experience in a given area can be assessed using rapid knowledge and cognitive tests to allocate learners to appropriate stages of learning.

1.1.7 Using AI in e-learning systems

AI-powered eLearning tools are becoming increasingly popular due to their ability to personalize the learning path [21]and improve learner outcomes [22]. These tools can help instructors identify learners' strengths and weaknesses and provide personalized learning experiences accordingly. The use of AI in e-learning can also enable the creation of more engaging and interactive learning experiences for learners [23]. AI-powered tools can create simulations and virtual reality experiences that can enhance the learning experience.

1.1.8 Tools for generating educational content with AI

One of the most significant advances in this field is the use of Natural Language Processing (NLP) techniques to generate expert textual content. AI-powered systems such as GPT-3 [24]and ChatGPT can generate high-quality text that is virtually indistinguishable from human-written text. These systems are able to understand the context and nuances of language and produce output that is tailored to the specific needs of the user. This makes them ideal for generating content for eLearning courses.

Overall, the use of AI in the development of digital e-learning resources has revolutionized the field. AI-powered systems can generate high-quality content quickly and efficiently, which can save course creators time and effort. They can also produce highly personalized content that is tailored to the specific needs of the user. As such, they offer significant advantages over traditional methods of content creation.

1.1.9   Expert systems for personalized e-learning

In today's education landscape, the integration of artificial intelligence (AI) is a disruptive force reshaping traditional approaches to teaching and learning. One notable application of AI in education is the incorporation of AI algorithms into closed expert systems[25] [26], which are designed to deliver personalized learning experiences to students [27] [28]. These systems use the power of AI to analyze vast amounts of data, including internal corporate documentation and external content from platforms such as OpenAI . Using this diverse range of information, closed-loop expert systems can adapt learning paths to meet the specific needs, preferences, and learning styles of individual learners.

The importance of personalized learning [29]cannot be overstated in the context of modern education. By integrating AI into education technology, organizations can unlock new opportunities to increase student engagement, improve learning outcomes and promote lifelong learning in a rapidly evolving digital age.

1.2   Current issues in the development and delivery of personalized e-learning content

Nowadays, personalized learning services are a key moment in the field of online learning, as there is no fixed learning path suitable for all learners. The adaptation of curricula to the labor market and business requirements is essential when developing curricula and specific courses. This approach may not be effective for learners of different backgrounds and abilities.

The creation of personalized e-learning content is a resource-intensive process that requires the authors of such content, a serious investment of time and knowledge of modern technologies in the field of e-learning. The main problems they face are the following:

- *Development time*
- *Expert knowledge of the subject matter*
- *Creators' motivation of content*
- *Motivation of learners*
- *Budget/Cost Efficiency*

The shift to personalized learning based on learners' prior knowledge is a process that will definitely be the future of e-learning. At present, due to complex technological and non-technological factors, this process is complex and inefficient.

1.2 Conclusions

Based on the conducted research in the field of e-learning and knowledge management, several key conclusions are established that emphasize the need to carry out specific scientific and applied tasks. The main challenges are the following:

- ***Lack of a specialized authoring tool***
- ***Need for a database of descriptive elements***
- ***Need for a complex technological solution***

The solution to these challenges creates the need to:

o Systematizing the functional requirements of e-learning and knowledge management systems is an important aspect for the future development of this field.

o Establishing a method for evaluating e-learning systems will allow institutions and organizations to evaluate and compare different systems, thus choosing the best solutions for their needs.

o Classification of online courses by delivery methods and type of educational content also plays an important role in this process.

o The integration of artificial intelligence in the process of creating educational content through generative AI.

o The design of a web-based platform for the development and delivery of interactive educational content.

o Developing a personalized e-learning model based on the learner's competency profile is another important step towards improving the learning process.

o The creation of a custom e-content tool architecture will also play an important role in this process.

o Finally, the development of a prototype of a complex system for the development and delivery of customized e-learning content would be essential to bring together all aspects of e-learning.

CHAPTER 2 - MODELS AND TECHNOLOGIES FOR THE DEVELOPMENT AND DELIVERY OF PERSONALIZED E-LEARNING CONTENT

2.1 Classification of online training courses according to delivery methods and type of training content

The rapid development of e-learning has also led to an active development of the forms in which the learning content is provided. Educational courses in modern scientific and technological fields such as artificial intelligence[27] [28], computer programming and mathematical modeling [30]require a specific approach and tools to improve learning and increase the efficiency of the educational process. In practice, the concept of "online course/training" is difficult to standardize and there are dozens of varieties depending on the mode of delivery, the type of media used, the degree of interactivity and the concept of learning design [31]used by the content authors and developers.

Online courses according to the mode of delivery

The main division of online courses is based on the method of delivery. How the online course is organized will largely depend on the medium chosen and the type of content. We can distinguish mainly three types of online training courses: Self-paced online courses, Instructor-led online courses and Hybrid courses

Content Types

The division according to the type of learning content can be done through the lens of the media used, but the more important division should be based on the type of activity that is being implemented. A key division is according to the type of activity, with the learning content divided into the following three types of components: Absorb , Do and Connect . Absorb-Do-Connect is a framework for building learning activities, according to which learning is not just absorbing content, but also making, connecting and applying the content to life outside the learning process. [32].

2.2 A Method for Generating Training Content Using Generative AI

Creating effective and engaging online courses requires a thoughtful and structured approach. By harnessing the power of generative AI, educators and instructional designers can streamline content creation and improve the overall learning experience [33]. This section presents a

comprehensive method for generating content using generative AI. This methodology includes four important steps:

- o AI-based content generation;
- o Breaking down content into small, independent "bites" of knowledge;
- o Separation of small pieces of knowledge into different types of content;
- o Generate the design of course screens, including interactions and visual assets.

2.3 Methodology for evaluating functional capabilities of systems for creating and providing e-learning

In this part of the dissertation, the methodology for evaluating the functional capabilities of the systems for creating and providing electronic learning is presented. The main objective is to develop an approach that provides an objective and systematic evaluation of the performance of these systems, taking into account their specific functional requirements. They address two key aspects: a classification of the functional requirements of e-learning and knowledge management systems, and a method for their evaluation.

2.3.1 Classification of functional requirements of e-learning and knowledge management systems

In this section, the effectiveness and efficiency of solutions for the digital transformation of learning processes are analyzed and the key functionalities for providing learning and development activities in the context of business organizations are analyzed. For each functionality, the benefits for the organization in its presence and the potential problems in its absence are considered.

The following 6 groups of requirements have been identified, which reflect the individual stages of the technological provision of the educational process in an electronic environment:

- Basic settings, user creation and integrations;
- Creation and editing of educational content;
- access management;
- Conduct training and communication and notifications;
- Accountability and statistics;
- Development and support.

2.3.2 Methodology for evaluating e-learning systems

The breakdown of evaluation criteria is mainly based on the different types of functional and technical capabilities, with the addition of financial evaluation criteria. The main disadvantages

of the methods described above are the following:

- insufficient granularity of assessment based solely on the presence or absence of specific functionality;
- lack of a weighting factor reflecting the degree of influence of the evaluated criterion on all other criteria;
- not taking into account the specific requirements and needs of organizations moving to learning management systems.

The methodology developed in this part of the dissertation offers an algorithm for evaluating learning management systems, based on the specific needs of different types of organizations, reflecting the relevant degree of impact of individual criteria and subsequent evaluation of the considered system based on the degree of compliance.

LMS Evaluation Methodology

An 11-point scale was developed to assess the degree of impact of the individual evaluation criteria defined in the previous section. It aims to assess the degree of conformity of the evaluated functionality to the specific needs of the organization.

Table 1. Scale for evaluating the degree of impact of individual evaluation criteria.

