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The Convergence Model of Education for Sustainability in the Transition to Digital Economy

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Abstract: The paper studies the problem of updating educational programs and content, taking into account changing requirements of standards and employers for qualifications and competencies of specialists. First, we show that the updating process in transition to digital economy is associated with the transition to the convergence model of education providing its sustainability perspective. Furthermore, we propose the technique and develop basic models and methods for updating based on the convergence approach, for assessing the degree of convergence of competency models and educational content. The problems of collecting, consolidating, and extracting information on the required competencies from vacancy advertisements in open sources on the Internet are also considered. The convergence approach to updating educational programs is being introduced and tested in the information and learning environment of Penza State University (Penza, Russia).

Keywords: convergence approach; ecosystem; sustainable education; sustainability; adaptation; updating; educational programs; educational content; lifecycle; smart learning environment

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1. Introduction

Scientific and technological progress and the evolutionary development of industry within the framework of the fourth industrial revolution (Industry 4.0) has caused widespread digitalization of socio-economic processes in the society and the use of artificial intelligence technologies. In modern conditions, there is an urgent need for the economy in highly qualified personnel with new competencies. "The economic growth based on knowledge relies on the human capital with competencies that help companies to surpass competition" [1]. In turn, the ever-increasing complexity of manufactured products, the interdisciplinary nature of new technologies, most of which are of a "cross-cutting nature" at the intersection of industries, require the involvement of a wide range of participants with various cross-sector competencies in the production process. At the same time, educational programs of universities often do not meet such requirements of the modern market, education should be as flexible and elastic as possible, and that is, constant monitoring of market demands, execution of new examinations, and immediate adaptation of educational programs and the teaching staff are required.

A survey developed in 2018–2019 in Russian universities by the Changellenge (career development online platform that conducts market research and propose recommendations that allow businesses, students, and young professionals to be in the market demand) [2] revealed an alarming situation: the most pressing reason for dissatisfaction with learning was outdated curricula. This factor was indicated by 31% of respondents. The respondents were asked to choose which of the listed factors do not suit them in their university education.

In our opinion, the cause for this phenomenon is the gap between the competencies provided by the universities through implementing the educational programs and the market demand [3]. Definitely, traditions are important for universities, but there are at least two factors, which make reforms inevitable. The main of them is the fact that the world is very changeable nowadays; all actors of the process: students, employers, even professors themselves, are under rapid change. The second reason is the fact that new possibilities can make teaching more effective, even within the traditional paradigm of competence-based learning [4–7]. The process of training specialists should develop trainees' skills that meet the requirements of the labor market and the digital development of society, regardless of the specific specialization. Thus, educational institutions are realizing the idea of achieving the Sustainable Development Goals (SDGs). It also requires the identification of urgent socio-ecological problems, planning and development of educational programs [7–11].

Thus, the educational system should be transformed towards increasing update rate, flexibility, personalization, focusing on learning throughout life, and development of "future competencies", which necessitates the search for new ways of organizing learning processes and new management models [12–17].

This determines the need for a transition to new smart and digital technologies in the field of education [18]. The process of obtaining education is becoming more open and remote, and goes beyond the classrooms and educational institutions [19,20]. The place of teachers is increasingly being replaced by an information educational environment with a developed ecosystem [21], which realizes the possibility of self-mastering the required competencies and meta-competencies (universal skills). Thus, the learning ecosystem should create conditions for the formation of students' necessary narrow professional, professional, and universal competencies.

Teaching in an open information and educational environment requires a change in traditional pedagogical techniques and methods [22]. The evolution of the education system in the world goes hand in hand with the emergence of new information and telecommunication technologies, mobile communication systems, the development of the Internet and the Internet of Things, intelligent and cloud technologies, virtual and augmented reality technologies, big data, digital platforms and ecosystems, etc. The main hypothesis of the article is that the evolutionary development of the generally accepted technology of competence-based learning within the framework of the 4th industrial revolution and the transition to the digital economy leads to the need to introduce a convergent approach for training specialists [23,24]. The convergent learning model complements the competence model and determines the use of the principles of convergence of competencies for specialists in different fields of knowledge when organizing and conducting the educational process in an open information and educational environment [25–27]. The convergent model requires the introduction of new mechanisms for updating educational programs and educational resources (content) to adapt them to the conditions of digitalization and intellectualization of all spheres of human life to the changing requirements of educational and professional standards and regional labor markets. The problem of modern education is the frequent discrepancy between the competencies of graduates and the actual requirements of employers, which is due to the great inertia in changing educational standards and training programs, the lack of mechanisms for the prompt updating of programs and their synchronization with educational content, which becomes a challenge for a sustainable development of society [28,29]. In the era of industrial revolution 4, with the ubiquity of digital, mobile, and smart technologies, educational content and curricula are rapidly becoming obsolete. Training specialists in outdated programs forces them to acquire competencies that are not required in the labor market, which leads to the risk that such specialists are not in demand. Educational institutions either do not have time to change training programs and their content or cannot make changes that do not meet federal educational standards. Other problems are related to the vagueness of employers' requirements for the competencies of graduates, the aging of the teaching staff of educational institutions, the lack of qualified pedagogical personnel who possess new digital technologies, the dynamics of changes in the requirements of the real sector of the economy, the time lag between the emergence of new requirements for competencies and changes in educational programs, and the duration of the training process. specialists.

The stability of the educational system can be defined as the ability to continuously maintain interaction between the participants in the educational process (ministries and departments, educational institutions, administrators, methodologists, teachers and students, libraries and employers). The main goal is to implement the professional activities of the participants in accordance with the principles of sustainability of business processes [30]. The concept of sustainability for educational activities determines the need to search for new models and methods for the release of in-demand specialists for a long time with minimal changes in educational programs and content [31]. To achieve sustainability in education, it is necessary to implement the process of adaptive updating of programs and content for specialists to acquire digital competencies and skills. The development of an actualization mechanism allows you to quickly track the changing needs of the innovative economy and employers in order to adapt training programs to obtain competencies related to the latest technologies. Within the framework of the existing conservative and insufficiently flexible bureaucratic system of conservative education, it is rather difficult to quickly adapt to new digital and innovative realities [32].

