Management and Production Engineering Review
Volume 2 • Number 3 • September 2011 • pp. 52–62

CONCEPT OF INTANGIBLE PRODUCTION NETWORK SYSTEM FOR COMPETENCE DEVELOPMENT IN OPEN AND DISTANCE LEARNING

Przemysław Różewski

West Pomeranian University of Technology in Szczecin, Faculty of Computer Science, Szczecin, Poland

Corresponding author:
Przemysław Różewski
West Pomeranian University of Technology
Faculty of Computer Science
Żołnierska 49, 71-210 Szczecin, Poland
phone: +48 91 4495572
e-mail: prozewski@wi.zut.edu.pl

Received: 2 June 2011
Accepted: 21 August 2011

Abstract
In the paper the model of the intangible production network system adapted to the Open and Distance Learning (ODL) environment is presented. The educational organization, which works according to the ODL objectives, is obligated to conduct continuous analysis of competences required by the market. The educational organization guarantees competences acquired through its curriculum. The competences guaranteed by the organization should reflect the market demands with regard to the continuous development of technology and knowledge. Intangible production is an advanced manufacturing process performed on the information level, where input materials, semi products and final products are in a digital form. The production network consists of nodes, each of which performs processing of information and knowledge through collaboration with other nodes. The paper focuses on the kind of intangible production where the production process utilizes different types of knowledge and competence is the final product. In the paper a model of intangible production network for competence development in the context of educational organization is discussed. The proposed approach can be used to develop and manage knowledge-base systems on the level of ontology.

Keywords
intangible production, intelligent products, knowledge management, educational organization.

Introduction

The companies which produce digital products are becoming the driver of the world's economy. The proof of the above statement can be obtained from the European or American stock market. Digital products are distributed in the internet, supported by the intellectual property protection solutions and internet payment systems. The on-line trade platforms allow for distributing a variety of products in digital form, which are the result of intellectual work at both conceptual as well as manufacturing stages. These products are an example of intangible products and they are a result of intangible production (de-materialized production). One of the best examples of intangible products is an e-book [1].

In recent years the issue of knowledge management has been expanded by the concept of competence [2, 3]. In educational organization's environment the competence represents knowledge acquired by students during the learning process [4]. The student's competence profile allows us to create a description of the knowledge domain, where the focus is shifted towards the actual qualifications of the person. Based on the competence's tools the description of the domain in the form of successive levels that represent increasing complexity (novice – expert) [5] can be formulated. Moreover, using competence it is possible to form a detailed description of the domain by specifying the related activities and skills in the form of meaningful textual descriptions and ontology [5].

We took under consideration the competence "production" process during a student's learning-teaching process. The discussed manufacturing process is designed to pass on the knowledge to the student in order to build a specific student's competence. Based on the achievements of cognitive science [5], we can assume that a product called competence arises from the combination of theoretical, procedural and project knowledge. A sequential process of transferring various types of knowledge requires a high level of student's involvement. The student and the teacher mutually cooperate to create and edit new knowledge [6, 7]. The student's motivation to work with more demanding tasks is an opportunity to note their success in the portfolio [8]. The teacher's motivation to actively work with the student is a possibility to put in the repository the records from the interaction with the student. The model assumes growth of knowledge in the organization as a result of the student-teacher collaboration. This approach is consistent with the postulate of the community-built systems [6]. In the proposed model, the key role is played by the repository. The repository management process allows for controlling the growth of knowledge. Moreover the repository is a workplace for students' and teachers' cooperation.

Intangible production is an advanced manufacturing process preformed on the information level, where input materials, semi products and final products are in a digital form [9, 10]. In order to produce an intellectual (intangible) product the intellectual resources, information tools, and competences and qualifications set have to be used. The market position of a company is decided based on the possessed patents and core competences [11]. All these elements are reflected in the company's intellectual capital [12]. This paper is focused on intangible production maintained by educational organization, where the production process utilizes different types of knowledge as semi-products and competence is the final product. Because the technologies are changing continuously, the existing production processes require for each specialist to renew vocational knowledge as well. Otherwise the specialist's social position cannot be lifted or even maintained, regardless whether it is management, engineering or worker staff. We can state that nowadays we are dealing with the following, important in the educational context, factors:

– Appearance of a new type of final products and a new type of production.
– Percentage increase in the number of people learning in regard to the number of citizens.
– The need to secure the mode of "life-long learning" for each specialist.
– Standardization of competences required on the job market.
– Increasing motivation of each potential learner for creating an individual path of obtaining required competences.
– The need to increase speed and flexibility of adjustment of curriculums to market needs.

