Education and Information Technologies (2020) 25:11–30
https://doi.org/10.1007/s10639-019-09903-5

Convergent approach to synthesis of the information learning environment for higher education

Alexey Finogeev[1] · Lejla Gamidullaeva[1] · Alexandr Bershadsky[1] · Ludmila Fionova[1] · Michael Deev[1] · Anton Finogeev[1]

Received: 15 June 2018 / Accepted: 15 March 2019 / Published online: 23 March 2019

Abstract
The article considers a convergent approach to the synthesis of the information learning environment for higher education, which includes tools for managing educational content and learning trajectories. The process of convergence is defined as synchronization and coordination of electronic educational resources, educational programs and skill levels of specialists. The process is presented within the framework of interaction and lifecycle model synchronization for components of the information learning environment. The environment ensures the convergence of new educational models (electronic, mobile, cloud, mixed, ubiquitous) on the basis of a unified educational management system. The system includes the Alfresco educational content management subsystem, the Moodle learning management subsystem, the learning material presentation subsystem, the knowledge assessment subsystem, the learning activity management subsystem, the requirements of education standards and employers analysis subsystem.

Keywords Convergence · Information learning environment · Convergent approach · Learning management system · Lifecycle model synchronization

1 Introduction

Modern e-learning is a system that uses information and telecommunication technologies, although UNESCO specialists define it as learning through the Internet and multimedia technologies. In any case, the learning processes are provided by these technologies for working with electronic educational

✉ Alexey Finogeev
alexeyfinogeev@gmail.com

Extended author information available on the last page of the article

resources (Hamidi 2011). Evolutionary development of wireless networks has led to the spread a ubiquitous access technologies according to the principle 4A (Anytime, Anythere, Anything, Anybody) (Horton 2000). Such access defines a road map for the modernization of the learning processes in the direction of creating distributed personalized environments for the continuous training of specialists (Deev et al. 2014). Information Learning Enviroment (ILE) is designed to support the convergence of advanced learning technologies such as e-learning (Cloete 2001), m-learning (Duncan-Howell and Lee 2007), cloud learning (Bhatia et al. 2012), blended learning (Bersin 2004) and ubiquitous learning (Hwang 2006). It provides an opportunity for personalized or adaptive learning support for individual students (Tseng et al. 2008), as well as adaptive lifecycles management of electronic educational resources, educational programs and specialist's training level.

Modern trends in education include:

- application of mobile devices (laptops, smart phones, tablets, smart gadgets) and technologies for remote access to educational resources,
- creation of Web resources and use of Web technologies for the publication of educational materials,
- implementation of cloud training technologies (Google Classroom, Moodle, Blackboard, "Mobile Electronic School", etc.),
- application of distance technologies for the interaction of teachers and students through Internet communication systems (e-mail, chat, blogs, forums, IP-phone) (Olofsson et al. 2011),
- the creation of the social networks communities of teachers and students, as a tool for their interaction,
- introduction of virtual and augmented reality technologies, 3D-printing for combining digital media with real objects and blended learning in the classroom and virtual reality,
- application of gaming technology that combines the learning process with game elements (Mouna et al. 2018),
- interaction with employers at all training stages to adjust educational programs.

These trends require the creation of an information environment for integrating educational resources and technologies, systems for supporting distance and open education, lifecycle management tools for environmental components. The ILE assumes the integration of the Educational Content Management System (ECMS), the Learning Management System (LMS), the Learning Activity Management System (LAMS), the tools for intellectual analysis of the standard and employer requirements, systems for forecasting the needs of specialists in labor markets. Most modern learning systems use electronic resources with content and metadata. The main components are already present on the market. In particular, a large number of educational management systems are proposed (Finogeev et al. 2015). Systems are used to develop, integrate, disseminate and update educational, methodological, regulatory and didactic materials with the possibility of ubiquitous and mobile access.

The goal of creating a convergent educational platform is synchronization of electronic educational resources, programs, standards and employers requirements. The main result is the interaction of the ILE components lifecycles and the student's qualification level. Other result are the synthesis of personalized learning space (PLE 2008; Severance and Whyte 2008) with the possibility of ubiquitous access.

In fact, the need for a convergent approach to the training of specialists is caused by the lag of existing educational technologies from the emergence and rapid development of new information technologies. The main problem here is related to the exponential growth of information and educational resources, programs and plans, which often overlap. The other problems of modern education include:

1. Absence of adequate models of lifecycles of educational programs, resources and skill levels of trainees that allow automating the processes of synthesis and configuration of personal learning environments (Kravets et al. 2016).
2. The inconsistency of state educational programs and educational content with modern requirements of employers and absence the synchronization and actualization mechanisms.
3. Absence of the intellectual analysis tools for employers requirements and comparison with competences in state educational standards.

To solve these problems, a convergent approach is proposed for creating an informational and educational environment based on the creation and use of models and methods for synchronizing the life cycles of its various components. The main objectives of lifecycles management of the ILE components include:

1. The lifecycle models development on the convergent approach. In the course of the research, life cycle models of such ILE components as electronic educational resources, training electronic systems, educational programs and the qualifications of students, which are discussed further in the article, were created.
2. The creation a lifecycle synchronization model. To implement the convergent approach, a complex model and method of synchronization of the proposed life cycle models for the ILE components has been developed.
3. The development a synchronizing and coordinating methods for educational programs, resources, training levels and employers requirements. This goal is the most difficult in terms of the synthesis of tools for its implementation. This is due to the difficulty of taking into account the requirements of employers and harmonizing them with existing curricula and educational standards. Employers' requirements change much faster, as they are determined by factors that cannot be foreseen at the stage of developing educational standards, curricula and programs. The proposed approach to synchronization is discussed later in the article.
4. The development and implementation a lifecycle management tools. To manage synchronization processes, tools are created that work with ILE components. The main functionality is aimed at the synthesis of personalized learning paths taking into account the requirements of educational standards and employers.

5. The development a remote monitoring tools for learning processes, teachers and students. Monitoring tools are needed to control the educational process, as well as to support the interaction of teachers and students in the information and educational space.
6. The integration components, technologies and intelligent learning support tools. The concept of convergence is based on integration processes through which the accumulation and consolidation of educational resources, models, methods and technologies of education, intellectual assistants and means of support for students is realized.
7. The development human-machine and human-human communications in augmented and virtual reality based on psychophysiological technologies and neurointerfaces. Using augmented and virtual reality for learning allows you to embed the technology of "full immersion" into the learning environment, to gain real experience of presence, to increase the effectiveness of learning and memorizing educational material. The ultimate goal is the consciousness immersion into the educational information cloud through the neuro interface. The development of augmented and virtual reality technology allows to obtain educational information through the visual interface, which has the largest bandwidth. In the future the trend in the creation of the neuro-interface «brain-educational space» will become a driver for the transition to virtual learning environments.
8. The development tools for remote effectiveness assessment in the ILE. These funds are needed to assess the effectiveness of the proposed approach and the toolkit to support the convergent learning model at different stages of the educational process.