Degree	Impact on the organization
0	The criterion (assessed functionality) affects a limited number of users (less than 20%) and does not affect the learning process to any extent.
1	The criterion (assessed functionality) affects a limited number of users (less than 20%) and the use is required very rarely.
2	The criterion (assessed functionality) affects a limited number of users (less than 20%), but frequent use is required.
3	The criterion (assessed functionality) affects a large number of users (over 20%) of the system, but use is rarely required.
4	The criterion (assessed functionality) affects a large number of users (over 20%), but is not of primary importance for ensuring the learning process.
5	The criterion (assessed functionality) affects a large number of users (over 20%) and requires frequent use.
6	The criterion (assessed functionality) affects all users of the system, but is not critical for ensuring the learning process.
7	The criterion (assessed functionality) does not affect users, but is of primary importance to the organization.
8	The criterion (assessed functionality) affects a limited number of users (less than 20%), but is of primary importance to ensure the learning process.
9	The criterion (assessed functionality) affects a large number of users (over 20%) and is of primary importance for ensuring the learning process.

Degree	Impact on the organization
10	The criterion (assessed functionality) affects all users of the system and is of primary importance to ensure the learning process.

A system has been developed to transform the degree of impact into a normalized weighting factor (0 to 100), which is then used to obtain a numerical value of the evaluated system based on the degree of compliance. The model allows adding an unlimited number of categories and evaluation criteria, according to the specifics of the user organization. The weighting factor (K $_{inf}$) for each criterion with a certain (defined by the organization) degree of influence is calculated according to the following formula:

$$(1) K_{inf} = \frac{100}{\left(\sum_{k=1}^{n} D_{inf}\right)} \times D_{inf} \text{ , where:}$$

K $_{inf}$ – the weighting factor for each criterion;

D $_{inf}$ – the degree of influence of the individual criterion;

n – the number of all evaluation criteria.

Compliance of the system with the requirements of the defined criteria for the evaluated criterion in many cases cannot be unequivocally confirmed or rejected, and therefore a more detailed scale should be used to reflect the degree of compliance for each criterion. For the purposes of the model, a 6-point compliance rating scale was developed.

Table 2. LMS Conformance Rating Scale for Individual Evaluation Criteria.

Degree	Compliance level
0	It doesn't meet the criteria at all
1	Meets the requirements to a very small extent
2	Partially meets the set criterion, the missing functionality cannot be compensated
3	Partially meets the set criterion, the missing functionality can be compensated (by using additional plugins/modules)
4	It meets the set criteria almost completely, and the missing functionality is not significant
5	It fully meets the set criteria

To determine the normalized score for each evaluation criterion, it is necessary to take into account the degree of impact of the evaluated criterion on the particular organization and the degree of compliance of the evaluated LMS component with the requirements. For this purpose,

the following formula is derived:

$$(2)\ G_{ec} = K_{inf} \times \frac{G_{res}}{G_{max}} \text{, where:}$$

G_{es} – the result of the LMS evaluation for the individual criterion ;

K_{inf} – the weighting factor for the individual criterion;

G_{res} – the degree of compliance of the evaluated LMS according to the individual criteria;

G_{max} – the highest grade of the LMS compliance scale used for the individual assessment criteria (G_{max} for the particular scale is 5 (five)).

The overall result of the evaluated system can be determined by the following formula:

$$(3)\ G_{lms} = \left(\sum_{k=1}^{n} G_{ec}\right) \text{, where:}$$

G_{lms} – the final result of the complex LMS assessment ;

n – the number of all assessment criteria;

G_{es} – the LMS evaluation result for the individual criterion .

According to the developed methodology, in order to obtain a normalized weight of each criterion, it is necessary to transform the degree of impact of the individual criterion into a weight factor. Based on the infrastructure assessment prepared in this way, tests and analysis of the individual learning management systems can be carried out, and the degree of compliance is determined for each individual criterion and for each system. The result of the compliance analysis together with the weighting factor of the assessed criterion determines the final assessment for the respective criterion. The complex final measurable result of the developed methodology is a sum of the scores for each of the criteria.

2.4 An approach to content development for e-learning courses

The effectiveness of e-learning content depends not only on the quality and development of technology. The preliminary analysis of the situation and the trainees, the correct determination of

the training objectives, the choice of strategies and means of provision, as well as the evaluation of the training results, are of essential importance.

Fundamental to the quality of e-learning and the development time are the activities of the first stage of the ADDIE model - Analysis, the main goal of which is to collect initial information from the author, as well as to get acquainted with the specifics of preparing educational content, necessary for building online trainings.

Effective passage through the individual stages requires, in addition to the excellent structuring of the learning content used in traditional training and the preparation of additional components, to eliminate the lack of direct contact with the teacher.

2.5 Conclusions

The development of e-learning courses is not an easy process, and the right choice of the delivery method, appropriate activities and form of presentation of the learning content is a complex task. On the other hand, it is extremely difficult to achieve customization of learning content and a high degree of individuality for courses designed for a larger and accordingly wider audience.

Automated creation of interactive online courses through generative AI represents a transformative solution to the challenges facing educators and instructional designers.

To optimize the process of building online courses, it is necessary to detail the structure and requirements for the authors of the educational content.

Evaluating e-learning systems is a complex task that depends on many factors. In order to carry out a maximally real and effective evaluation of LMS, first of all, it is necessary to differentiate the functional evaluation from the financial one. Based on the presented methodology, the assessment should be carried out based on predefined criteria distributed by category, and the person performing the assessment should comply with the specific needs of the organization and the purposes for which the system will be used.

CHAPTER 3 - SYSTEM ARCHITECTURE FOR THE DEVELOPMENT AND DELIVERY OF PERSONALIZED E-LEARNING CONTENT

3.1 Designing the architecture of a web-based platform for the development and delivery of interactive training content.

The integration of all the tools for creating and conducting e-learning into a single integrated knowledge management system is not an easy task, which requires a detailed analysis of all the

necessary functionalities of the different types of users involved in the learning process. An additional challenge is to design a model that ensures integrity between modules/subsystems while making it easy to use.

As a result of the conducted analyses, a model of an innovative multi-component web-based platform for the development, use and distribution of interactive e-learning content management for knowledge management was developed. The main objective of the model is to develop a platform structure that allows the creation and distribution of specific, personalized and motivating learning content leading to the improvement of well-defined competencies or skills of the learner, to be created, delivered, consumed and adopted in a possible the most time-saving way for everyone involved in the process. The model includes modules for: Learning Content Creation, Learning Management, Learning Content Sales and Orders Module, Competency Management Module, Payment Management Module, Virtual Communication Module, User Profile Management Module and Management Module of portfolio. By implementing the multi-component web-based platform, the entire e-learning process can be implemented in one place, which will greatly facilitate all participants in the process.