The model of convergent education is considered in the article as a natural development of the competence-based learning process [33–35]. To achieve the research goal, we provide for the solution of the following tasks:

(a) Research and development of a convergent education model, taking into account the aspects of the 4th industrial revolution and the widespread introduction of digital technologies in all spheres of human life,
(b) Synthesis and implementation of intelligent mechanisms for supporting the life cycles of the basic components of the educational process,
(c) Synthesis and implementation of technology for synchronizing the life cycles of educational programs, educational content, and qualification levels of specialists,
(d) Development of methods for updating educational programs, electronic educational resources and learning technologies, taking into account the regional characteristics of labor markets, employers' requirements, educational and professional standards,
(e) Development of personalized educational trajectories for training specialists in different fields of activity within the framework of a convergent learning model,
(f) Generation of convergent content for the training of specialists in various fields of knowledge based on the search and consolidation of isomorphic subsets of educational resources on the Internet,
(g) Development of an intelligent mechanism for managing educational processes within the framework of the convergent model of education as the main component of the information educational environment. Intelligent components ensure the implementation of converting processes through lifecycle management of electronic educational resources and educational programs with adaptation to the requirements of labor markets and the conditions of the digital economy and four industrial revolutions.

The results of the research carried out are promising in terms of the development of advanced technologies for the modernization of educational processes in accordance with the requirements of the innovative and digital economy. The practical significance of the results lies in bridging the gap between the competencies of graduates of educational institutions and the actual requirements of regional labor markets through the introduction of mechanisms to improve the quality and sustainability of educational business processes through the development of employment skills.

This work is organized as follows: In Section 2, related works on convergence model in an educational context are presented. The section concludes with a gap analysis and an explanation of how our work addresses the noted gaps. Then, our research design is described in Section 3, including problem statement and technique for solving the task of updating educational programs and content. In Section 4, models and methods for updating educational programs and content and their sub-frameworks are formulated as an overarching category foundation for the consolidation and analysis of the results. Drawing on these results, we propose a method for assessing convergence of educational content for a convergence model of education. Finally, the results are discussed in Section 5 to highlight the implications, opportunities for future research, recommendations for lecturers, and limitations of our work.

2. Convergence Model of the Educational Process to Provide Sustainability in the Digital Age

In the context of the transition to the digital economy, the processes of convergence of technologies and services in various spheres of human life, including education, are of particular importance. The convergence of technologies determines the process of their interpenetration and overcoming the boundaries between them, the emergence of interdisciplinary fields of knowledge [36–38]. Convergence occurs in the process of functioning and evolutionary development of complex systems under given conditions and is considered as a paradigm of a system-synergetic approach in relation to the manifestation of integrative and emergent properties in phenomena, processes, and systems

Convergence in education in our understanding means such an evolutionary development of a competence model when due to the widespread dissemination of digital and telecommunication technologies, in almost all sectors of economic activity, specialists with similar competencies are required. The convergence of the required competencies, in turn, necessitates the concurrence of educational programs, which, in turn, leads to the convergence of educational and methodological resources, methods, and pedagogical techniques in teaching.

The convergent model of competence education defines the process of synthesis of holistic academic disciplines, in which scientific knowledge and technological achievements are integrated based on the development of advanced technologies (nanotechnology, biotechnology, information, digital, telecommunication, and cognitive technologies). The model is implemented using an ecosystem of information and educational environment and an integrated teaching methodology STEAM (science, technology, engineering, art, mathematics) [39–41]. This methodology includes is on new principles of acquiring knowledge through a single platform and contributes to the acquisition of convergent competencies in different subject areas.

Representation of convergence education development trend is in the hierarchy of sequential approaches to studying disciplines [41].

1. The stage of an intradisciplinary approach to teaching involves the use of educational content within the studied discipline of a specific specialty. The transition to the study of a new discipline and work with another educational content occurs after going beyond the established disciplinary boundaries.
2. The stage of a multidisciplinary approach to teaching involves the use of educational content from different disciplines to master the studied one. In fact, the educational content of this discipline is the integration of knowledge from other disciplines.
3. The stage of a cross-disciplinary approach to teaching involves the use of educational resources of other disciplines in combination with the original content of the discipline being studied. At the same time, the coordination of interaction between resources of different disciplines is implemented to search for intersecting (concurring) parts of the content.
4. The stage of an interdisciplinary approach to teaching involves the integration of educational resources of different disciplines for the synthesis of new content with uniform methodological techniques for assimilating knowledge and obtaining competencies. In fact, here we can talk about the transition to convergence education.
5. The stage of a transdisciplinary approach to teaching or a fully convergence teaching model involves the use of an open learning environment that combines common educational resources for studying disciplines in different subject areas.

The convergence model of education provides the integration of competencies specified in professional and educational standards, taking into account the requirements of employers and the latest technological trends. It has resulted in the integration of educational programs, the creation of a unified educational content, the use of similar methods and technologies for training specialists. The concept of convergence requires the integration of educational resources and technologies in a single information educational ecosystem with intelligent mechanisms for the synthesis of personalized training trajectories and monitoring of acquired competencies with the possibility of adaptive adjustment of the training process to changes in the external environment [42,43].

The analyses conducted by the authors revealed the following main factors influencing the updating process:

- requirements of professional and educational standards, which are mandatory in the implementation of basic educational programs of general, secondary, professional, and higher education;
- consolidated (integrated) requirements of employers for the competencies of specialists, taken from open sources on the Internet (websites of recruitment agencies, job fairs, message boards, vacancy sections of the websites of enterprises and institutions, information on vacancies in messengers and social networks, etc.);
- information about innovative and disruptive technologies emerging during the fourth industrial revolution.