A convergent approach to creating ILE determines that in order to achieve these goals it is necessary to consolidate a wide variety of toolkits to support the educational process and various educational resources from interdisciplinary areas of knowledge. In general, they must meet both educational standards and most employer requirements. To achieve the goals of life cycle management and the implementation of a convergent learning model, it is advisable to use the existing competency-based approach. Educational process management tools allow integrating the competencies of specialists from different areas to build a personalized learning path and synchronize them with the requirements of specific employers. In the course of solving this problem, the methodology of synthesis of the directed matrix of competencies is implemented. The matrix includes competencies from educational standards that best meet the requirements of employers. Before the synthesis of the matrix, a search is made for requirements that are often presented in job advertisements on the websites of recruitment agencies. Requirements are derived from open sources on the Internet, clustered by specialties, areas of knowledge, skills and abilities, taking into account industry, regional, qualification and other aspects. A dictionary of keywords is compiled, according to which the standards search for suitable competences for inclusion in a matrix that meets the requirements of a particular group of employers. After filling in the matrix of competencies, educational programs and electronic resources are selected, the development of which will allow to obtain the required competencies and synthesizes a personalized learning trajectory for the initial requirements cluster.

2 Theoretical review

Currently there are four well-known education theories (Januszewski 2001):

1. Behaviorism: Learning is a response to external stimuli.
2. Cognitivism: Learning is a process of acquiring and storing information.
3. Constructivism: Learning is a process of building an understanding.
4. Connectivism: Learning is a process of connecting nodes or information sources, which is dependent upon technology and recognizes the role the Internet in helping people expand their learning.

The development of e-learning technologies and the use of online training courses with open registration, public curriculum and open-ended results led to an evolutionary convergence of these approaches, which suggests a new convergent concept of education. This concept is closest to the connectivist approach (Siemens 2005), since it similarly places non-educational material in the center, in the learner and his ability to actively interact with information. Базовыми принципами такого подхода являются (Kalogeras 2015): a) the dominant role of the student as a seeker of information and its interpretation; b) the role of the teacher as a factor supporting the search for and interpretation of knowledge; c) the use of errors as an element of gaining knowledge in the process of accumulating experience.

The term convergence was introduced (Bainbridge and Roco 2005) to determine the convergence process of nano-, bio-, information, cognitive and social technologies. The convergence process is associated with the evolutionary development of information and telecommunication technologies, the emergence of innovations in the interdisciplinary field of knowledge (Roco and Bainbridge 2004). Information and technological convergence means the technologies interpenetration and the boundaries blurring between them, when results and innovations appear at the various science and technology fields (Chul and Gunno 2016). The National Science Foundation (NSF) defines convergence as the deep integration of knowledge, techniques, and expertise from multiple fields to form new frameworks for addressing scientific and societal opportunities (Cordova 2016). Convergence integrates knowledge and tools from life and health sciences, social sciences, the humanities and the arts, physical, mathematical, and computational sciences, engineering disciplines (National Research Council 2014). Convergence opens the prospect of gaining new knowledge and ideas for new discoveries that can affect all areas of human activity. The convergence of educational, social, cognitive and information technologies determines the concept of convergent education (Canton 2004).

The term convergent education or training is quite common today. For example, in schools, convergent learning determines the process of creating an interdisciplinary educational environment that is used in the classroom and in extracurricular activities to form a holistic perception of the world among schoolchildren. Convergent approach in school education is a qualitatively new level for the successful socialization of the younger generation in the future world.

In the field of vocational education, the process of convergence of sciences and technologies determines the need to create convergent educational programs. (Arshinov and Budanov 2016). Designing convergent-oriented programs and their implementation takes place in a network of interested parties (students, teachers and employers). This allows you to create unique conditions for the definition of vocational and educational trajectory for the development of the necessary competencies. Thus, convergent vocational education is the process of forming competencies based on the interaction of disciplines from different subject areas, including the integration of natural science, technical and humanitarian knowledge (Sharp et al. 2011).

The convergent approach to learning is based on the evolutionary development of information, telecommunication and educational technologies. Digital convergence brings opportunity and challenge to education (SRC-NSF Report 2016). The lifelong learning process in ILE includes study, research, creativity, analysis, discussion, publication and project activities. Individual and student-owned devices allows for access to multiple sources of information. In other ways, digital convergence holds the potential to alter the balance of power in teaching and learning.

Convergent approach to the ILE synthesis determines the convergence of educational programs and standards for different specialties, as well as the convergence of educational resources, systems and teaching methods (Schatsky et al. 2015). The convergent model of the ILE describes the learning technologies integration on a single platform (Chan et al. 2001) with content management and presentation systems, knowledge assessment, learning process management, accounting standards and employers requirements. The result of convergence is a multi-structural environment for learning support (Finogeev et al. 2017). As an example, we note the approach to learning based on the interactive multimodal learning environment (Moreno and Mayer 2007). Multimodal learning environments представлено авторами as learning environments that use two different modes to represent the content knowledge: verbal and non-verbal. The main types of education convergence should be considered:

1. Technological convergence of the teaching technologies, learning programs and resources lifecycles;
2. Methodological convergence of the learning programs and electronic educational resources of different disciplines;
3. Professional convergence of the various specialists qualifications, competences from educational standards and employer's requirements;
4. Organizational convergence of the LCMS and LMS platforms in a unified information and educational environment;
5. Convergence of the creative and cognitive technologies in the specialists training for professional activities in various areas.

The leading technologies in the implementation of convergent education are cognitive and integrated technologies that involve the use of certain principles, methods and means of training aimed at integrating educational material and educational resources with the provision of wide open access to them. University courses with large enrolments hold challenges for managing and maintaining course consistency, and in accommodating different student learning approaches that are conducive to the realisation of high quality learning outcomes (Cope and Staehr 2005).

Convergence education methods include (Roco 2015): a) Integration along disciplines, levels, borders and cultures, b) "Trading Zones" among various areas of relevance, c) Team Science with a system view, d) Incentives for convergence of domains and modes of education in degree accreditation and academic promotion, e) Improving interpersonal and intrapersonal training, f) Revising organizational structure and regulations to allow convergence processes to be more effective, h) Using higher level languages, such as art, mathematical and other abstractization tools, i) Confluence of topics by bringing together societal challenges, feasibility (science and engineering), desirability (art and humanities) and viability (economics and management).

Convergence education creates a natural environment that nurtures integrated STEAM learning, which includes science (S), technology (T), engineering(E), the arts (A) and mathematics (M) (Culén and Gasparini 2019). STEAM offers a transdisciplinary and platform-enhanced educational process that promotes disciplinary depth and breadth, as well as a common language, across all disciplines. It helps prepare students for careers that value creativity and innovation.