The paper's goal is to present the model of intangible (non-material) production network for competence development. The competence development process occurs during the learning-teaching process based on e-learning [4, 5, 8]. The production process is maintained in the educational organization according to the Open and Distance Learning concept [5]. A novelty is the analysis of intangible production entirely oriented on knowledge. So far, the models proposed in literature have been oriented on the content production (i.e. e-books) [10, 13]. This paper is an extended version of the paper presented on the KSEM 2011 conference [14].

Intangible production network

The production network is a familiar concept and traditionally refers to material production. In the previous century this type of production was the basis for any industry where the main product supplied to the market was machinery, vehicles, chemical products, etc. The turnover in these sectors affected the state of the national and world economy. At the turn of the century the situation has changed, and since then the changes are gaining momentum. The main determinant of the changes is the emergence of a new type of market good, the so-called intangible products that are manufactured within the network of intangible (non-material) production. Changing the characteristics of the finished product also drives the change in the production process.

The intangible production is high-tech production, where input, output and interim products are direct results of the intangible production. Manufacturing and distribution of products in intangible production are realized only on information level. Peculiarity of the intangible production is that it does not require mechanical processing, with the exception of the final stages of the technological process (for example printing in electronic publishing, CD-making in entertainment and programming production). A corporation network in intangible production is unification of IT, hardware and software, local area and worldwide area telecommunication net-

works. The last are intended for transmission and distribution of intelligent products. The main characteristics of intangible production are [10, 13, 15]:
– distributed production process,

- digital character of products and semi-products,
- groupware,
- use of corporate network,
- semi-products are distributed between production stages on the information level,

– on-demand production,
– mass customization.

An intangible product typically has a digital form, and is a result of human intellectual work. The intangible product can be materialized through its recording, print, burning to a CD, etc. The fact of materialization of the intangible product does not change its contents, only the form of dissemination [15]. The main features of the intangible product:
– digital, personalized,
– copyrighted,
– knowledge-based,
– creation based on mental operations.

One of the main problems is the issue of intangible products standardization. It is difficult to develop quantitative standards for unambiguous assessment of knowledge related issues (i.e. competence). Therefore, in intangible production we need to depart from the norms of ISO, which only work here at the layer of communication, and look for new approaches.

The intangible production changes its character due to increasing complexity of the manufacturing process and the evolution of the final product (see Table 1). In the initial stage of intangible production the production process was oriented on content production based on the data and information processing. The printing process (PDF to e-book) is a good example of this kind of production. The Content Management Systems (CMS) can personalize the content (on some limited level) and adapt the content's format to specific customer's technical needs (i.e. in order to fulfill the mobile devices requirements). However, the customers expected a product that is personalized not only on the format level but on the content level as well. The next stage is intangible production focused on knowledge (competence) processing. One of the examples of this new kind of intangible production is the learning-teaching process based on an e-learning systems and a knowledge repository [8].

Table 1
The production process evolution [14].

Production types	Tangible/ material production	Intangible production oriented on content	Intangible production oriented on knowledge
Quality factor	Production in accordance with accepted standards ensures the final product quality.	Quality of individual workstations has the greatest impact on the quality of the final product.	The workstation's processing capabilities combined with suitable knowledge and competence of the knowledge worker have the greatest impact on the quality of the final product.
Criterion function	Suitable for calculation in integral units (length of time, production costs, etc.).	Difficult to calculate because of the qualitative character of production.	
Manufacturing process	Order of operations results from pre-defined operations with standardized parameters and their values in accordance with the standards (ISO).	Order of operations results from the nature of the object and it is changing during the manufacturing process.	
Raw Materials (consumables)	Material: wood, steel, petrol, etc.	Digital: datasets, software libraries, pdf, etc.	Digital + mental: knowledge objects, etc.
Final product	Material	Digital (i.e. content)	Mental (i.e. competence)
Example	Bicycle	Software	E-learning course