A scheme of interaction and flow of information between the individual modules of the integrated platform model has been developed, as well as the main functions of each of the modules.
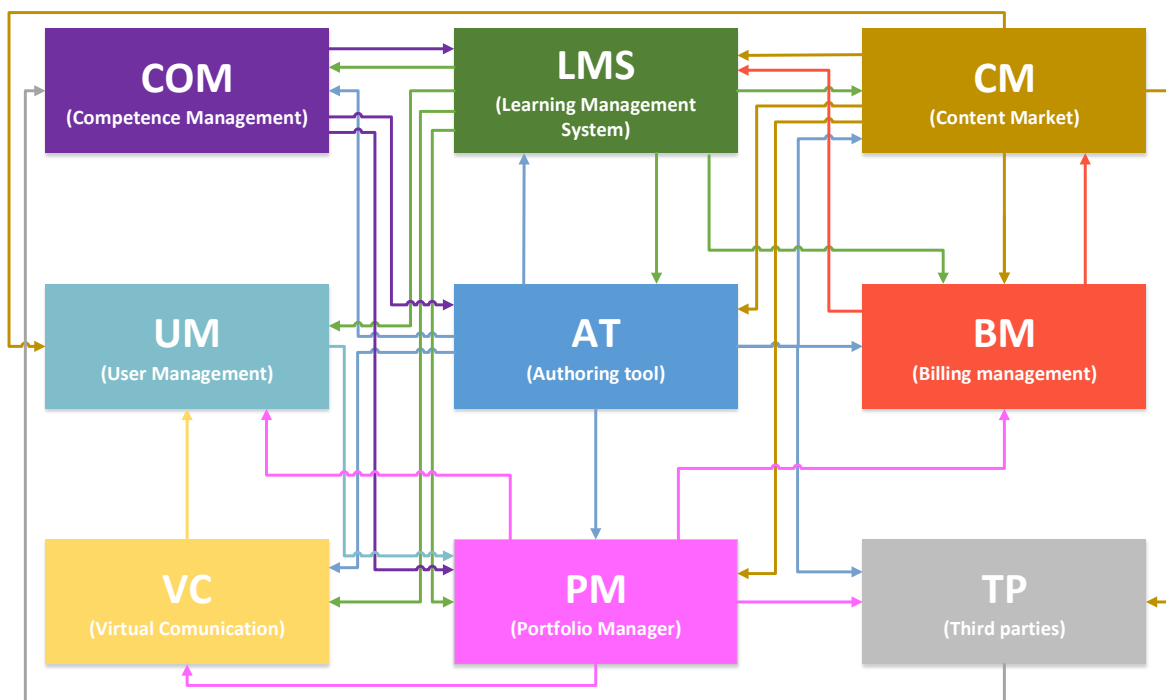
Figure 1. Block diagram of a complex e-learning system

For each of the different groups of tools, an analysis of the most popular and used software solutions (paid or open source) was performed, taking into account the degree of compliance with the functional requirements defined in the previous step.

3.2 A model for personalized e-learning based on the competence profile of the learner

In the development of the model, a methodology was adopted based on the following concept of adaptability based on the prior knowledge of the learners.

Achieving effective personalization depends on the prior knowledge of the user and the appropriateness of the data stored in the user profile.

Prior knowledge influences future understanding. By recording learner performance on a set of parameters it can be compared and used in formative or summative assessments. Prior experience in a given area can be assessed using quick knowledge tests to allocate learners to appropriate stages of learning.

presented in this section, which takes into account the accumulated competencies of each learner, is developed based on the prior knowledge model and includes several key stages shown in Figure 2.

- Stage 1 - Decomposition of the learning content into small learning objects;
- Stage 2 - Description of learning objects with competence;
- Stage 3 - Connecting the learning objects;
- Stage 4 - Creation of assessment/analysis components;
- Stage 5 - Development of a competent profile;
- Stage 6 - Providing individual learners with access to learning content based on the competency profile.
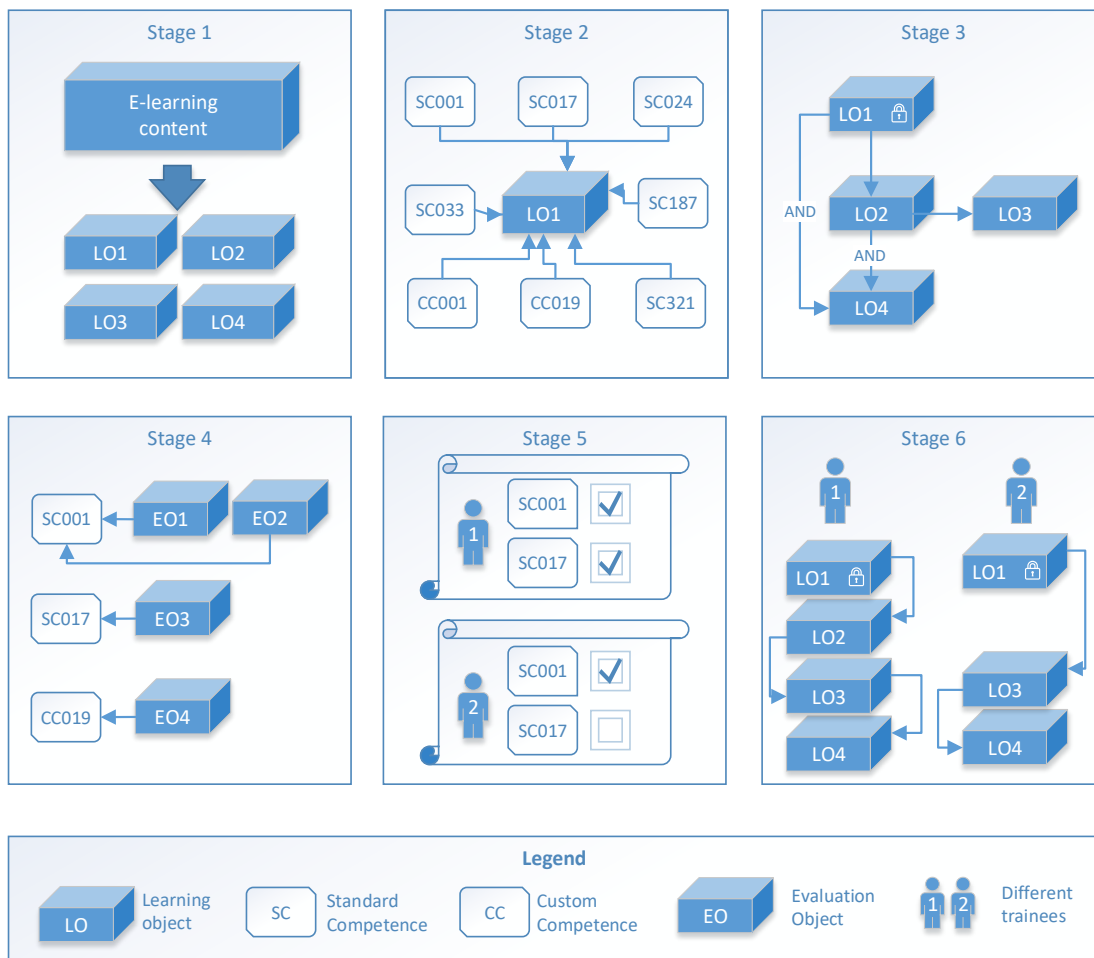
Figure 2. Stages in the development and delivery of personalized e-learning

The development of the model is based on the need to decompose the learning content into small learning objects to be parameterized with descriptive data already at the stage of creating e-learning. For this purpose, a methodology was chosen to describe decomposed knowledge with specific labels, which are united under the general term "competencies".

3.3 Architecture of a tool for creating personalized eLearning content

This section develops a model for creating personalized e-learning content, including its main components and tools.

Building a responsive online course in most cases requires the use of open assessment components, i.e. components that require the intervention of trainers.

3.3.1 Description of the architecture

The architecture is designed to put into practice a step-by-step process of creating and delivering personalized knowledge. Through the development of mock-ups, a conceptual architecture of a personalized learning content creation tool has been created through which the six stages detailed in Section 3.2.