The convergent education system focuses on developing a convergent educational ecosystems that catalyze innovation and breakthrough creations (Herr 2016). A well-designed educational ecosystem nurtures, leverages, and engages a diverse set of convergent and emergent ideas, inclusive relationships, interdependent networks, and creative hands-on opportunities throughout the formal and informal educational supply chain. An educational ecosystem thrives on a well networked infrastructure that reflects and engages the natural web of adaptive processes and mentoring relationships.

To work in this environment requires intelligent platforms to support a converged educational process. Note as an example the "MeinKosmos" learning platform (Martens et al. 2019). An important "smart" feature of the "MeinKosmos" portal is the meta-search, which is designed to help students from different backgrounds find relevant information and literature sources for their current study content. For the synthesis of this intellectual platform, the authors used the evaluation approach. The basic idea of the evaluation approach was to define tasks for information retrieval that can be performed both with meta-search and without meta-search.

3 Materials and methods

The new education model determines the convergence of the educational standards competences with employer's requirements. This process is carried out at all lifecycle's stages of the specialist's qualifications, including at the training stage in colleges and universities and at the retraining and advanced training stages. Such moments as position change, labor functions change, scientific and technological progress require the acquired competences improvement or the new competences acquisition that lie beyond the specialist's qualifications limits. The modern specialist must constantly engage in self-education, so that his competencies meet employer's requirements. However, self-education is

often not enough to gain new competencies. Educational programs for retraining should be coordinated with the specialist's training level and new employer's requirements. Input and control actions, output information and training mechanisms are shown on the specialist's training diagram, shown in Fig. 1. The convergent ILE model describes:

1. The convergence of the lifecycle models for educational programs, content and specialist training levels;
2. The convergence process of educational technologies.
3. The integration process of the learning management and learning activity management systems on the cloud educational content and ubiquitous access.
4. The adaptation process of the control and administration mechanisms of the educational components.

4 Lifecycles synchronization of the environment components

The lifecycle's concept of a system determines a successive change in its evolution stages. The educational program, like the system, also goes through the lifecycle, shown in Fig. 2. The training programs content for specialists of different directions has recently coincided on a number of points. Specialists require similar competencies in the work, especially with respect to information technology.

The first stage of the program's lifecycle is an analysis of the standards and employers requirements. Planning is the next step, which collects information about educational resources for the learning process. The next stage is the development of a program and a tool for assessing it for compliance with the

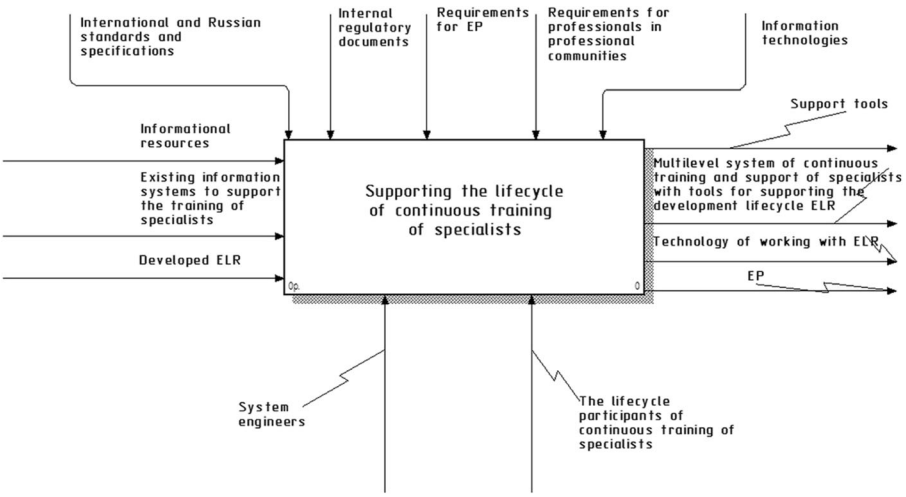

Fig. 1 Context diagram of continuous specialist training

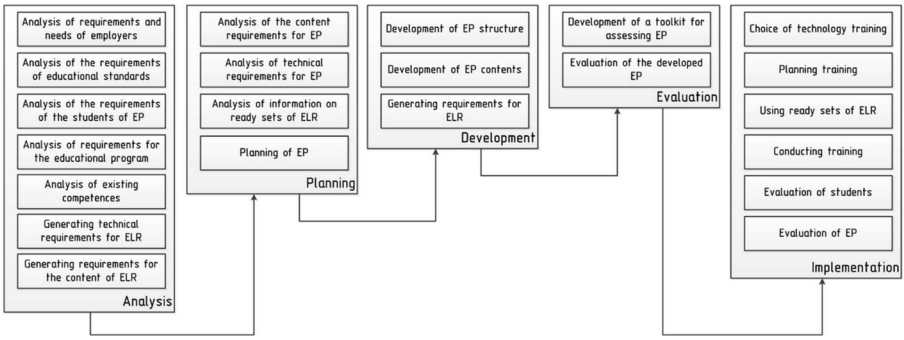

Fig. 2 The educational program's lifecycle

standards and employers requirements. The program's implementation involves the training technologies selection and the educational process planning. The learning process is performed using selected or synthesized educational resources. The program's implementation is completed by evaluating the obtained competences (Van Gog et al. 2010).

The process of program convergence is related to the lifecycle of educational content. The lifecycle of the educational resource includes the analysis & creation/modernization stage, implementation & integration stage, version control stage, checking & publication stage, shown in Fig. 3.

The process of a resource's creating begins with the analysis of external requirements (required formats and technologies, information materials, normative documents), the requirements of the specific training program and the conditions for its implementation (training technologies, content requirements).

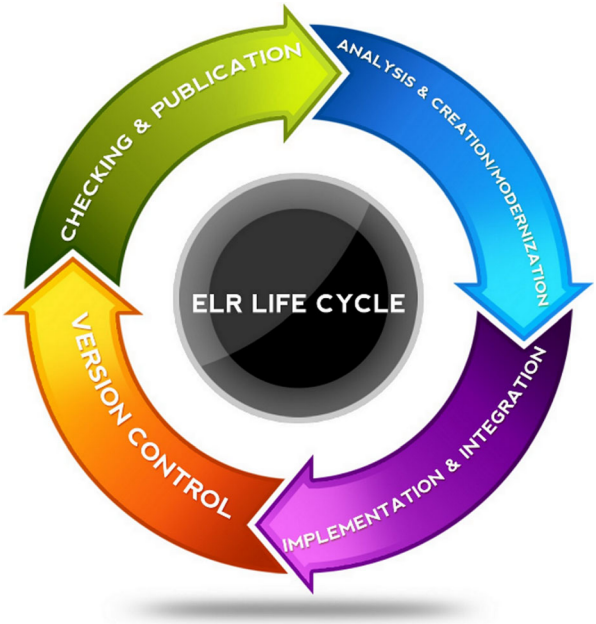

Fig. 3 The educational content's lifecycle

Based on the analysis, the resource's design is carried out, taking into account the requirements for it from the program for which it is developed. Further steps are implementation (taking into account the refined structure and the program material's content), component integration, version control, verification and publication. The content is used in the training program's implementation, as well as in the specialist's self-education in the framework of convergent education.