In intangible production oriented on knowledge the essential problem is the processing of competence and knowledge. The final product of the production process is competence, which consists of an appropriate combination of different types of knowledge: *competence={theoretical knowledge, procedural knowledge, project knowledge}* [2, 5, 16]. The ISO 24763 document describes competence as "demonstrated ability to apply knowledge and skills". Theoretical knowledge combined with proper procedural and project knowledge creates the basis for competence. The necessity of combining these types of knowledge arises during performance of practical tasks, laboratories and projects. The concept of competence is widely used, but in different contexts it differs significantly [2]. In the context of the labor market, competence is understood as a characteristic of a person, which might constitute for motivation, ability, skill, knowledge, in regard to performing the up-front defined tasks.

In material production the final product's quality depends mainly on the technology involved in the production process (fig. 1). The resources (raw materials) are characterized by concrete parameters. The content and structure of resources is difficult to change. On the other hand, the technology and resources' content can be changed in intangible production. Knowledge as a resources can be modified and changed in some way. In the proposed system the repository plays the role of the knowledge and resources modification tool.

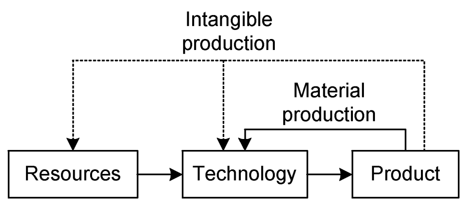

Fig. 1. The different feedback organization in material and intangible production.

The important issue is to relate the intangible product with the intelligent product. The fundamental idea behind the intelligent product concept is the inside-out control of the supply chain deliverables and of products during their lifecycle [17]. The product instances in the supply chain themselves are in control of where they are going, and how they should be handled. Such characteristic is required for the intangible product due to its information nature and copyright issues. Intelligent products are defined in various ways in the literature [18, 19]. The most important features of the intelligent product are:

- Communication skills: the intelligent product is capable of communicating effectively and actively with its environment [20]. The intelligent product reacts and adapts to environmental and operational conditions [21].
- Identification capabilities: the intelligent product possesses a unique identification, can retain or store data about itself [20].
- Decision making: the intelligent product is capable of participating in or making decisions relevant to its own destiny [20], maintain optimal performance in variable circumstances, also in case of exceptions [21].

The intangible product should be characterized by some level of intelligence (Fig. 2). The intangible product should be able to handle the information, at least. Information handling is the main feature of the intelligent product according to [18]. Moreover, some intelligence should be located in intangible product. Based on that feature, the ODL systems can perform in a truly open and distributed manner.

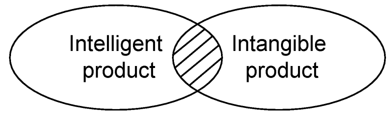

Fig. 2. The intangible and intelligent product relations.

Competence modeling based on the ontology approach

Competence is defined by knowledge (Fig. 3), but the difference lies in detailing the type of knowledge, its scope and depth, and the set of skills. The intangible production process has to ensure the student has such a set of knowledge and skills that enables him/her to acquire and systematize theoretical knowledge of a given domain, and to associate it with proper procedural knowledge in order to independently solve project tasks developed by the teacher, or create new tasks.

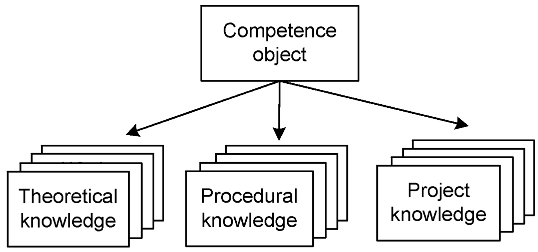

Fig. 3. The content of competence.

One of the approaches to expressing the competence is the ontological one [22, 23]. The ontology concept allows for development of a domain ontology in such a scope, that it covers all knowledge included in the set of several required competences belonging to one topic.