3. Problem Statement and Technique for Solving the Task of Educational Programs and Content Actualization

On the one hand, the problem of educational programs actualization and content is solved after the emergence or changes of new professional and educational standards. On the other hand, it is solved after information search and acquisition of changing requirements for specialists' competencies of regional labor market employers.

There are a lot of problems with actualization, for example:

1. An ambiguity or impossibility of formulating the required competencies by the employers.
2. Differentiation in the formulation of knowledge, skills, and abilities as components of the competencies.
3. Lack of qualified specialists in regional labor markets.
4. Lack of necessary competencies in educational programs of regional educational institutions.
5. High dynamics of changes in the requirements for the real sector of the economy to the knowledge of specialists.
6. Long time delay between the emergence of both new requirements for the competencies in the region and the introduction of necessary changes in educational programs and content, and graduation of trained specialists.
7. Need for bureaucratic coordination of the changes introduced with the relevant ministries and departments, and with the requirements of professional and educational standards.

The listed problems lead to a great inertia of educational institutions with regard to a prompt response to changes in the labor market in the era of the technological revolution, which is also relevant in the context of the pandemic and the growing demand for distance technologies and digital competencies. Educational programs and content actualization is implemented by analyzing the requirements for the competencies of specialists, operational information about which is posted in open sources on the Internet (on the websites of enterprises, recruitment agencies, labor exchanges, forums, chats, social networks, and instant messengers, etc.). To collect and process data from a huge number of information sources, big data and mining technologies are in demand [44–46]. The problems result in the impossibility for educational institutions to quickly track and respond to the ongoing changes in the regional labor markets, which is especially relevant in the context of a global pandemic, closure of innovative industries, growth of the rise in unemployment and reduced requirements growing demand for graduated specialists new digital skills and competences.

Information for updating educational programs and content can be found in open sources on the Internet, such as sections with vacancies on the websites of enterprises, recruiting agencies, labor exchanges, message boards, on forums, in chats and groups of social networks and messengers, in rich site summary (RSS) mailing lists, etc. Due to the huge number of possible information sources on the Internet, Big Data technologies and Data Mining intelligent analysis are in demand for monitoring and analyzing data [44,45]. Big Data technologies require preliminary preparation or consolidation [44–46].

In the process of consolidation, the tasks of data cleaning, removing duplicates, combining similar or analogous information, normalizing and systematizing data, and preparing for loading into the storage are solved. To systematize and classify information about the required competencies, we use the method for synthesizing vector models of keywords that describe competencies [47]. It is necessary to formalize competence description, its identification, classification by type, comparison of competence descriptions by the degree of similarity.

A vector model is a numerical representation of a group of semantically related keywords that characterize competence [48]. The problem is that information about similar vacancies and required competencies has different data formats and an unstructured form in open sources. Vector representation is a compact and unified data type for storage and processing. It considers context and allows structuring event data by representing in the form of a system of vectors and sets of keywords. A modified *Word2Vec* algorithm is applicable to represent information in the form of word vectors [49]. In the classical version of the algorithm, the softmax cross entropy loss (SCEL) function is used as an optimization criterion. However, this function is well suited only for solving binary problems with two results. In vacancy announcement, the number of words in phrases can be measured in tens. Therefore, to calculate the function, it is necessary to calculate the cross-entropy losses for all outputs. To reduce complexity, we will use the sampled softmax loss (SCL) function. At first, to obtain the result, the cross-entropy function is calculated between the true context value for the target word and the predicted word value corresponding to the true context value. Then the cross-entropy loss of k negative samples (target word + out-of-context word) is added, which are sampled according to the noise distribution. Next, we define the loss function L as follows:

$$L = SigCrEnt(Prediction,\ Correct\ Word) + \sum_{1}^{K} E_{noise} SigCrEnt(Prediction,\ Noise), \quad (1)$$

where *SigCrEnt* is an error that can be detected at a single output.

The most accurate solution to the problem is possible when the vocabulary of keywords for describing competencies becomes large enough.

The technique for transition to a vector description of vacancies includes the following stages:

1. Synthesis of data tuples in the format [input word, output word], where the word is represented as a binary vector of length n, and the i-th value is coded by one at the i-th position and zeros at the rest ones (one-hot code).
2. Synthesis of a learning model, where input and output get one-hot vectors.
3. Determination of SCL function, which predicts the right word to optimize the learning model.
4. Determination of qualitative characteristics of the model, after adapting of vector representations of similar words, that is, determining how accurately, adequately, and efficiently the model works.

To remove duplicates and integrate similar data on competencies, we use time and geospatial marks, and formalized vector models of keywords. Time marks of messages on vacancies and geotagging information about employers are also needed for analysis and predictive modeling of dynamics of changes in employers' requirements in specific regions and at specified time intervals. Coordinates of employers (enterprises) who advertised for vacancy and time frames of the advertisement are used as bindings. Spatial analysis shows the distribution of the required competencies in the regions and allows analyzing the compliance of the requirements with the level of qualifications and competencies of specialists who are currently being trained by regional educational institutions. An analysis of time frames makes it possible to assess the need and economic feasibility of adapting educational programs and content in the selected region to the requirements of employers. It is necessary to take into account the given horizon for forecasting needs in the regional labor market and the possibility of training specialists in neighboring regions. Changes made to educational programs and content and acquired competencies should be in demand after having trained specialists for several years.

The technique for updating educational programs and content includes a number of stages. After consolidation of information on vacancies and synthesis of vector models of competency descriptions, a graph model of competencies is synthesized. It is a weighted modified König graph (Figure 1). The graph contains three main sets (parts):

- a set of K (K^p, K^o) competency vectors defined by professional (subset $K^p{}_i$) and educational (subset $K^o{}_i$) standards,
- a set of R competency vectors taken from the employers' vacancy announcements,
- a set of F competency vectors defined in non-actualized educational programs.