3.3.2 Main screen of the authoring tool

The main screen of the training package, illustrated in Figure 3. Main AT screen, provides access to the necessary tools for creating interactive content and provides access to all accompanying menus for setting up and building customized training content.
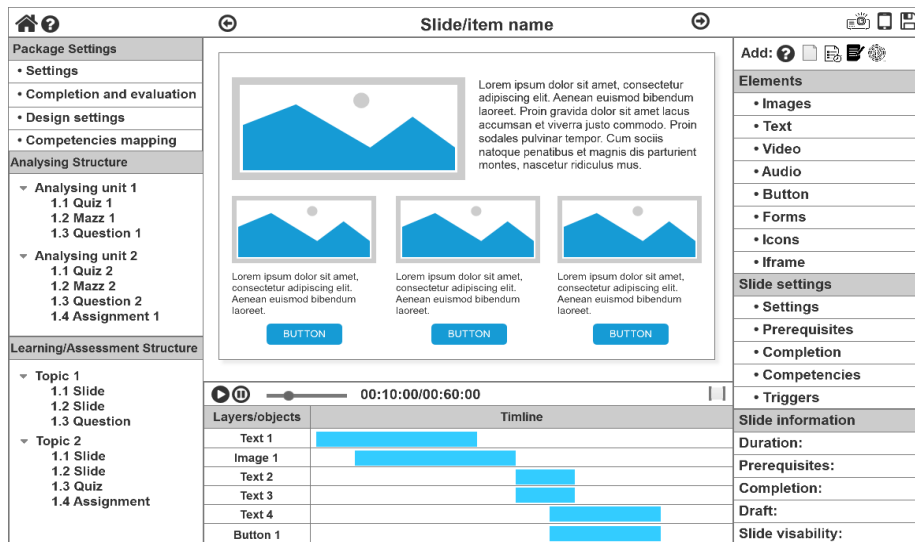
Figure 3. Main AT screen

3.3.3 Add a competency to a slide or assessment component

To facilitate content authors and eLearning developers, teams need to have an integrated competency database.

By describing learning objects with competencies, a link is built between an analytical complex and learning content, and this base creates the possibility for personalization.
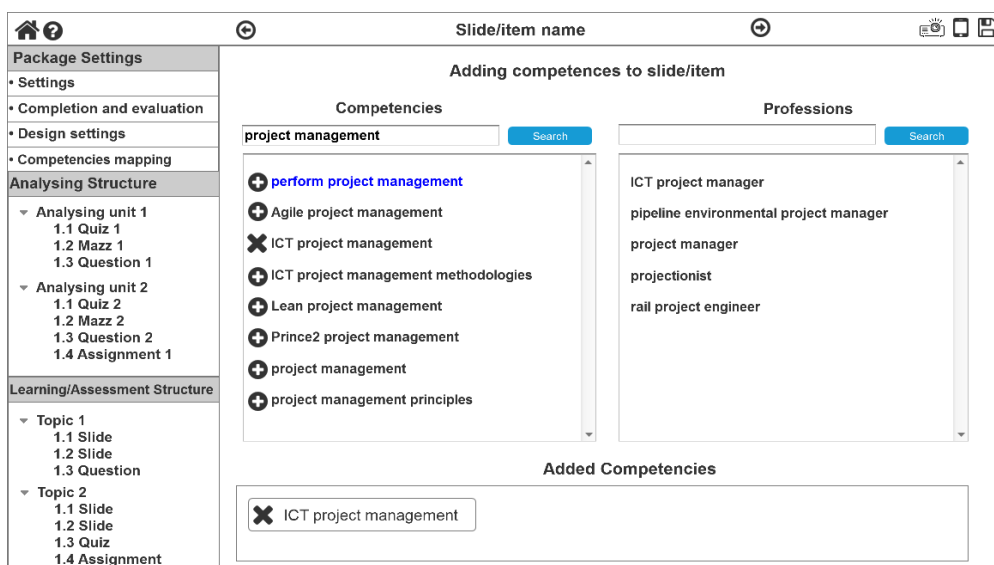
Figure 4. Add a competency to a slide

Determining the required percentage for each tested competency and evaluating the option as mandatory regardless of the result

Figure 5. Determining the percentage required for each competency tested

Through the functionality provided in Figure 5, the training author determines the required percentage collected by the analysts as the arithmetic mean of all the analytical elements defined as an assessment of this competency.

A screen for tracking competency gaps between Analytical Complex, Learning Content and final assessment components
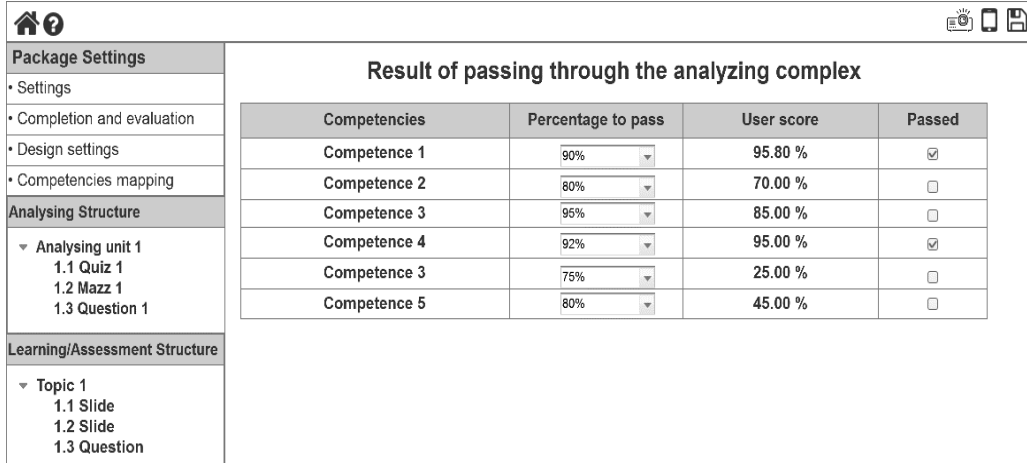
The main purpose of this screen is to enable the author of a single screen to track whether there are content slides for which no analytical or final assessment components have been entered, and whether there is no training content for a particular competency.

Figure 6. Monitoring of competency mapping

Screen with the result of passing through the analyzing complex

The screen illustrated in Figure 7shows the result to the user before moving on to the actual learning content.

Figure 7 Result of passing through the analyzing complex

3.4   Conclusions

The results of the analysis show that there is no single integrated software solution available that includes all the tools needed by the various participants in the process of creating, providing, receiving and certifying the acquired knowledge through online learning.

Taking the analyzes into account, a model is developed for an innovative, multi-component, web-based platform for the development, use and distribution of interactive content management for e-learning.

The main goal of the model is to develop a platform that allows the creation and distribution of specific, personalized and motivating learning content, leading to an increase in well-defined competencies or skills of the learner. Content must be created, delivered, consumed and consumed by individual users in the most time-efficient manner possible.

A scheme of interaction and information flow between the modules of the integrated platform model is presented.

By implementing the model of the multi-component web-based platform, the entire process of providing e-learning can be carried out in one place, which will greatly facilitate all participants in the process.

A model has been developed that, through a complex of case and problem-based analyses, places the learner in situations that have been previously described, which competencies and the degree of reliability they validate. Based on the solutions/answers/results provided, each learner is assigned a competency profile.

The model developed in this chapter for creating and delivering personalized eLearning to ensure lifelong learning provides an efficient way to navigate through the actual learning content based on the learner's acquired competency profile, pre-programmed relationship logic and degree of the importance of the individual segments of the eLearning course.

An analysis of existing eLearning content development tools was performed and their suitability for creating personalized learning content reflecting learners' prior competencies was assessed. As a result of the research, a conceptual model and architecture is proposed, including tools for creating interactive resources and evaluating the accumulated prior knowledge of the learners. The model and architecture are designed to create and deliver personalized e-learning based on the integration of an analytical complex, including assessment tools, a database of the necessary competencies, the content of the training and the prior knowledge and skills of the learners. In

this way, the learner is given an efficient way to go through the entire learning process and acquire the desired competency profile. Future work will focus on incorporating the proposed model into an interactive software system capable of building and delivering e-learning content according to learners' specific needs and prior knowledge.

Finally, it should be noted that the transition to personalized learning based on learners' prior knowledge is a process that will definitely be the future of e-learning. Currently, due to complex technological and non-technological factors, this process is complex and inefficient. With the development of effective solutions in this area, supported by advanced technologies such as artificial intelligence (AI) and big data analysis, new advances will gradually remove technological challenges and, as a function of them, reduce costs and increase the motivation of creators of personalized learning content and of the learners themselves.