The structure of competence has been specified already. The competence consists of theoretical, procedural and project knowledge. Figure 4 shows the relation between the competence's elements and different types of ontology. The description of the ontology content and structure can be found in [22]. The approach to ontology formalization is the following: top-level/upper-level ontology (example: SUMO, CYC, formalization framework: SUO KIF, CycL), task ontology (example: Scheduling Task Ontology, formalization framework: OCML), method ontology (example: PSM, formalization framework: UPML), application ontology (example: AEDSS, formalization framework: OCML), domain ontology (example: WGS84 GEO Positioning, formalization framework: RDF). Theoretical knowledge can be reflected based on the domain and top-level/upper-level ontology. Theoretical knowledge covers the concepts definitions and relations, which can belong to a specific domain or be related to general concepts. Project knowledge is a result of project performance or development. Project knowledge is located in the method, application and task ontology. Procedural knowledge provides tools for problem solving and can be found in the method, application and task ontology as well.

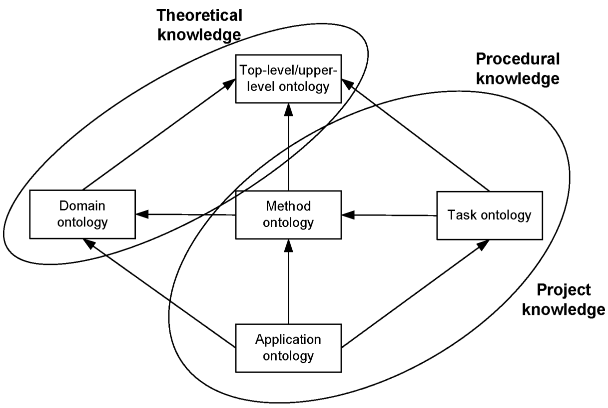

Fig. 4. Relation between the competence elements and different types of ontology [14].

Model of intangible production network for competence development

Competence development in educational organization

The socio-economic system of educational organization is developed to prepare the experts for demanding new technology and competitive job market. The existing technology and internet allow for dealing with this challenge based on the information systems such as e-learning. The experts' education is the main responsibility of a university. The university creates its curriculum based on the standards and guidelines form the authorities and the market. According to the European Union policy the educational standards and guidelines are founded on the competence concept [5]. Every competence achieved during the learning-teaching process is a product of specific educational organization curriculum. The curriculum is made of courses, which are aimed to covers different types of knowledge. Organization of the production system for competence development for each student in educational organization is presented in Fig. 5.

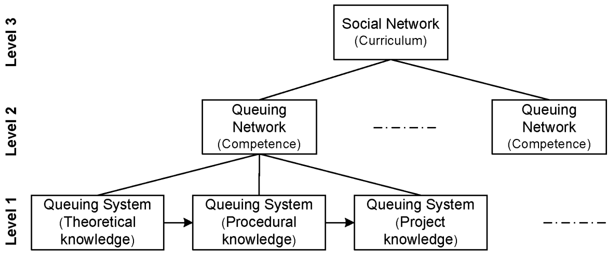

Fig. 5. Organization of the production system for competence development in educational organization.

In Fig. 5 Level 1 represents the knowledge (theoretical, procedural, project) objects transfer, which is the component of competence. Every type of a knowledge object is transferred to the student in a separate sub-process based on the repository capabilities [5, 8]. The repository plays the role of a cooperation workplace for students and teachers. All messages, knowledge objects, and tasks go through the repository interfaces [24]. The sub-processes for theoretical, procedural, and project knowledge transfer are linked together and depend on each other. Project knowledge can be transferred only if procedural and theoretical knowledge was already obtained by the student. Moreover, the transfer of procedural knowledge can only start if the theoretical knowledge was already mastered by the student. Every sub-process can be interpreted as a queuing system. The teacher works as a server in consultation and examination mode. Moreover, the server also supports the student-teacher and student-didactical material interactions. As with every queuing system, the system's capacity, waiting time, student flow intensity, are important issues. However, in the discussed system the crucial parameter of the queuing system is knowledge increase in the repository (limited by time restrictions).

Level 2 in Fig. 5. represents competence acquisition within the frame of a particular specialization. The queuing systems for the theoretical, procedural, and project knowledge are combined into a queuing network (tandem type) for every competence transfer. Several competences (queuing networks) are linked together into one specialization (queuing network). Each node in the queuing network represents a sub-system for a specific competence transfer (specialization – subject(course) – topic – task). The quality factor on level 2 is discussed in context of relevance. The relevance level is computed based on compatibility with competence standards, with the time and resources restriction. The acquisitioned competence, which covers the technology market demands, is the final product of the learning-teaching process. Because of that, the queuing network can be treated as a production network for the competence development process. The queuing network approaches allows to determine the quality-price relation.

