Knowledge management system of an industry-specific research and education complex

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Abstract. Topicality of the research is determined by the fact that it addresses the issue of a gap between actual production and professional education. Digitalization creates ample opportunities for the development of the leading material production industries (transport industry is among them) due to the totality of technologies, including knowledge engineering. This fuels digital transformations of professional education. The form of syllabus presentation is changing due to the use of ontologies as a contemporary standard of knowledge representation, and this ensures semantic openness of educational resources. Information technologies in education are changing: the management of educational paths is assigned to artificial intelligent training agents (AI-based tutors). The existing model of education is changing: it is becoming personalized. Finally, the nature of interaction between the industry and industry-specific universities and colleges is changing as well. The paper provides a business model of interaction between production, science, and professional education through an integrated life cycle of knowledge. The knowledge management system of the industry-specific research and education complex is regarded as a mechanism for implementation of this model. Its structure and tools developed by the team of the Transport Information Technologies research laboratory in the Siberian Transport University (Novosibirsk) are described.

1. Introduction

Digitalization of knowledge directly affects industry-specific universities and colleges, which are naturally involved in the life cycle of forming the knowledge of corporations in the industry. This makes it possible to define an industry-specific university or college as the main building block of the industry-specific research and education complex (REC) and to define the complex itself as a special form of integration of production, science, and education that interact during the exchange of knowledge flows, their interconnection and synchronization in an integrated life cycle of knowledge. This necessitates the creation of a system for managing such cycle. A knowledge management center is regarded as a management body of the industry-specific REC; its principal function is to use the potential of its participants and interested partners (administration, business community, etc.) for the purpose of mutually beneficial exchange of knowledge for comprehensive solution of educational, research, social, and production tasks. At the stage of the world community’s transition to the knowledge economy and formation of a paradigm of digital economy, knowledge management becomes a crucial activity for corporations that apply modern methods of artificial intelligence to retrieve knowledge from “big data”, and that use knowledge engineering methods to formalize expert
knowledge and to present it in the forms that are convenient for distribution, accumulation, and use, including in the course of professional training of the employees who are to implement such large-scale projects as “Digital Railway”.

Analysis of “knowledge management” definitions, the results of which are set forth in [Volegzhanina et al., 2017], makes it possible to talk of three levels of semantic meaning of this concept. At the first level—innovations and strategy—this is an innovative strategy of development which, if implemented, transforms all types of the industry’s intellectual assets (library collection, databases, patents, licenses, standards and other regulatory documents, descriptions of technologies, project documentation, software, R&D results, programs of proficiency enhancement and professional development of personnel, experts’ knowledge, etc.) into better performance and efficiency, creates new value, and ensures increased competitiveness on national and international sector markets.

At the second level—functionality and activities—this is a systematic activity of a labor subject (worker, engineer, manager), the content of which is determined by successive stages of the knowledge life cycle that affects the nature of the life cycle of his/her professional competence. At the third level—instruments and technologies—this is a technology that ensures interaction between natural and artificial intellectual agents in a hybrid corporate environment and implies formalization of industrial regulations into an ontological form (knowledge base) and mechanism of management through knowledge-based inference (logical inference). Here, knowledge becomes the basic element of Industry 4.0 that seeps into all areas of human activities, including production and education.

One of the most important reasons for turning to the concept of knowledge management is to ensure preservation and development of the industry’s intellectual potential. In this context, renewal of the life cycle of professional competence of the industry’s personnel becomes particularly relevant. When life cycles of a person, his/her professional competence, and industry-specific knowledge are considered with reference to each other, this offers great opportunities for systematic management of the life cycle of professional competence of the industry’s workers. For example, it is possible to initiate new stages of the life cycle of this competence in a system of continuous professional training (extended learning, proficiency enhancement, professional development) in order to prevent a worker from leaving the industry. To that effect, it is suggested to identify the following set of components within the industry-specific knowledge: fundamental, general professional, highly-specialized, and corporate knowledge. The identified components of the industry-specific knowledge vary in the length of their life cycles, and this allows arranging individual educational paths for each worker of the industry, with account for his/her professional and personal needs.

The foregoing unveils opportunities for knowledge management aimed at overcoming the gap between the real production sector, achievements of the applied science, and professional education, as well as outlines the benchmarks for the development of a mechanism of their integration within the industry-specific REC.