Convergent process is the synchronization and harmonization of educational standards, training programs, educational content and specialist's skill levels in obtaining competences from various knowledge fields within the framework of the education model, shown in Fig. 4.

A graph model has been developed to formalize the process of lifecycle's synchronization, shown in Fig. 5.

The model represents the oriented pseudograph $M = \{F, S, X)\}$, where F is the synchronization process, S is the contiguity matrix, X is the incidence matrix. The vertices of the three main subgraphs in the model denote the lifecycle's stages of the main environment components. Vertices A1-A8 determine the lifecycle stages of electronic educational content: requirements analysis, design, implementation, integration, version control, verification and publication, content use, decommissioning. These stages can be divided into subsets of vertices. For example, the requirements analysis phase involves

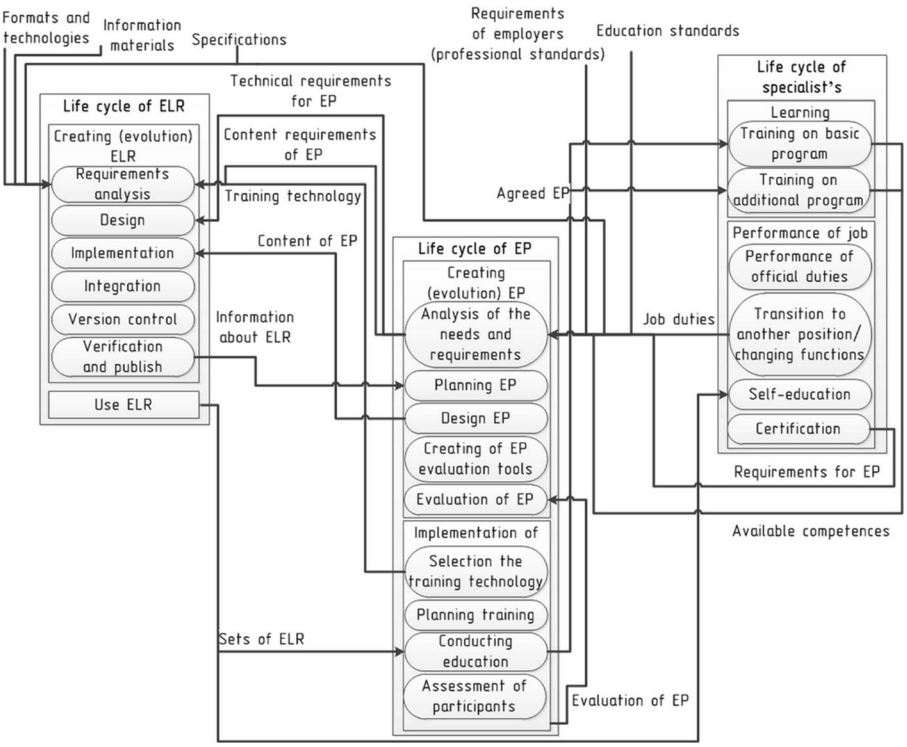

Fig. 4 The process of lifecycle's synchronization for the learning environment components

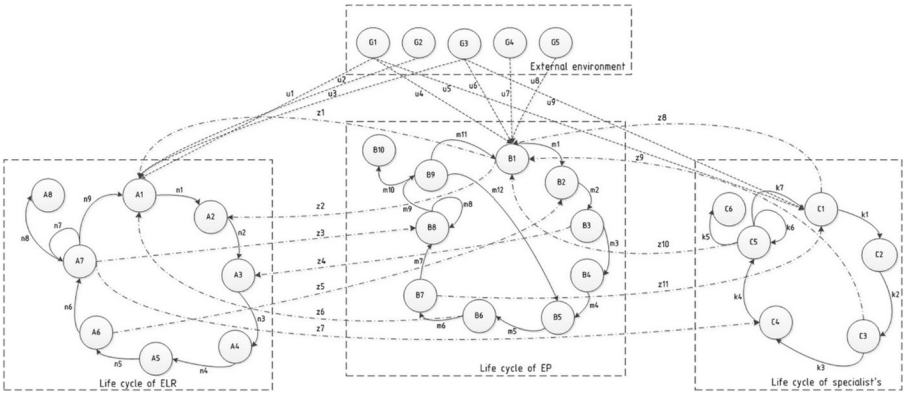

Fig. 5 The model of lifecycle synchronization

methodological analysis, analysis of technical requirements, content analysis. The design stage includes actions for structural content analysis, its design, definition of presentation formats for users, etc. The implementation phase includes presentation in the required format, saving. The verification stage contains the stages of checking for compliance with standards, employers' requirements.

Vertexes B1-B10 designate the lifecycle's stages of the educational program: the requirements analysis, the educational program planning, the development, the assessment tools creation, evaluation, the teaching technology choice, the learning process organization, the training, the participant's evaluation, the program decommissioning. Vertices B1-B10 designate the lifecycle stages of the trainee's qualifications level: training, performing job duties, switching to another position, self-education, attestation, graduation. The fourth sub-graph defines the components G1-G5 of the external environment in relation to the intellectual educational space, namely: teaching technologies, information materials, regulatory documents, employers' requirements, standards.

To test the synchronization model's adequacy and evaluate the convergent educational process, integrated indicators of the training specialist's quality were developed (Hirner and Kochtanek 2012).

5 Results and discussion

The main ILE components are LMS Moodle (Cooch 2010), CMS Alfresco (Alfresco website 2018), LAMS (LAMS Internationalization website 2018), the module for employers' requirements collecting and intellectual analysis, shown in Fig. 6.

Integration of these components allows implementing the adaptive lifecycle management of training components and educational technologies. In the educational space, personalized student's environments are synthesized, united in clusters according to the preparation level, socionic types, psychological portraits and other characteristics (Deev et al. 2015). The introduction of a