Chapter 4 - A PROTOTYPE SYSTEM FOR THE DEVELOPMENT AND DELIVERY OF PERSONALIZED E-LEARNING CONTENT

The prototype system for the development and delivery of personalized e-learning content presented in this chapter was created with the idea of saving the time of teams managing the learning processes in organizations, while giving them powerful tools to internally create engaging personalized interactive online courses, a built-in virtual classroom , administration of on-site training and detailed reports and reports in real time. The main modules of the system are:

Contipso LMS - An e-learning system designed and developed to make the online learning process as close as possible to face-to-face learning. The system offers a wide range of intuitive tools for access management, communication, monitoring and performance reporting of individual users.

Contipso Author - A tool for building interactive multimedia training content, to the maximum extent possible for authors and developers of online courses. Through Contipso Author, authors themselves produce interactive multimedia training content that interacts with the learner.

Contipso Catalog - A place where people who want to contribute their knowledge meet those who want to develop continuously in the context of lifelong learning.

Contipso Market - A specialized store for elements, templates and training resources to quickly and attractively build online courses.

These modules form a complete solution for knowledge management and training in organizations, providing flexibility, interactivity and the possibility of personalization of the educational process.

4.1 E-learning system

A next-generation learning process management system that provides a quality user experience to all participants in the learning process, regardless of the device they use.

The system offers a wide range of intuitive tools for access management, communication, monitoring and performance reporting of individual users.

The training process is conducted through the use of an interactive training content player , which provides an adaptive presentation of the training content for maximum comfort under any device.

The system is designed on the principle of separation of roles, providing for the following roles:

- Educable;
- Teacher
- Content editor
- Head of structure
- Training organizer
- Administrator

For each of the roles, a separate dashboard is designed after login, which gives specific information according to the role. Each user of the system can have one or several roles. Figure Figure 8illustrates the learner dashboard with a primary focus on enrolled courses and programs, displaying for each a pass deadline, score, current status, and progress rate.
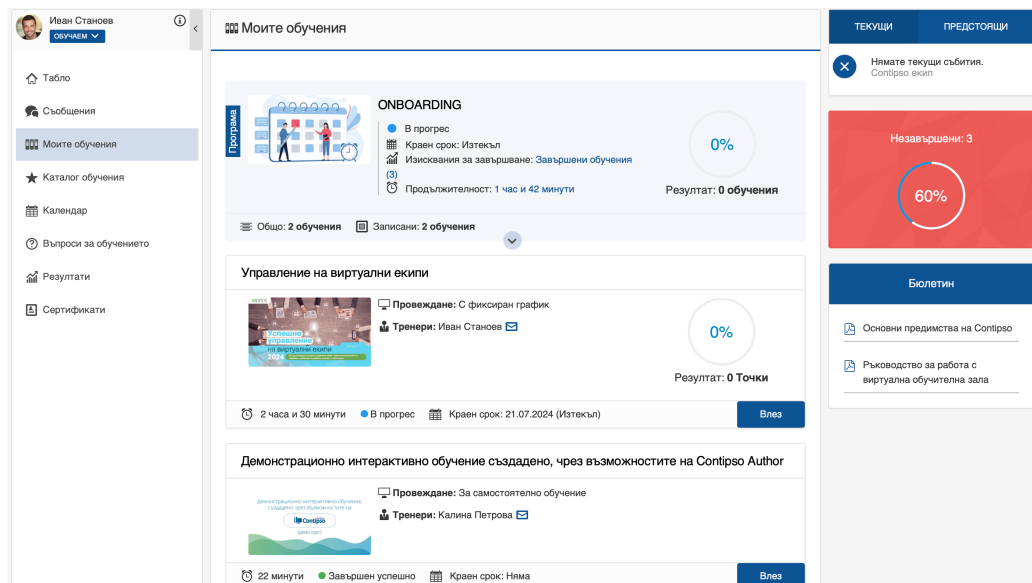
Figure 8 Main learner dashboard

Each individual training is visualized in the form of an interactive player (Figure 9), which contains both educational slides combining audio, video, animations and interactivity, as well as assessment components such as tests, case studies and independent works, questionnaires and entire educational mazes. to provide the element of personalized traversal through the training content.

Thanks to the deep integration with the training content development tool, the system can track the progress of the learner through each of the individual screens of the training for which a completion requirement has been set in Contispo Author. At any moment, the learner has information about the current requirements for completion (Figure 10) and the achieved result and status of the individual training assessment components (Figure 11).

Based on the set requirements for completing each screen of the training, the system offers the possibility to configure the training path of the trainees, which makes it possible to set requirements for access to certain content. An example of such a requirement could be that the post-topic quiz be available only after the learner has gone through the learning content.

For the purpose of fixed-schedule trainings, the possibility of time-fixed trainings, where each training topic or assessment component can be unlocked and locked precisely in a certain time slot, has been designed and implemented. This is illustrated in Figure 12, where you can also see how against each training content item there is a link to instantly edit the content directly in the built-in training development tool.

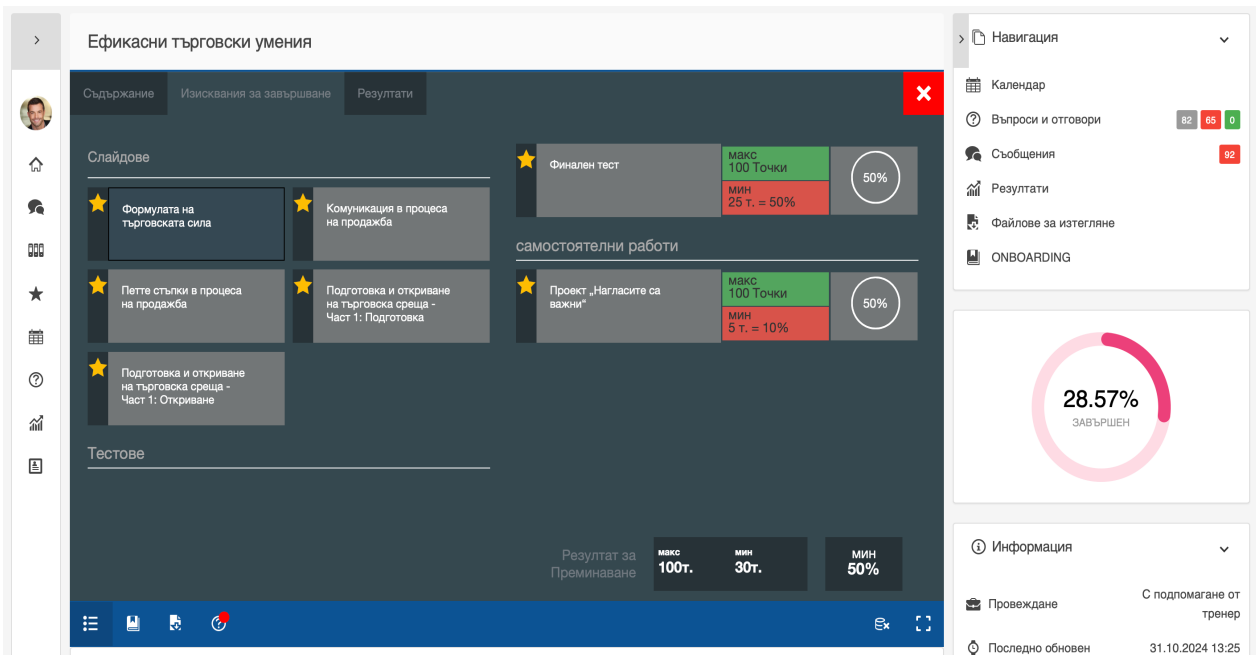*Figure 9 Learning screen with interactive player and progress tracking*