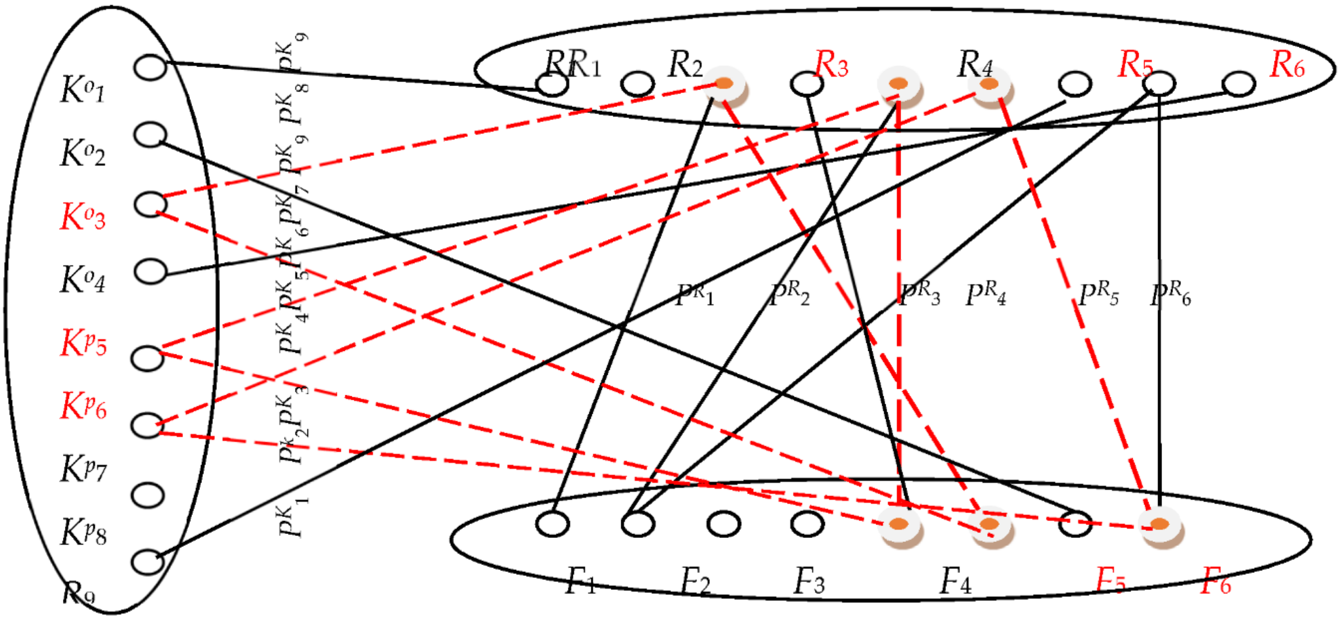

Figure 1. Graphical representation of competency vectors.

The edges show the compliance of competencies in different sets, and the weights P_i ($P^K{}_i$, $P^R{}_i$) display the degree of this compliance. The subsets of vertices in three sets are highlighted in red, and the connections between them show the presence of full or partial (depending on the weight of edges) compliance of competencies of employers, standards and specialists studying in educational institutions of the region. The pendant vertices without connections show a complete mismatch of competencies. This is a signal to update educational programs for educational institutions. The goal of graph model optimization is to solve actualization problems so that, at least, there would be no pendant vertices, and in the ideal case, all vertices would go into the red subset with fully connected subgraphs between the vertices of different parts of the graph.

Optimization of graph models of competency vectors is performed for all enterprises in the region that post their vacancies. The method of pairwise comparison (benchmarking) is used for a comparative analysis of similarity measure of graph models with a reference model, which determines the complete convergence of employers' competencies, educational and professional standards, and competencies of graduates in regional educational institutions. This model is an ideal model for convergence education in the region. The degree of similarity (convergence) for real models with the ideal one is determined. The models are ranked according to the similarity degree with the converged model. Thus, educational institutions with minimal discrepancy for the chosen specialty are selected in the region.

The threshold convergence criterion is set expertly, and educational institutions that are not ready for updating are excluded from consideration. If none of the educational institutions has been selected at this stage, then educational institutions from neighboring regions are added for analysis and the process is repeated.

The possibility and economic feasibility of updating educational programs and content in selected educational institutions is assessed, taking into account available resources, qualified teaching staff and the ability to obtain the required competencies in educational institutions of other regions according to targeted programs.

Leaders are selected according to the criteria of maximum speed and minimum costs for making changes to educational programs and updating educational content. After the selection of leaders, it is necessary to implement the stage of updating the educational content. The authors propose the following stages:

1. The choice of competencies that require changing educational programs and content.
2. An analysis of the program and content to determine obsolete and inappropriate parts for obtaining competence.
3. Replacement of selected parts of the program and modernization or synthesis of new educational content.
4. Validation and testing of a new program and content.
5. Implementation of the educational program and content in the educational process.

To implement the technique, the authors have developed tools for analyzing and working with competency models in Smart Learning Environment (SLE):

- Moodle Learning Management System (LMS), which provides support for the educational process,
- Learning Activity Management System (LAMS) used to support synthesis, modernization, and implementation of educational programs,
- Alfresco Learning Content Management System (LCMS) used to support the lifecycles of electronic learning resources,
- software and hardware complex for collecting, storing, and analyzing data on the requirements of employers and sets of competencies.

4. Models and Methods for Updating Educational Programs and Content

To update educational programs, we have developed models of lifecycles of educational programs (EP) and electronic learning resources (ELR); techniques for managing models and a method for synchronizing their lifecycles, taking into account changing requirements of standards and employers, which determine the stages of their evolutionary transformation in SLE.

Each training program for specialists determines the initial trajectory of the educational process, within the framework of which he will acquire knowledge and master the necessary competencies to achieve a given level of qualifications in accordance with professional and educational standards. The disciplines themselves that he studies according to the educational program are presented in the form of work programs and are associated with educational content [50].