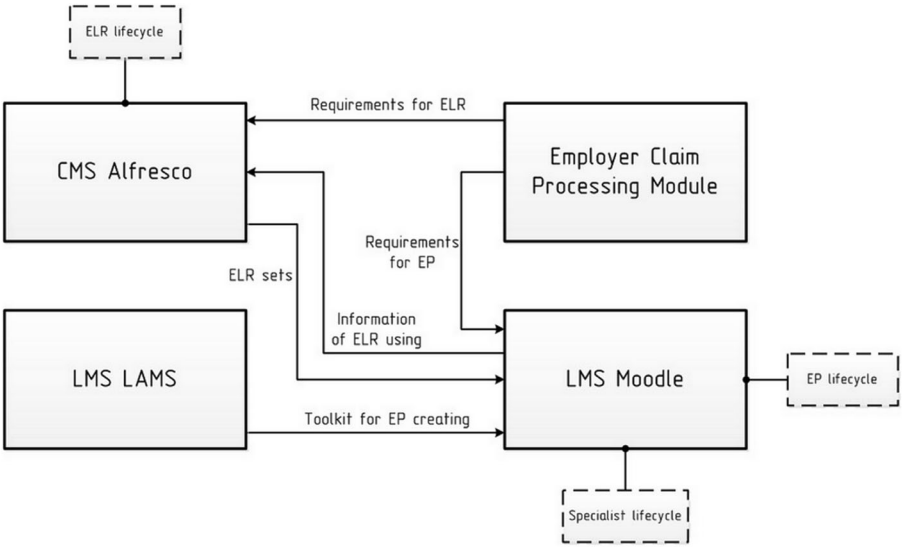

Fig. 6 The main IME components

personalized learning process based on the lifecycle models synchronization for the environment components ensures the learning process monitoring and the educational trajectories changing taking into account the changing standards and employer's requirements. The developed mechanisms help to analyze the destabilizing factors, leading to the risks of obtaining a low-quality and obsolete education.

The educational management system is an instrumental tool for creating and modifying educational programs. LAMS has the functionality to manage learning activities and is used to develop, upgrade and distribute online training materials with the provision of shared access.

The LMS Moodle is suitable for managing the specialist's training in the IME in most cases. It represents the distance learning platform. The structure of the system includes categories and courses where educational content is located. Categories combine courses related to similar topics. In each course, you can use various elements (questionnaires, lectures, polls, forums, tests, hyperlinks, books, SCORM packages, files, etc.) as tools to support the learning process. LMS Moodle provides a large list of functions and Representational State Transfer (REST) queries and uses the access keys for authorization. To access REST requests in the system, you must create a web service with only authorized users access to it, assign REST functions related to checking and generating categories and courses, select users and create authorization keys for them.

Currently, there are a lot of different CMS for creating, editing and managing Web content. CMS works with multimedia data: documents, video and audio material, images and photos. The main purpose of CMS systems is the storage and Web publishing of information materials. The information educational space is created on the CMS Alfresco, which implements the basic functionality of supporting the component's lifecycles. To support the life cycle synchronization process, the IME

component developed new Alfresco CMS modules in the form of web scripts and dashlets. The Alfresco web script is a REST request service that is linked to a specific Universal Resource Identifier.

For educational resources and data exchange between the environment's components, the following technologies and formats are used:

1. Requirements for educational programs and resources are exported in XML format (eXtensible Markup Language).
2. REST and WebDAV protocols are used to access educational resource kits.
3. Data on the use of educational resources are transmitted through Asynchronous Javascript and XML (AJAX) requests in the text-based JavaScript Object Notation (JSON) data exchange format.

The methodology of work in the intellectual educational environment includes the following main stages:

1. Search, analysis and selection of standards and employers' requirements for educational programs and electronic educational resources.
2. Export requirements to CMS Alfresco and LMS Moodle.
3. Synthesis of electronic educational resources in CMS Alfresco, taking into account the requirements and information about the previously created content in LMS Moodle.
4. Synthesis of a personalized training program according to the specialist training level, taking into account the standards and employer's requirements (Harmelen 2008).
5. Selection and filling of a personalized training program for a specialist with a certain level of qualification with electronic educational resources.
6. Training specialists using the toolkit environment LMS Moodle.
7. Competences evaluation in accordance with the standards and employer's requirements and making decisions on training completion or referral for retraining with correction of the personalized training trajectory.

Many scripts have been developed for support the training specialist's technology. It's can be divided into 2 main types: data repository scripts and presentation scripts. Data processing scripts are designed for reading, changing and accessing educational content through the Application Programming Interface (API) for JavaScript. Presentation scripts are required to provide a Web interface. Sample scripts:

1. *Viewfiles webscript* provides data collection for building a cloud storage tree with educational content, defines documents and folders, returns a response to requests in the JSON format,.
2. *Repository-operation webscript* performs file operations on documents and folders in accordance with user rights (copying, moving, renaming, creating directories, deleting), returns the status of the execution results.
3. *My-favorite webscript* adds documents and folders to "favorites", deletes them, returns the execution status.

```
<?xml version="1.0"?>
- <root>
    <file name="213878-1366x768.jpg" uuid="20020c78-e3f7-4d1b-ac23-058c078a8933"/>
    <file name="615653-1680x1050.jpg" uuid="5d872636-05d2-45ef-a4ec-a77846003990"/>
    <file name="619147-1920x1080 (1).jpg" uuid="2ff1c649-c9ba-435a-8ca2-75116982acbd"/>
    <file name="619459-1920x1080.jpg" uuid="2308daf8-a755-4154-a87e-afbaef337424"/>
    <file name="630362-1920x1080.jpg" uuid="8ffbc51f-bb3b-4bdc-a0d0-a093286c36ac"/>
    <file name="634605-1920x1080.jpg" uuid="171a58e3-cb55-4bdf-873a-8090cdc0868a"/>
    <file name="635304-1920x1080.jpg" uuid="4d118ddb-32f8-4c92-8379-51786580028c"/>
    <file name="636268-1920x1080.jpg" uuid="1c7353d8-17a3-404f-8708-33b47d6472a1"/>
    <file name="644247-1920x1080.jpg" uuid="4d956ee7-a5a7-4850-ab5b-de7096ef82f4"/>
    <file name="668131-1920x1080.jpg" uuid="97e22f83-a1d6-478b-9e20-7cde599ca6c2"/>
    <file name="676589-1920x1080.jpg" uuid="c91fe687-379f-4f74-ae3d-662b65e9934a"/>
  - <folder name="Новые документы" uuid="9ef85232-618b-407f-9b34-87e263fe1d31">
      <file name="11 (1).doc" uuid="fadbddfc-06f7-43fc-98aa-de6114dd5cdd" version="2.1"/>
    </folder>
  - <folder name="ФГОСы" uuid="f99416b9-6840-46a1-9d47-eddb918e4fed">
      <file name="211396-1366x768.jpg" uuid="96dd62dc-2863-495a-9c4f-d5ed27ce6eb0"/>
      <file name="213039-1366x768.jpg" uuid="f17bd044-4895-48fb-88fd-b7395ed92912"/>
      <file name="213874-1366x768.jpg" uuid="80b852d5-6f0d-4031-ac74-d1e9acf2d6ff"/>
      <file name="214239-1366x768.jpg" uuid="2bd30b29-fa72-4ad0-bbce-64740cac50cf"/>
      <file name="214841-1366x768.jpg" uuid="d670746d-b4a0-4908-9f6a-be3b6662f2a6"/>
    - <folder name="Тексты" uuid="37693d72-fa05-4b1b-9e36-9f28c54a9a15">
        <file name="11 (1).doc" uuid="5ef7b073-e2c0-4e2d-9db3-601f83b27282"/>
        <file name="11(2).doc" uuid="8cd5f44d-6081-44c3-84c9-c1cf6ce490dd"/>
        <file name="12560-1366x768.jpg" uuid="d0ea3f69-de3b-4fe7-beb3-b091c4bbfa2c"/>
        <file name="341188-1366x768.jpg" uuid="6e26d874-d980-41c2-ba47-
          0b16217e00c0"/>
        <file name="9Models of supporting continuing education of specialists for high.doc"
          uuid="a5c1bf7c-239e-46bc-8f98-f70c300a0dd7"/>
      </folder>
    </folder>
  </root>
```

Fig. 7 Example XML file

4. *Get-path webscript* gets information about the directory location, returns the path to the object.
5. *Get-xml webscript* gets the file structure and writes it to an XML file with nested elements, returns a link to the generated file, shown in Fig. 7.