Figure 10 Information in the player about how to complete the training
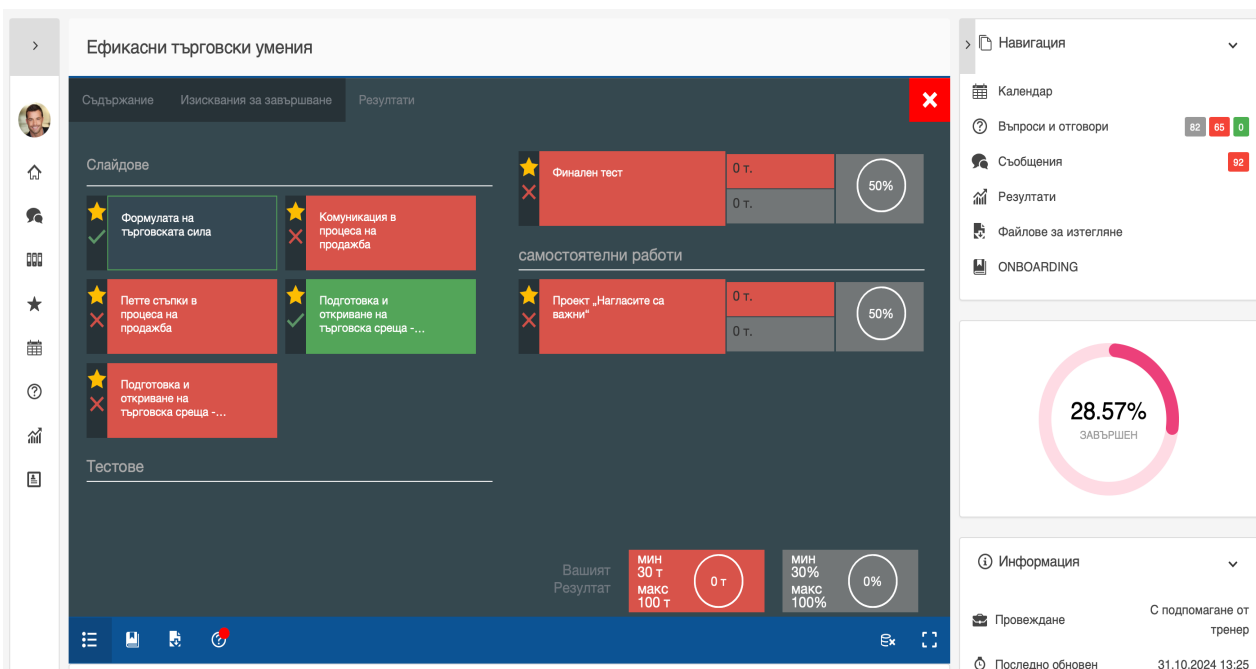
Figure 11 Information in the player about the results achieved
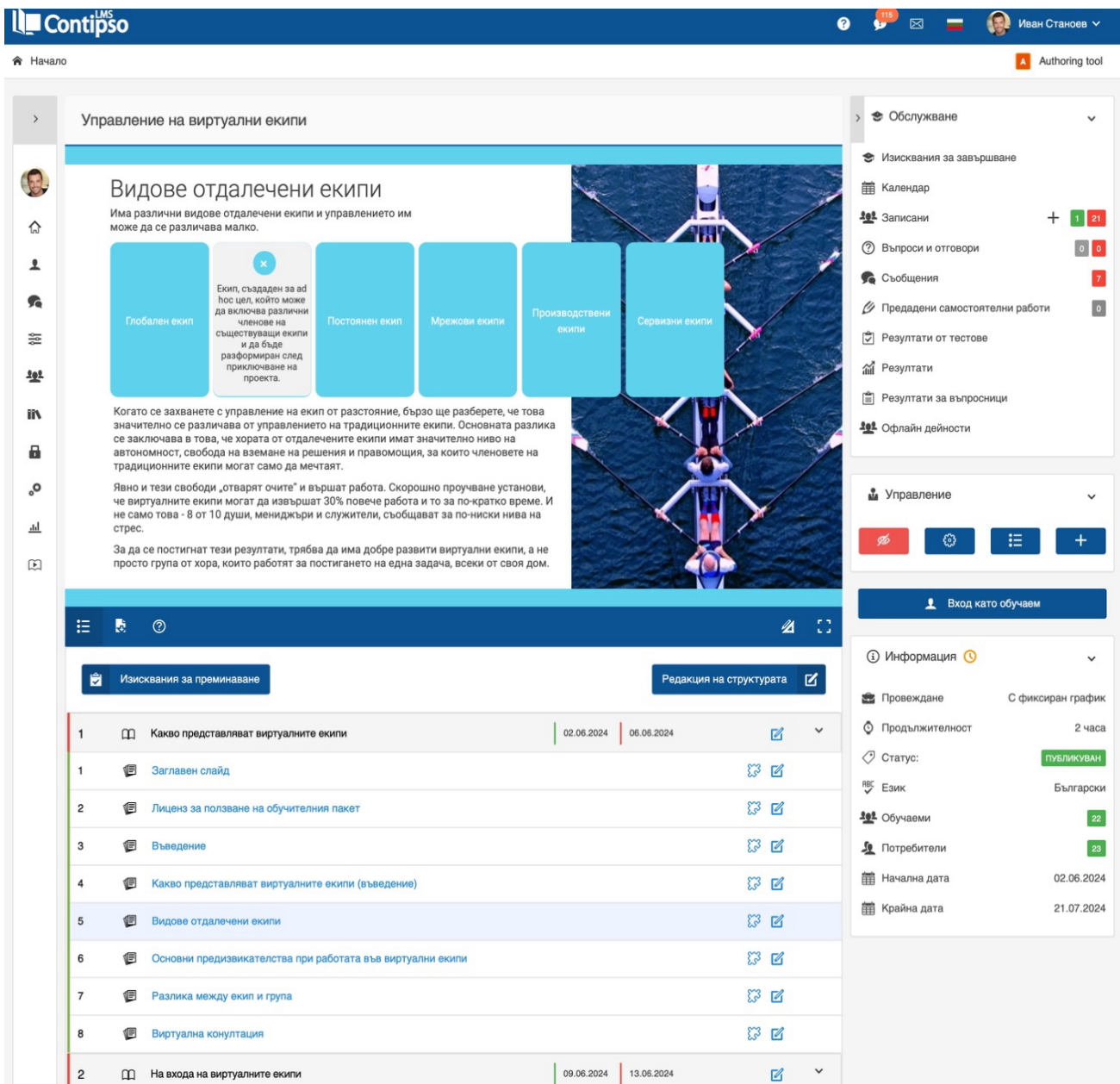
Figure 12 Learning view with Learning Organizer role

4.2 An interactive learning development tool

The heart of the developed prototype Contipso Author is an Internet-based tool for preparing multimedia educational content that interacts to the maximum extent with the learner.

Easy and fast creation of interactive slides based on many pre-prepared templates, learning path management, interactive questions and tests, easy and powerful configuration of completion and assessment, ready-made components that save your time.

Full integration with Contipso LMS to organize and manage the training process, with Contipso Market to access a variety of free and paid training resources.