The initial trajectory will change in accordance with changes in the requirements of educational standards and employers in the process of a sufficiently long-term training of a specialist, which is determined by the life EP model, which is an iterative model [51]. Let's change the typical iterative model by adding stages of updating and assessing the degree of convergence of the finished program with programs for training specialists from other areas of knowledge (Figure 2).

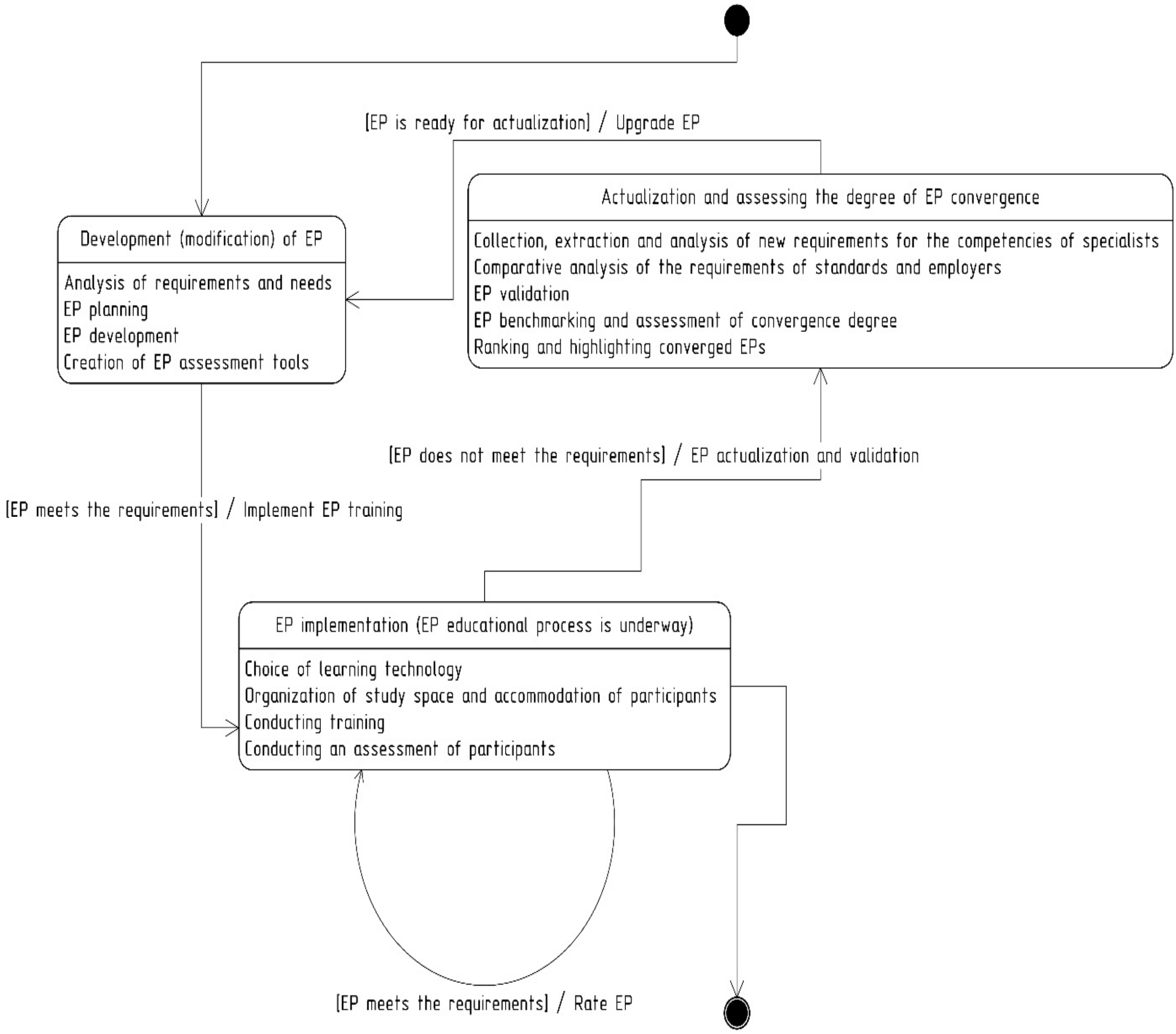

Figure 2. Model of the EP lifecycle with an actualization stage.

Thus, the educational program can have three states in accordance with the new model:

- ➢ Creation or modernization of the program (there is no difference between the creation of a program and the modernization of the existing one),
- ➢ Implementation of educational programs (the process of training specialists in accordance with the program),
- ➢ Updating and assessing the degree of programs' convergence (the process of making changes to programs in accordance with the requirements of the innovative and digital economy, employers, new professional and educational standards, and assessing the degree of convergence of updated programs for different industries and areas of knowledge).

Here, the object of management is the process of updating the program; the subject is the management system of educational programs, for example, Moodle LMS. A characteristic feature of the model is the presence of two feedbacks: the first one is designed to regulate the updating process itself, and the other one is designed to consolidate the identified convergence educational programs and adjust the convergence educational process.

Feedback in the model is implemented through assessments of the conformity of competencies that specialists receive when training in educational programs synthesized on the basis of requirements from employers and updated educational standards. To support the qualimetry of competencies, assessment tools necessary to assess the effectiveness of updated educational programs are used. Evaluations influence decision making on the compliance of the program with new requirements and its use, modernization or termination.

Information on the assessment of the convergence of educational programs, obtained in the course of their benchmarking analysis is used as the second feedback. Based on the assessments, decisions on the need for updating are made, recommendations for changing programs are generated taking into account new requirements, the possibility for transition to a convergence model of the educational process is assessed, and decisions for the introduction of convergence education technologies for training specialists in different sectors of the economy are made.