ECM-browser is an example of JavaScript dashlet. It controls the menu buttons pressing, events, is responsible for displaying the data, creates and processes AJAX requests. Its main functions include: directory tree display, electronic educational resource viewing, resource metadata changing, resource saving, folders XML exporting, directories creating, viewing, copying, moving, deleting, adding a resource to your favorites. AJAX requests are dynamically generated, for example, GET requests:

1. GET http://localhost:8080/share/proxy/alfresco/file_repository/get-path?uuid=515c05d8-8d71-407d-9a40-c5feaa7aaebc (returns the path to the file with the identifier uuid).
2. GET http://localhost:8080/share/proxy/alfresco/file_repository/viewfiles?site=test&userId=admin&parent=/ok (returns an folders and files from the site's parent directory).
3. GET http://localhost:8080/share/proxy/alfresco/file_repository/my_favorite?userId=admin&action=set&is_folder=true&uuid=515c05d8-8d71-407d-9a40-c5feaa7aaebc (add user id to the selected folder with uuid), etc.

In the process of synthesizing educational programs and training, a large number of educational resources are used in different subjects, areas and complexity levels. To solve the problem, a cloud storage with a set of

electronic educational resources and various information and regulatory materials are developed. The model of the educational content warehouse is represented by IDEF1X modeling tools, shown in Fig. 8. The model contains the main storage entities with the specified attributes and relationships between them.

The diagram shows the basic entities, namely educational programs, objects, version archives, object types, availability status, object relationships. The versions of educational content contain comments that indicate changes in relation to previous versions. Interconnections are established between the initial information and regulatory materials and ready-made versions of electronic educational resources. Many versions of educational content allow you to monitor the stages of its lifecycle and use different versions for training in different disciplines and directions within the framework of the convergent education model. Since the development of educational content is often performed by author's team, it is also necessary to store data on the modernization and refinement of previously created elements of educational content. Content authors can change at the lifecycle stages of an electronic resource. Therefore, the convergence model defines one more lifecycle feature of educational content. The parts of content developed for one educational program can be repeated many times in electronic educational resources intended for other programs. At the same time, convergence of training programs leads to the fact that the number of repeating parts should strive for maximum. Therefore, content's fragments in one direction completely or with adjustments are included in electronic educational resources in other directions. An example is the animated videos that are used to demonstrate the work of the models ISO/OSI and TCP/IP. Rollers are used in any resources in the areas related to computer networks, administration of information systems, work on the Internet, etc.

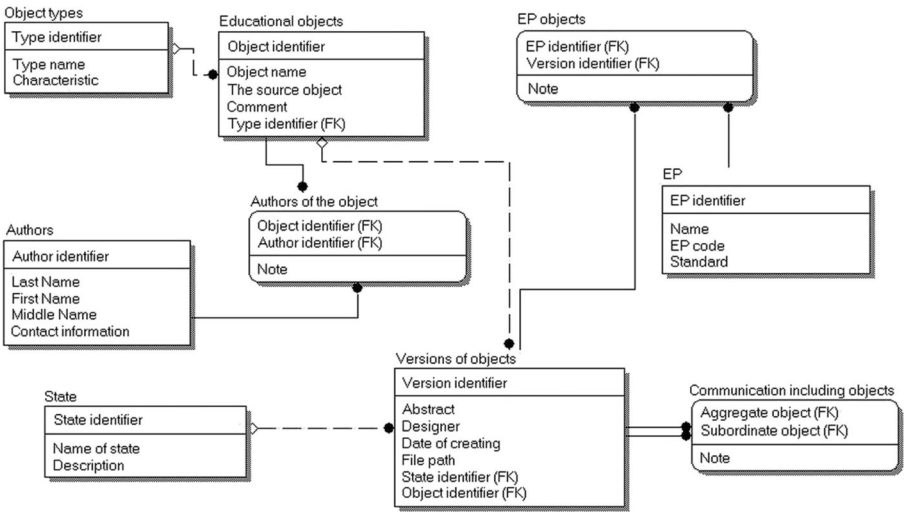

Fig. 8 Diagram IDEF1X of the storage data fragment model

The ILE architecture with intellectual mechanisms for training managing is built as like an open information system, shown in Fig. 9.

Intellectual modules include:

1. The modules of search, intellectual analysis and clustering of educational standards and employers requirements.
2. The module for automated synthesis of personalized or group training trajectories in accordance with the identified clusters of standards and employers.
3. Module for predicting the training results on personalized trajectories based on neural networks with the deep learning mechanism.