2. Current status of the problem
The modern science regards “knowledge management” as an interdisciplinary category. Its formation stages are described in the study [Sağsan et al., 2016]. The first stage (1948–1994) is characterized by the use of this term in such domains as artificial intelligence and cybernetics. The second stage (1995–2001) is associated with addressing the problems of knowledge management at organizations and emergence of such concepts as “intellectual capital”, “on-the-job training”, “knowledge management process”, etc. The third stage (2001–2004) deals with criticism and rethinking of the content of this concept. The fourth stage (from 2005 to the present day) marks the introduction of knowledge management into the education sector. New studies appear where knowledge management is presented as a comprehensive set of measures aimed at preservation of a corporation employee’s life cycle [Antonova et al., 2006]. In the article of [Dante et al., 2015], knowledge management is associated with a number of milestone events that served as a catalyst for more active studying of professional competence of a “labor subject”, namely: emergence of key technologies of the digital economy (in
particular, artificial intelligence methods); formation of the “knowledge management” concept based on the idea that knowledge as a component of a person’s competences can be used by organizations to acquire competitive advantages; creation of knowledge management technologies (Semantic Web) making it possible to develop global knowledge resources on the basis of ontologies (today, ontologies are recognized as an international standard for presentation of knowledge in certain production industries and for e-learning [ISO/IEC 20016-1:2014]); building the models of competences with a focus on a corporation employee, his/her individual path of learning and development; emergence of e-learning 2.0 paradigm that facilitates the knowledge acquisition process.

Integration of participants of the industry-specific REC on the basis of knowledge management requires a mechanism that is adequate in the context of digital transformations of production and education. The knowledge management system (KMS) can be considered as such mechanism. KMS are currently used in virtually all significant sectors of the global economy. In Russia, they are implemented at such industry-leading corporations as Gazprom, Tatneft, Rosatom, RZD. Interest to KMS development is also observed in pedagogy. Analysis of scientific literature, the results of which are provided in [Khabarov, Volegzhagina, 2018], has shown that over the last ten years, the number of studies dealing with the development of KMS in the education sector has considerably increased [Gasmi, Bouras, 2018; Hornos et al, 2012; Khater et al., 2015, etc.]. For example, building a university’s educational information environment on the basis of the knowledge management technology is considered in [Kudinov, 2010]. The article [Lishilin et al., 2015] describes a conceptual model of KMS for formation of professional competences in information technologies. The KMS creation process requires its concept, model, and tools of implementation. Note that the studied literature does not address KMS integrating the industry and industry-specific universities and colleges through the knowledge life cycle, and this substantiates the novelty of the business model proposed by the authors.

3. Research Methods
During the research, the following methods were collectively used: interdisciplinary analysis of technical, economic, and pedagogical literature; studying the best world practices in KMS development; modeling; knowledge engineering methods.

4. Principal Results
The business model of interaction between production, science, and education in the industry-specific REC through the integrated life cycle of knowledge is shown in Figure 1 where ISKLC is industry-specific knowledge life cycle and R&D is research and development.
Exchange of knowledge flows takes place in the intellectual field of the industry, which includes manufacturing enterprises and industry-specific universities and colleges. The latter act as research centers of applied science with integrated research laboratories, whose activities are aimed at solving the industry’s critical production tasks. In the domain of the industry’s manufacturing enterprises, their own “internal”—corporate—life cycle of knowledge is formed. Similarly, in the domain of industry-specific universities and colleges, there is their own “internal”—academic—life cycle of knowledge. As a result of the knowledge exchange, there appears an integrated knowledge life cycle that is common for the industry and industry-specific universities and colleges. This justifies introduction of the concept of “industry-specific knowledge”, which is understood as the entirety of the knowledge circulating in a certain industry and reflecting the specifics of activities of the enterprises and organizations of this industry. This knowledge is constantly forming during interaction between production, science, and education at the stages of the integrated life cycle. Knowledge used in the educational process of industry-specific universities and colleges belongs to industry-specific knowledge. It has all the characteristics of industry-specific knowledge but is adapted for better understanding by students [Mitsuk et al., 2016].

It is obvious that the integrated ISKLC is an attribute of the “industry—industry-specific universities and colleges” system; however, it has not been explicitly identified before. To overcome the gap between the real production and professional education, the academic and corporate life cycles should undergo regular synchronization. Certainly, such synchronization has always been carried out, and the knowledge life cycle in the industry used to be long enough to cope with the knowledge mismatch. However, in the context of production digitalization, this mismatch is increasing so much that syllabus becomes obsolete long before graduates begin their independent labor activities. Identification of the integrated ISKLC makes the process of interlinking and synchronization of local knowledge life cycles of the industry and industry-specific universities and colleges controllable, given the standardization of knowledge. It also determines characteristics of the proposed business
model implementation mechanism, in which capacity KMS of the industry-specific research and education complex is considered.

The KMS structure (Figure 2) is represented by the following interrelated and interacting components: statutory and regulatory, value-oriented and communicational, functional and resource-related, technical and methodological. We will review them one by one.