It is proposed to use the degree of isomorphism between graph models as an estimate of the convergence of educational programs. The input data for the methodology of identifying isomorphic subgraphs and assessing the degree of isomorphism are graph models synthesized using competency matrices from educational programs. Allocation of isomorphic subgraphs of competencies allows us to identify groups of similar educational programs for different specialties and highlight them for implementation in a convergence learning environment.

Updating educational programs requires modernization of learning resources and technologies (content). Electronic learning resources form the basis of the educational content in smart learning environment. The requirements of standards and employers will be taken into account when developing new and modernizing old electronic learning resources. Thus, the lifecycle of educational programs is associated with the lifecycle of learning content. In the process of updating, the tasks of synchronizing models of the lifecycles of educational programs and content are being solved to implement methods of mastering new competencies in accordance with the requirements of employers.

Electronic learning resources include both theoretical material, and various virtual laboratories and digital simulators of real objects and processes for practical development of competencies. Each resource can represent a website or a sharable content object reference model (SCORM) package that contains learning content. Content includes web pages, pictures, text files, audio or/and video recordings, programs in Flash, JavaScript, PHP, and other elements, which are also modeled by graph vertices with appropriate connections, and are involved in solving the problem of analyzing convergence with other resources.

The lifecycle model of the educational content includes an updating stage, where the degree of convergence of the updated content is assessed with the one corresponding to other educational programs (Figure 3).

The model for actualization educational content using Alfresco LCMS is presented in Figure 4.

The object of management in the model is the lifecycle of the learning resource, and the subject is the educational content management system that was used to create it. A characteristic feature of the model is the presence of two feedbacks: the first one is designed to assess the effectiveness of obtaining the required competencies and regulating the updating process; the other one is designed to assess the degree of convergence of the identified learning resources, their integration and application in the convergence model of the educational process.

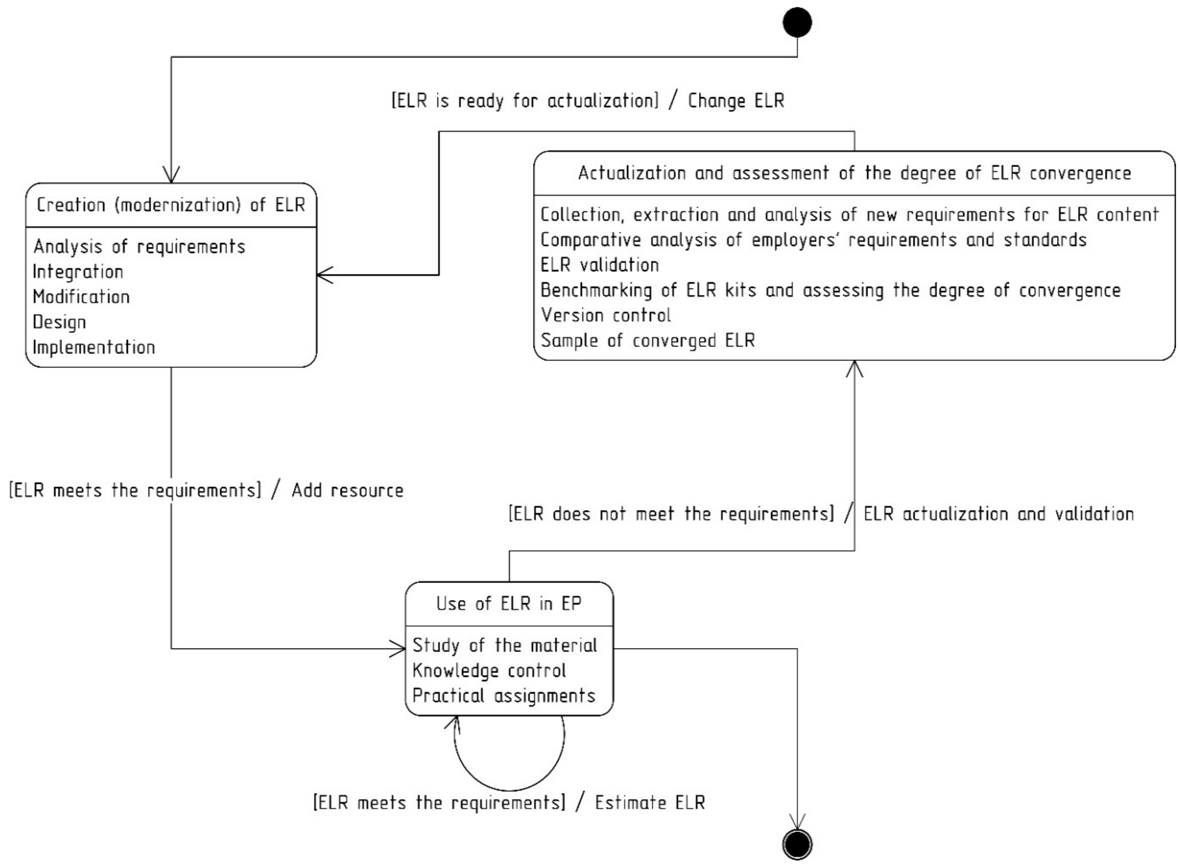

Figure 3. Lifecycle model of the educational content with an actualization stage.