The main screen of the tool is a kind of library with training content and templates (*Figure 13*). This is where access to the individual content editor packages and the question bank is managed.
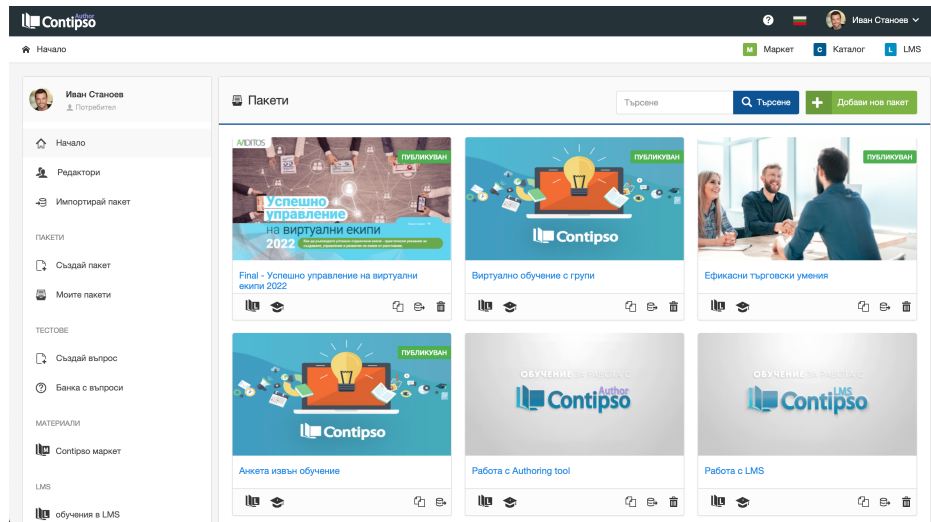
Figure 13Learning Library main screen in the Interactive Content Development Tool

Figure *Figure 14*shows the main screen of the training content development tool, which consists of the following components:

- **Stage –** the place where educational content is created;
- **Timeline –** a screen in which the display and hiding time of individual elements is managed, effects and animations are added;
- **Context menus –** when selecting an element, multiple submenus are opened, from which the visualization and its behavior when interacting with the user can be adjusted;
- **Structure –** hierarchical arrangement of educational content within topics and modules;
- **Elements -** a library of different types of elements that can be called on stage.
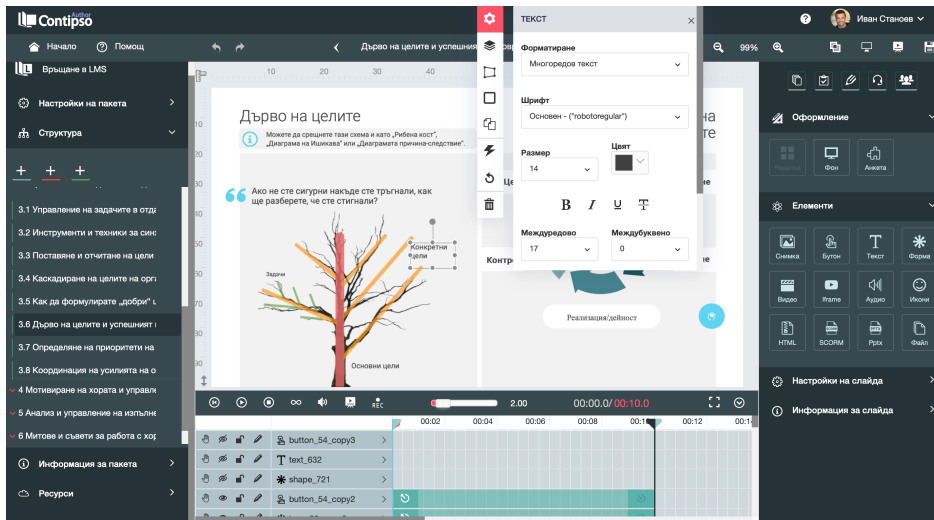
Figure 14 The interactive content development tool

A key functionality of the tool is the ability to set triggers. These are essentially pre-defined rules that can be programmed to track user action and. On this basis, take the learner to a different part of the slide or the training as a whole. This is precisely the main functionality for building personalization of the training path in relation to the learner's behavior.
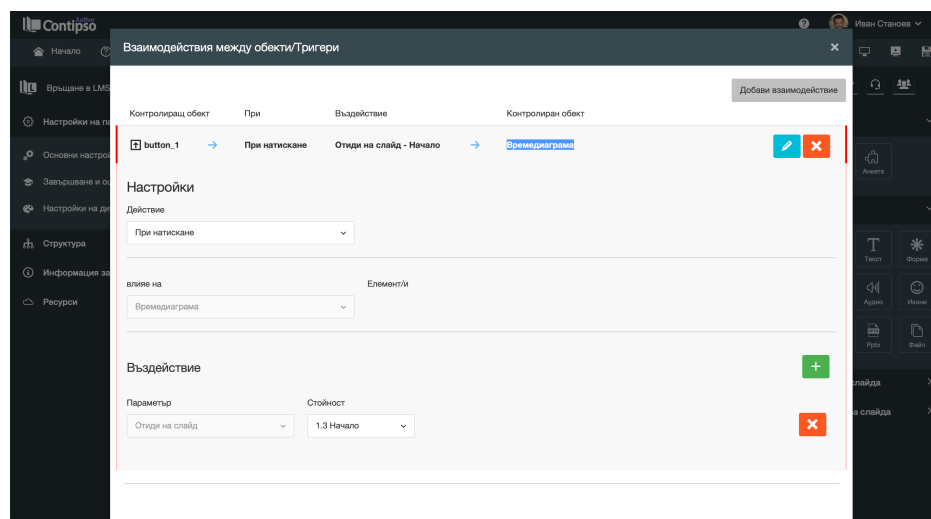
Figure 15Add Interactivity screen

4.3   Competency management

The chosen model for the personalization of the training process is based on assessment and accumulation of competencies. Figure *Figure 16*shows the basic interface for describing the individual competency training screens. Integration with the EU ESCO Competence Model has been implemented in the prototype. Described in detail in Chapter 3.
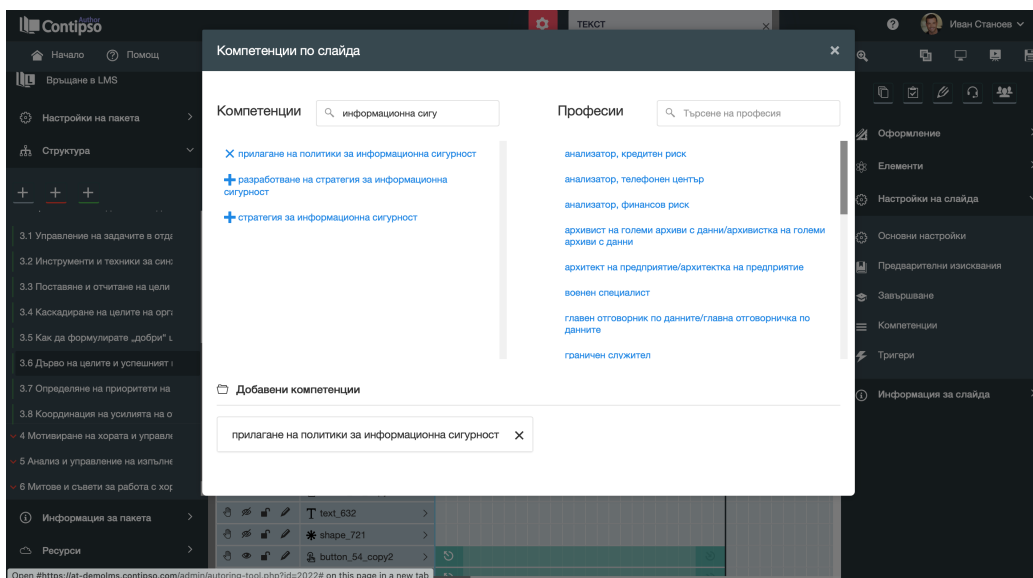
Figure 16Screen for describing training content with competencies