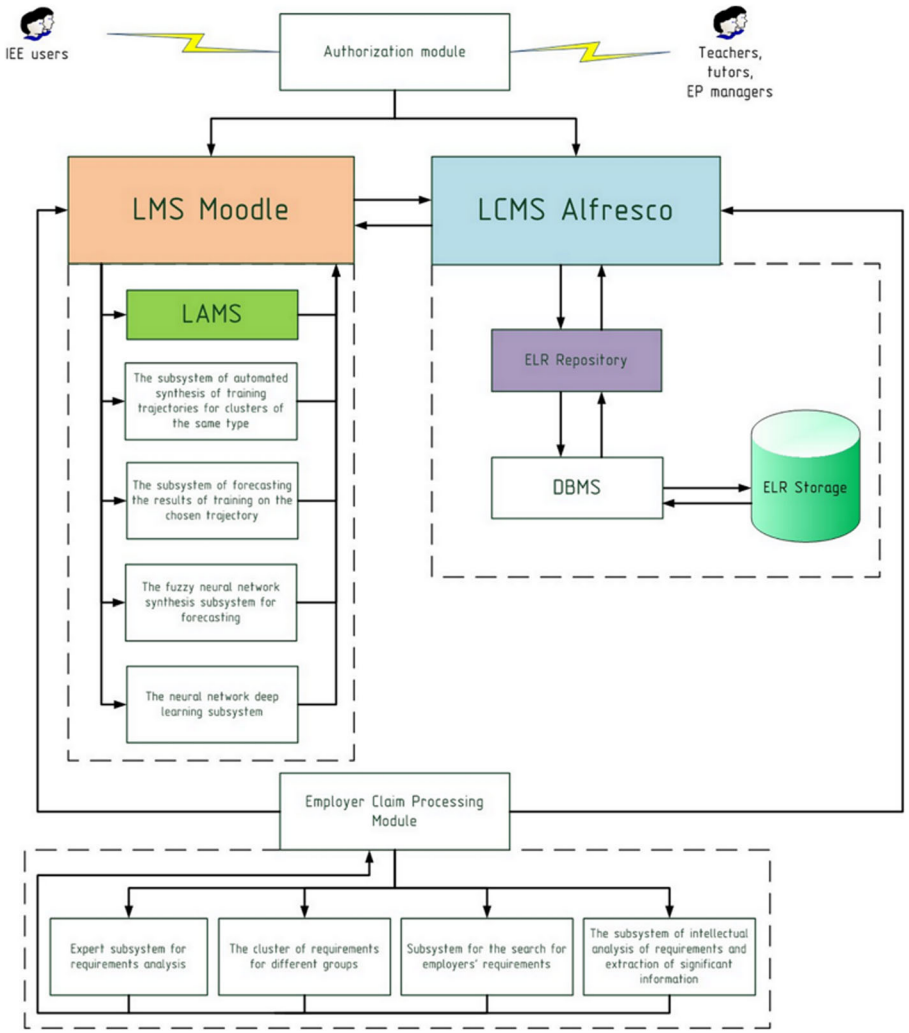

Fig. 9 The IME architecture

For the collection and intellectual analysis of requirements, open sources on the Internet are used, such as websites of employment agencies with a list of vacancies and specialist requirements, social networks, forums, etc. At the same time, polling technologies, questionnaires and search tools are used to adapt the individual learning trajectories and synthesize a personalized educational environment for the training of specialists. For questioning representatives of the real sector of the economy, an Internet site has also been created in the region for which the training specialist's process of the required profile is being implemented. For scanning and selection of job advertisements on the Internet, a search robot has been developed. It collects information about requirements for the specialist's competencies and forms the final report in XML format.

The main system's users are administrators, educational content authors (teachers, tutors), web designers, trainees, guests, employers. Access to the environment is provided through the Internet and local networks with support for mobile access technology. Administrators have the rights to any actions with content. They perform the managing functions of layout designer's work, assigning tasks, forming training modules and exporting resources to the storage. For each module, metadata is created with links to the resource and source objects. This allows to automate the training modules updating in the event that the author makes changes. Imposers have access to the materials assigned to them for work. Authors have the right to manage their materials and view the finished resources of other authors. All users can communicate through messaging systems.

6 Conclusion

The article presents the ILE model for the convergent education concept. Synthesis of electronic educational resources is realized on the CMS Alfresco, which is integrated with the learning management system Moodle and the learning activity management system. Intellectual mechanisms for managing personalized learning in the educational environment have been developed. The learning model in the smart environment is the convergent education model, which determines the possibility of using universal educational content for training in a variety of areas and specialties. The managing learning process in the ILE is based on a lifecycles synchronization's model of educational programs, educational content and training specialist's levels. To manage the environment component lifecycles, a software-tool complex is developed that synchronizes the educational content with training programs, the employer's requirements and the training specialist's levels. The ILE architecture integrates several software products and allows:

1. Use tools and built-in services that enhance the capabilities of the system.
2. Automate the synthesis and modernization of educational resources in accordance with the educational standards and employer's requirements.

3. Automate the synthesis of personalized learning paths with the educational content's selection to gain competencies.
4. Synthesize and train the predictive model of training specialists in the trajectories of training
5. Implement the training trajectory with an the assessment quality of specialist's training, the forecast models correction, the replacement or supplementation of educational resources
6. Update the educational content in accordance with the standards and employer's requirements

The ILE architecture has made it possible to significantly reduce the costs of creating and maintaining its components lifecycles, to accelerate and simplify the educational content synthesis, and to realize its actualization mechanism. The environment is intended for use in colleges and universities, as well as in organizations for retraining and improving the training specialist's quality.

The ILE for convergent education has now been implemented and is being used at the Penza State University (Russia, Penza) to manage the educational process and train specialists in accordance with the requirements of federal educational standards and employers' requirements in the Volga region of the Russian Federation. The ILE has significantly reduced the time of synthesis and modernization of electronic educational content. In the further research, new intellectual mechanisms are being developed to synchronize and interact the educational environment components lifecycles on the basis of machine learning technologies.

Acknowledgements The reported study was funded by Russian Foundation for Basic Research (RFBR) according to the project № 19-013-00409, 18-07-00975, 18-010-00204

Funding The reported study was funded by RFBR according to the projects: № 19–013-00409, 18-010-00204, 18–07-00975.

References

Alfresco website. Retrieved from http://www.alfresco.com/ (accessed 30 June 2018).

Arshinov, V. I., & Budanov, V. G. (2016). The paradigm of complexity and sociohumanitarian projections of convergent technologies. *Voprosy filosofii [Problems of Philosophy]., 1*, 59–70 [in Russian].

Bainbridge, M. S., & Roco, M. C. (2005). *Managing Nano-bio-info-CognoInnovations: Converging Technologies in Society*. NY: Springer.

Bersin, J. (2004). *How did we get Here? The history of blended learning. The Blended Learning Book: Best Practices, Proven Methodologies, and Lessons Learned*. NY, John Wiley & Sons.

Bhatia, G., Anand, M., & Shrivastava, P. (2012). Cloud computing technology in education system. *International Journal of Advanced Technology & Engineering Research, 2*, 2250–3536.

Canton, J. (2004). Designing the future: NBIC technologies and human performance enhancement. *Annals of the New York Academy of Sciences, 1013*, 186–198.

Chan, T., Hue, C., Chou, C., & Tzeng, O. (2001). Four spaces of network learning models. *Computers & Education., 37*, 141–161.

Chul, L., & Gunno, P. (2016). The impact of convergence between science and technology on innovation. *The Journal of Technology Transfer, 2*, 1–23.

Cloete, E. (2001). Electronic education system model. *Computers & Education, 36*, 171–182.