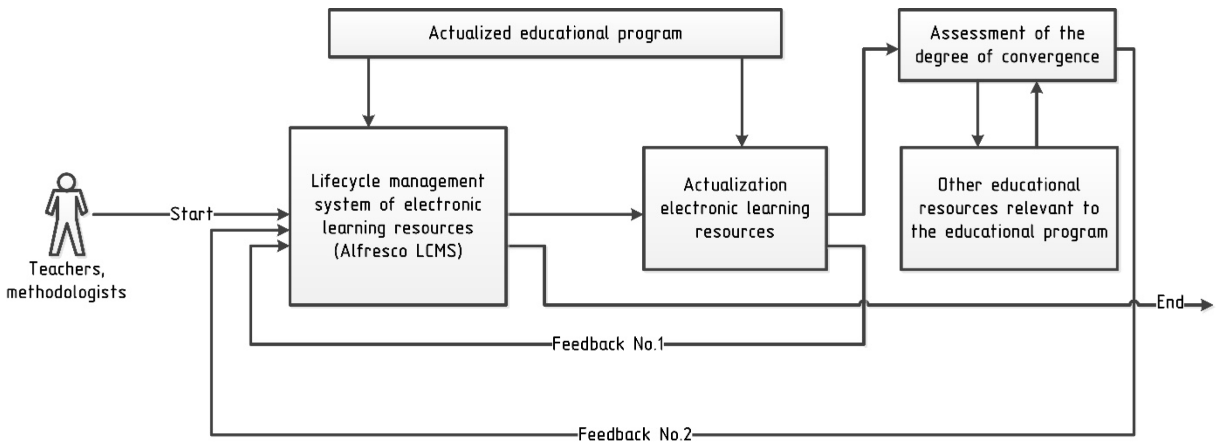

Figure 4. Model for managing the process of actualization educational content.

5. Method for Assessing Convergence of Educational Content for a Convergence Model of Education

Educational content is a structure that can be represented by a graph model of related studied sections, topics, and concepts with connections between them. There are many similar educational resources in information educational space, as lecturers from different educational institutions work according to the same educational standards and create similar content. One of the tasks in transition to a convergence model of the educational process is the search, analysis, and integration of many similar resources in a convergence model of educational content. It is a content graph model that has isomorphic subgraphs of related topics and resource sections.

We define isomorphism of the educational content as correspondence and identity of its parts studied in various disciplines for different specialties. The process of selecting isomorphic subgraphs from graphs of learning resources G consists in defining a subgraph that is isomorphic to some reference graph H. The task is a generalization of a graph maximal clique problem and is NP-complete. To solve the problem, an algorithmic typing method is used. It consists in splitting the general content graph model into parts with minimization of identity (isomorphic) subgraphs, which further will serve as components in the process of synthesizing a new resource. Thus, it is necessary to find a partition of the graph G into the set of groups $Q = \{Q_1, Q_2, ..., Q_f\}$ of isomorphic subgraphs satisfying the following conditions:

- any two subgraphs G_{ij} and G_{im} belonging to an arbitrary partition group Q_i should be isomorphic;
- the sets of vertices of any two partition subgraphs should not intersect each other;
- the number of vertices of any subgraph should not exceed the given one (limitation on the number of topics studied);
- the total number of exterior edges of each subgraph should not exceed the specified one (limitation on the number of related topics).

The number of obtained subgraphs is an estimate of similarity degree of learning resources. The convergence criterion is the maximum number of isomorphic subgraphs for resource graph models. All resources are ranked according to this criterion and the maximum convergence resources are selected as universal content for training specialists in different areas. The algorithm for determining the isomorphism of graph models includes the following steps (Figure 5):

1. Equally invariant vertices of the graph $G = (X,U)$ are combined into groups Q_{ki}, where κ is the step of isomorphic subgraphs selection, the initial step being $k_i = 0$.
2. Groups Q_{ki} with cardinality $t = 1$ are determined and excluded from consideration.
3. The number of possible integrations of groups Q_{ki}:$L = l \cdot (l - 1)/2$ is determined, where l is the number of groups J_{ki}.
4. Groups Q_{ki} and Q_{kj} are integrated, and groups of isomorphic subgraphs $Q_{k+1,i}$ with cardinality $t = k + 2$ are determined. To select isomorphic subgraphs, the maximum number of identical and non-zero elements of submatrix $R[Q_{ki}/Q_{kj}]$ of the connectivity matrix of R graph placed in its different rows and columns is determined. The submatrix is placed at the intersection of the rows corresponding to the vertices x_i belonging to Q_i, and the columns corresponding to the vertices x_j belonging to Qj.
5. Next, transition $K = K_i + 1$ to the next step of isolating isomorphic subgraphs is carried out.
6. The initial array M_{ki} containing the vertices that are not included in the group is determined for each group.
7. Partition of M_{ki} into new groups of equally invariant vertices of Q_{ki} is performed, similarly to item 1.
8. Item 2 is fulfilled, and the estimated groups G_{kMi} with cardinality $t = 1$ are excluded from consideration.
9. The condition that the selected set M^*_{iK} is not equal to 0 is checked. If the condition is not met, then further growth of isomorphic subgraphs is impossible, since there are no equally invariant vertices, and the algorithm ends.
10. Otherwise, the number of possible unions of groups Q_{ki} with groups of arrays M_i^* is determined. Each Q_{ki} group is integrated with Q_{kMi} groups of the initial array M^*_{iK}.
11. Integration of Q_{ki} and Q_{kMi} groups is performed, and groups of isomorphic subgraphs Q_{kMi+1} with cardinality $t = k + 2$ are determined.
12. The transition to item 6 is performed, and steps are repeated until the set M^*_{iK} becomes zero.