Successfully passing a screen or an entire training, certified competencies are automatically accumulated in the training file (*Figure 17*).
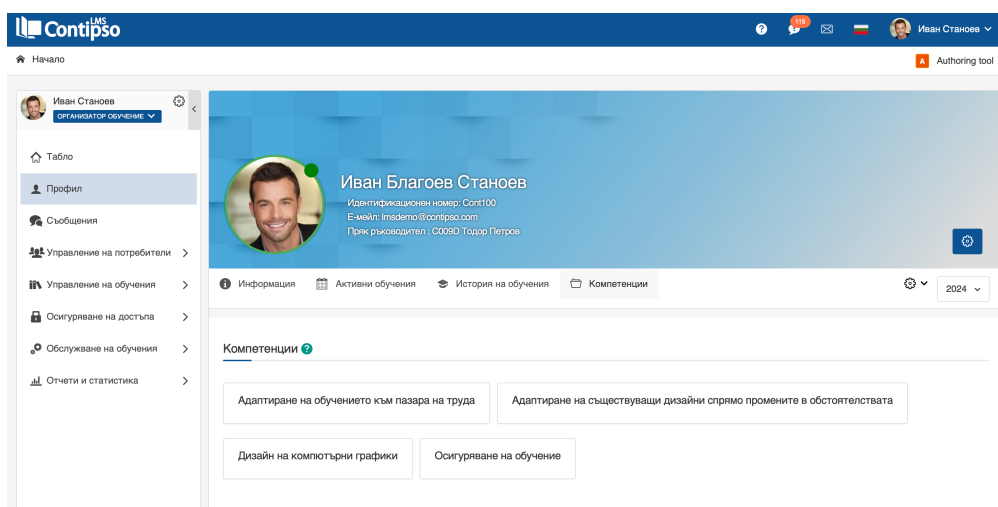
Figure 17Profile of a learner with accumulated all competencies from successfully completed trainings

4.4 User management and access

Key to user management is integration with other systems or importing and entering user data. The main goal is to have as much data as possible in the system that characterizes the user.

The automation setup screen is illustrated in *Figure 18*. The learning path between courses is also set from the same place.
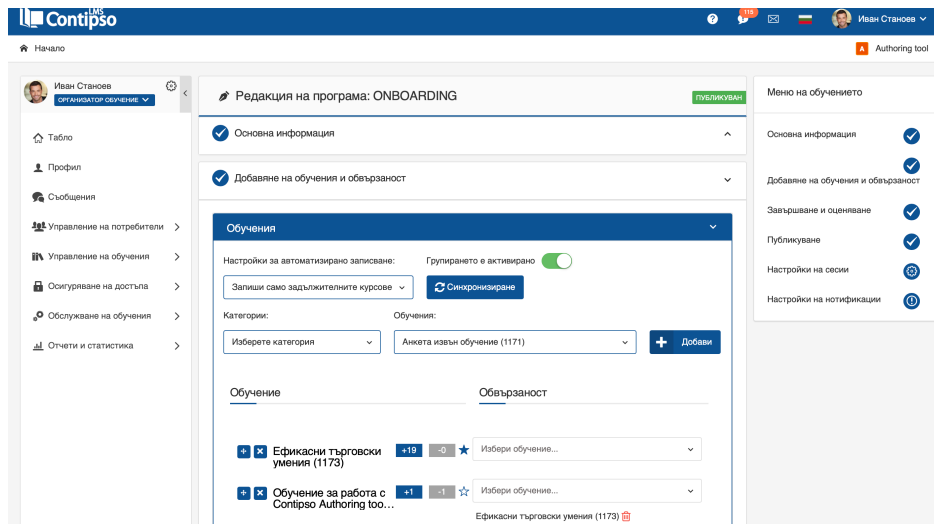
Figure 18Creating a study plan and adding prerequisites to access a course

The prototype has been validated in an operational environment and is used for the purposes of the project "CYBERsecurity 4 All STAkeholdeRs" (No. 101083793), funded by the European Commission's Digital Europe Program and the Research, Innovation and Digitalization for Smart Transformation Program (RIDI). IICT of the Bulgarian Academy of Sciences is a partner in the project.

More than 800 learners have gone through the system, who receive access to training content, tests, surveys and automatic issuance of a certificate after successful completion of the training.

Conclusions

By developing a prototype of the multi-component web-based platform, the entire process of providing e-learning can be done in one place, which greatly facilitates all participants in the process.

The integration of a custom content development tool with a built-in competency description module with the e-learning system enables:

- Quick build and update of interactive personalized trainings;
- Detailed analysis of user behavior;
- Analyzing the input competencies of the trainees;
- Providing an individual learning path for each learner;
- Accumulation of acquired competencies in the learner's portfolio and their use to automatically provide access to other trainings;

The developed add-on modules for delivery of ready-made trainings, marketplace for ready-made interactive content, module for asynchronous learning and portfolio complement the basic infrastructure and provide a communication environment and feed content authors and responsible training and development teams with ready-made training and interactive learning elements.

Conclusion and summary of the obtained results

The dissertation presented a model, architecture and prototype of a web-based platform for the development and delivery of interactive educational content that would provide an integrated solution for all aspects of the educational process.

A systematization of the functional requirements of e-learning systems has been carried out and knowledge management is an important aspect for the future development of this field, and a method for evaluating e-learning systems has been developed which allows institutions and organizations to evaluate and compare different systems, such as thus choosing the best solutions for their needs.

A classification of online courses by presentation methods and the type of educational content also plays an important role in this process, and standards have been developed for the creation of electronic educational content.

A web-based platform for the development and delivery of interactive training content was designed to provide an integrated solution for all aspects of the training process. Developing a personalized e-learning model based on the learner's competency profile is another important step towards improving the learning process.

A customized e-content tool architecture will also play an important role in this process, which has been realized through the development of a prototype of a complex system for the development and delivery of personalized e-learning content, which is essential to unify all aspects of e-learning. training.

In view of the work carried out in this dissertation and the results obtained in the course of the research and presented above, the following **scientific and applied contributions can be formulated** :

1. A methodology has been developed for the evaluation of e-learning and knowledge management systems, and for this purpose a classification of the functional requirements of these systems has been carried out, it allows institutions and organizations to evaluate

and compare different systems, thus choosing the best solutions according to their specific needs;

2. A classification of online training courses according to delivery methods and type of training content is made, and a content development approach for e-training courses is developed. Defining such an approach ensures high quality of the developed educational content and facilitates the integration of various tools used to create educational materials . This leads to greater consistency and improved interoperability between different systems and resources;

3. Created a method for generating training content, using generative AI. With this method, training materials can be customized according to the needs of each learner, making the learning process more efficient and adaptable. The created method based on artificial intelligence supports the creation of content tailored to the individual knowledge and interests of the learner, which is a step towards more personalized learning.

4. A model has been developed for personalized e-learning based on the competence profile of the learner. The model provides individualized training that takes into account the specific needs and competencies of learners and ensures higher efficiency and increased commitment of learners;

5. Based on the developed model, a tool for creating personalized e-learning content was designed. Creating a custom e-content tool also plays an important role in this process. This tool facilitates the creation of adaptive content tailored to the individual needs of each learner by providing the necessary resources for personalization;

6. The architecture and prototype of a web-based platform for the development and delivery of interactive training content have been developed. A comprehensive system for the development and delivery of customized e-learning content is essential to bring all aspects of e-learning together. This prototype serves as the basis for an integrated solution that combines the creation, management and distribution of personalized training materials in one comprehensive platform.

Directions for future research

AI-powered technologies could be actively used to generate expert textual content, images, videos and multilingual audio for e-learning courses. These tools have the potential to improve efficiency, personalization and learner engagement and are at the heart of the solution to the

fundamental problem of implementing a personalized learning process based on learners' prior knowledge.

The main directions for future research on the topic of the dissertation include:

1. Implementing an AI model to generate text and multimedia learning
2. Training an AI model to take on the role of training designer
3. Development of a model for transforming generated content into a structured one that will be enriched with examples, stories, mazes and other elements that will play the role of both an analytical complex and serve as basic educational content.
4. Development of an architecture for automatically creating interactive multimedia trainings with human editability and validation.

Publications on the subject of the dissertation

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2. **Blagoev, I.,** Vassileva, G., Monov, V.. From Data to Learning: The Scientific Approach to AI-Enhanced Online Course Design. Proceedings of the 8th IEEE International Conference on Big Data, Knowledge, and Control Systems Engineering – BdKCSE'2023, 02 -03 November **2023** Sofia, Bulgaria, IEEE Xplore, 2023, DOI:10.1109/BdKCSE59280.2023.10339693, 1-5

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