![Figure 2. Structure of the KMS of industry-specific REC.](image-url)
The statutory and regulatory component includes normative documents of the federal, sectoral and local levels regulating the process of KMS development and use (laws, guidelines, directives), web technologies standards developed by World Wide Web Consortium (W3C) (in particular, Semantic Web), ISO/IEC standards of knowledge presentation for certain industries of production and e-learning. The value-oriented and communicational component is represented by a network structure of KMS users, which includes geographically distributed industry-specific educational establishments (universities and colleges, secondary specialized educational institutions), corporate universities, manufacturing enterprises of the industry, R&D organizations, partner organizations (administration agencies, business and professional communities, foreign field-specific universities and colleges, etc.). KMS users can be organized into two enlarged groups: authors of the content (experts from production, scientists, teachers) and students. A formalized social network of industry-specific nature, within which the exchange of values, i.e. the knowledge, takes place, is considered as the main form of interaction between the users.

An open educational resource whose content is developed with the use of ontology editors supporting Semantic Web standards and stored as “knowledge packages” in OWL (Ontology Web Language) in a virtual environment is the core of the functional and resource-related component. A special system of distance learning provides management of the ontological content. Finally, the technical and methodological component includes systematic—technical and methodological—support of KMS users. Methodological support is an organized maintenance of the process of KMS implementation into educational practice by means of the combination of models, techniques, and instructions that are intended for subjects of the learning process and that ensure concurrence and technological efficiency of actions of a team of the open educational resource content developers.

Implementation of the proposed model of KMS requires creation of special tools. Such tools have been developed for training transport industry engineers and technicians; however, upon certain adaptation, they can be used for training personnel in other production industries. In particular, the following software and methodological solutions have been developed: software with an embedded multi-user ontology editor that supports Semantic Web standards and allows for simultaneous work of several authors on the development of ontologies of training courses in a great number of natural languages (at the commission of the Training and Methodology Center for Railway Transport, Public Contract No. 30/16 of June 30, 2016) [Khabarov V. I., Volegzhanina I. S., 2018]; Onto.plus, a multilingual e-learning environment prototype developed by means of this software, which allows students to simultaneously use different forms of content presentation (text, hypertext, ontology, graph, multimedia) in various national languages [Volegzhanina et al., 2018; Khabarov, Volegzhanina, 2018]; a version of controllable Russian language allowing for ontological content development by Russian-speaking authors who do not have programming skills, as well as a methodology for creating ontologies in the proposed variant of controllable Russian language; a model of actions sequence of ontological content developers; a methodology for developing the students’ cognitive skills on the basis of ontologies.

5. Conclusions

Transition of the world community to “Industry 4.0” technological paradigm, in the furtherance of which the “RF Digital Economy” program is being implemented, makes it possible to talk of digital transformations of all areas of human activities, including industry-specific production facilities and universities and colleges that carry out training of personnel for these facilities. Digitalization offers opportunities for the birth of new, previously impossible business models, due to the “end-to-end” technologies, with artificial intelligence being the most important among them. Digital transformation of production dictates digital transformation of professional education, which manifests in the following: the form of knowledge presentation is changing; it becomes possible to standardize it (ontologies are recognized as such standard), which ensures “semantic” openness of educational resources; technologies in education are changing: the management of a person’s educational path is assigned to artificial intelligent training agents (AI-based tutors). As a result, the model of education is
changing: it is becoming personalized. The teacher’s role is expanding: he/she becomes a source of expert knowledge, a knowledge technologist, a lecturer, a mentor, and a scientist—all in one. The role of students is also changing. Much of the study time will soon be devoted to the implementation of the end-to-end interdisciplinary projects and self-learning activities. Finally, the nature of interaction between the industry and industry-specific universities and colleges is changing as well.

The definition of an “industry-specific knowledge” has been proposed; identification of integrated life cycle of industry-specific knowledge in the “industry—industry-specific universities and colleges” system has been substantiated, which made it possible to propose a business model of interaction between production, science, and education in industry-specific REC, as well as a mechanism of such interaction: KMS. Structure of the KMS of industry-specific REC is represented by a set of the following structural components: statutory and regulatory, value-oriented and communicational, functional and resource-related, technical and methodological. The content of the aforementioned components makes it possible to define requirements to the tools of the model implementation in the educational practice. The following complex of software and methodological solutions has been developed, with due regard to such requirements: software with the embedded multi-user ontology editor that supports Semantic Web standards and the method of knowledge presentation in controllable Russian language; a prototype of multilingual e-learning environment based on ontologies; techniques and instructions intended for KMS users: authors of ontological content, teachers, students.

The developed software and methodological basis of KMS ensures its implementation and development as an open project, in which the industry, industry-specific educational establishments, and interested partners are involved.

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