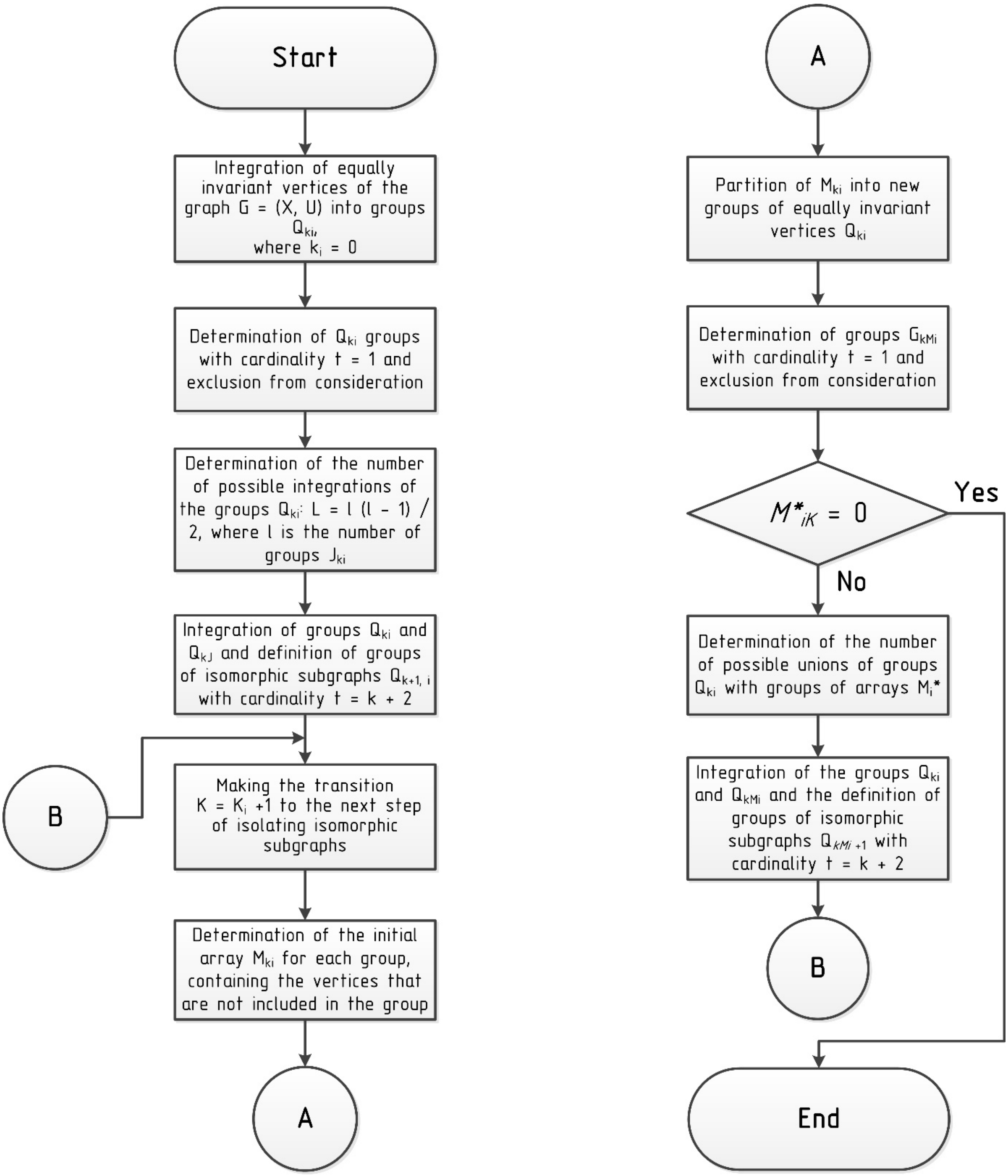

Figure 5. Algorithm flowchart to determine isomorphism of graph models for assessing convergence of the educational content.

The process of updating educational content with the integration of isomorphic parts into a single structure is the basis for building a convergence model of the educational space. The process ensures cost minimization for creating and updating resources, increases content quality and efficiency to implement a convergence approach to education. After updating educational programs and synthesizing convergent learning resources at the verification stage, the task of their synchronization and coordination is solved to correct the personalized trajectory of specialist training, taking into account the new requirements for his competencies. The system of automated synthesis of universal educational content of a variety of similar educational resources, identified by selecting isomorphic parts, is implemented in Alfresco LCMS.

6. Discussion and Conclusions

The article presents the results of research and development of the hypothesis about convergent processes in education caused by technological transformations in the economy and society in terms of digitalization and intellectualization of production processes and the social sphere of human life. The National Science Foundation (NSF) defines convergence as the deep integration of knowledge, methods, and experiences from different disciplines in order to form a new and expanded framework for solving scientific and social problems [41].

The emergence of similar requirements for the competencies of specialists in different fields of knowledge and spheres of activity in the labor market, associated primarily with digital, information, and telecommunication technologies, determines the evolutionary development of the competence model of education towards integration with the model of convergent education [37,38]. The works [52,53] confirm the fact that the modernization of the educational process is moving towards the introduction of a convergent learning model along with the competence model. In our case, for the integration of the competence model and the convergent approach, a mechanism is proposed for educational programs and educational content actualization based on the collection and intellectual analysis of employers' requirements and the automated determination of subsets of similar competencies for different fields of activity. As another feature of the convergent model, we note the tendency towards convergence of personalized training trajectories of different specialists.

The research results are intended to achieve the goals of sustainable development of the competence-based model of education using the intellectual information and educational ecosystem as a toolkit of the convergent approach [54]. The concept of a converged model requires the integration of educational technologies into a single ecosystem with intelligent mechanisms for monitoring and educational programs and content actualization, adaptive adjustment of the process of training specialists to changing external factors. The innovative educational environment presented in [54] includes a training system with intelligent and interactive content for personalization and adaptive adjustment of the educational process. Technologies of intellectualization of the educational process and design of an intellectual educational environment are discussed in [55,56].

Our experience in developments in the field of intelligent analysis of big data makes it possible to implement research results to create mechanisms for managing educational processes within the framework of [57,58]. Management of the process of training specialists in a created information and educational environment is implemented through the automated actualization of educational programs and content and the synchronization of models of their life cycles with adaptation to the changing requirements of educational standards and employers. As a result, a convergent model of competence learning is formed, which includes many isomorphic personalized trajectories for training specialists with the ability to synchronize their life cycles.

The research has scientific novelty, which consists in the development of a methodology for studying complex processes of multifunctional convergence in the education system during the formation of isomorphic clusters of similar competencies of specialists from different industries. The advantage of the proposed approach lies in the development of the concept of convergence as applied to the generally accepted competence-based learning model and the creation of a method for adaptive management of the educational process with the general digitalization of the economy and social sphere of human life during the fourth industrial revolution [59].

An integrated convergent and competence-based learning model is being tested in the process of developing an open educational ecosystem at Penza State University (Penza, Russia).

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