Cooch, M. (2010). *Moodle 2.0 First Look*. Packt publishing.
Cope, C., & Staehr, L. (2005). Improving students' learning approaches through intervention in an information systems learning environment. *Studies in Higher Education, 30*(2), 181–197.
Cordova A. (2016). *10 Big Ideas for Future NSF Investments National Science Foundation*. Retrieved from www.nsf.gov/about/congress/reports/nsf_big_ideas.pdf
Culén, Alma Leora & Gasparini, Andrea. (2019). STEAM Education: Why Learn Design Thinking?: Science, Technology, Engineering, Arts and Mathematics. *In book: Promoting Language and STEAM as Human Rights in Education*, pp.91–108. https://doi.org/10.1007/978-981-13-2880-0_6.
Deev, M.V., Glotova, T.V., & Krevskiy, I.G. (2014). Models of supporting continuing education of specialists for high-tech sector. In *Proceedings of the 11th Joint Conference Knowledge-Based Software Engineering*. (vol. 466, pp. 100–112). Volgograd (Russia): Springer.
Deev, M.V., Glotova, T.V., & Krevskiy, I.G. (2015). Individualized Learning Trajectories Using Distance Education Technologies. *Creativity in Intelligent, Technologies and Data Science. Series "Communications in Computer and Information Science"*. 535, 778–792.
Duncan-Howell, J., & Lee, K. (2007). M-learning: Finding a place for mobile technologies within tertiary educational settings, in ICT *Proceedings ascilite: Providing choices for learners and learning*. Singapore. Retrieved from http://www.ascilite.org.au/conferences/singapore07/procs/duncan-howell.pdf.
Finogeev, A. G., Fionova, L. R., Finogeev, A. A., & Vinh, T. Q. (2015). Learning Management System for the Development of Professional Competencies. *Creativity in Intelligent Technologies and Data Science. Series «Communications in Computer and Information Science», 535*, 793–803.
Finogeev, A. G., Parygin, D. S., & Finogeev, A. A. (2017). The convergence computing model for big sensor data mining and knowledge discovery. *Human-centric Computing and Information Sciences., 7*, 11.
Hamidi, F. (2011). Information Technology in Education. *Procedia Computer Science, 3*, 369–375.
Harmelen, M. (2008). Design trajectories: Four experiments in PLE implementation. *Interactive Learning Environments, 16*(1), 35–46.
Herr D.J.C. (2016) The need for convergence and emergence in 21st century Nano-STEAM+ educational ecosystems. In K. Winkelmann and G. Bhushan, (Eds.), *Global Perspectives of Nanoscience and Engineering Education*, pp. 81-115, springer international publishing (springer nature) ISBN 978-3-319-31833-2.
Hirner, L., & Kochtanek, T. (2012). Quality indicators of online programs. *Community College Journal of Research and Practice, 36*(2), 122–130.
Horton, W. (2000). *Designing web-based training: How to teach anyone anything anywhere anytime*. NY: John Wiley & Sons.
Hwang, Gwo-Jen. (2006). Criteria and strategies of ubiquitous learning, in *Proceedings of the Sensor Networks, Ubiquitous, and Trustworthy Computing*, (pp. 72–77). IEEE International Conference.
Januszewski, A. (2001). *Educational technology: The development of a concept*. *Libraries Unlimited*. isbn:1-56308-749-9.
Kalogeras, S. (2015). Media-education convergence. *International Journal of Information and Communication Technology Education., 9*, 1–11. https://doi.org/10.4018/jicte.2013040101.
Kravets, A. G., Belov, A. G., & Sadovnikova, N. P. (2016). Models and methods of professional competence level research. *Recent Patents on Computer Science., 9*(2), 150–159.
LAMS Internationalization website. Retrieved from http://lamscommunity.org/ (accessed 24 June 2018).
Martens, A., Sandkuhl, K., Lantow, B., Lehmann, H., Lettau, W.-D., & Radisch, F. (2019). An evaluation approach for smart support of teaching and learning processes. *Smart Learning Environments, 6*, 2.
Moreno, R., & Mayer, R. (2007). Interactive multimodal learning environments. *Educational Psychology Review, 19*(3), 309–326.
Mouna, D., Tlili, A., Essalmi, F., & Jemni, M. (2018). Implicit modeling of learners' personalities in a game-based learning environment using their gaming behaviors. *Smart Learning Environments, 5*, 29. https://doi.org/10.1186/s40561-018-0078.
National Research Council (U.S.). Committee on Key Challenge Areas for Convergence and Health. (2014). *Convergence: Facilitating Transdiciplinary Integration of Life Sciences, Physical Sciences, Engineering and Beyond*, National Academies Press (NAP 18722), ISBN 978–0=309=30151–0.
Olofsson, A. D., Lindberg, J. O., & Hauge, T. E. (2011). Blogs and the design of reflective peer-to-peer technology-enhanced learning and formative assessment. *Campus-Wide Information Systems, 28*, 183–194.
Personal Learning Environment. (2008). Retrieved from http://en.wikipedia.org/wiki/Personal_Learning_Environmnent.

Roco M.C. (2015) Principles and methods that facilitate convergence. In: Bainbridge W., Roco M. (eds) Handbook of science and technology convergence. Springer, Cham.

Roco, M., & Bainbridge W. (2004). Converging Technologies for Improving Human Performance: Nanotechnology, biotechnology, Information Technology and Cognitive Science. Arlington. . Retrieved from http://www.wtec.org/ConvergingTechnologies/Report/NBIC_report.pdf.

Schatsky, D., Muraskin, C., & Gurumurthy, R. (2015). Cognitive technologies: The real opportunities for business. *Deloitte Review., 16*, 56–74.

Severance, C., & Whyte, A. (2008). The coming functionality mash-up in personal learning environments. *Interactive Learning Environments., 16*(1), 47–62.

Sharp PA, Cooney CL, Kastner MA, Lees J, Sasisekharan R, Yaffe MB, Bhatia SN, Jacks TE, Lauffenburger DA, Langer R, Hammond PT, Sur M (2011) *The third revolution: the convergence of the life sciences, physical sciences, and engineering*. Massachusetts Institute of Technology, Washington, DC, [online]. Available: http://dc.mit.edu/sites/dc.mit.edu/files/MIT%20White%20Paper%20on%20Convergence.pdf

G. Siemens (2005). *Connectivism: A learning theory for the digital age.* Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.87.3793.

SRC-NSF Report (2016). *Intelligent Cognitive Assistants Workshop Summary and Recommendations*, https://www.nsf.gov/crssprgm/nano/reports/2016-1003_ICA_Workshop_Final_Report_2016.pdf.

Tseng, J. C., Chu, H. C., Hwang, G. J., & Tsai, C. C. (2008). Development of an adaptive learning system with two sources of personalization information. *Computers and Education*, *51*(2), 776–786.

Van Gog, T., Sluijsmans, D., Joosten, B., & Prins, F. (2010). Formative assessment in an online learning environment to support flexible on-the-job learning in complex professional domains. *Educational Technology Research and Development, 58*(3), 311–324.

Affiliations

Alexey Finogeev[1] · Lejla Gamidullaeva[1] · Alexandr Bershadsky[1] · Ludmila Fionova[1] · Michael Deev[1] · Anton Finogeev[1]

Lejla Gamidullaeva
gamidullaeva@gmail.com

Alexandr Bershadsky
bam@pnzgu.ru

Ludmila Fionova
lrfionova@mail.ru

Michael Deev
miqz@yandex.ru

Anton Finogeev
fanton3@yandex.ru

[1] Penza State University, 40, Krasnay st, Penza, Russia 440026