Level 3 is a social network level. The student's and teacher's cooperation is based on the community-built system paradigm [6, 7]. The collaborative efforts can be a powerful tool to build a knowledge repository. Moreover, the competence acquisition process is founded on social interaction [25]. The learning-teaching processes merge several parallel and intersect processes of competence acquisition. On the university level the processes are combined into a social network. The structure of the social network is derived from curriculum and is unique for every student.

The intangible production network is a system. From the point of view of the system approach every system must have a goal and a purpose. For the discussed production system the main goal is competence transfer. The objective of the competence "production" system is to guarantee every student with competence acquisition within the time and resources limitations and in the frames of a specified curriculum.

The production system analysis requires interpreting the system in the context of existing mathematic approaches of production modeling. Such concepts as event, operation, input and output stream should be properly interpreted. In addition, the mathematics-based approach allows for determining the production process characteristics like performance measurements, management criterions, etc. In the case of the knowledge-based process, mathematic interpretation is difficult due to the complex nature of the process. In the next chapters the model of the system will be simplified. The base element will be the queuing system. The social network aspect is discussed in [25].

Structure of intangible production network for single competence development

The proposed model of production network is adapted to the conditions of the "learning-teaching" process realized in the Open and Distance Learning (ODL) educational organization [4, 5]. The "learning-teaching" process can be interpreted as a production process for the following reasons (Fig. 6): we can distinguish the final product (competence) and the intermediate steps associated with the transmission of different types of knowledge (semi-products) into the product (competence). Such an interpretation of the production process allows for use of the tool from the theory of production, which helps to formulate the model of production process.

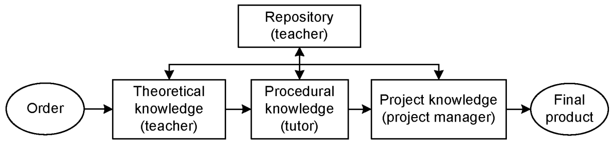

Fig. 6. Structure of the intangible production network for competence development [14].

A production network is a system of components and unidirectional connections that can be represented by a digraph in which the components are the nodes and the connections the arcs [26]. The proposed production network consists of nodes, each of which performs processing of information through collaboration with other nodes. The result of processing information is increase of knowledge. Knowledge is stored in the knowledge repository in the form of different kinds of ontologies [22]. The process is aimed at the student and has the following objectives:

- Transfer a portion of knowledge to the student to have him/her acquire competencies.
- Generate new knowledge and place it in the repository.

Proper combinations of theoretical, procedural, and project knowledge result in efficient competence acquisition by the student (Fig. 7). The process of transfer of various types of knowledge, which make up the competence, assumes that a task is downloaded from the repository. The student can download tasks of different level of complexity. One way of distinguishing the tasks is by assigning levels to them: easy or hard. The proposed mathematical model can be extended on the other level's schemes. An easy task can be interpreted as a consolidation task and a hard task can be interpreted as a creative task [16]. The aim of the consolidation tasks is to reinforce knowledge and assimilation of already acquired skills through their practical application in solving typical learning problems. The creative task is aimed at stimulating the student to individually search for and obtain new knowledge through completing atypical assignments. These tasks are used by teachers or tutors to prepare students to individually solve learning problems and to learn how to manage unfamiliar and atypical situations. The main idea laying behind creative tasks is individual searching for solutions through discovering new knowledge and developing new skills. The creative (complex) tasks, as opposed to consolidation (routine) tasks, require significant student's effort. After positive verification of the solution, the creative task is placed in the repository.

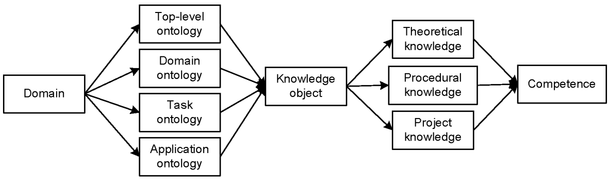

Fig. 7. The domain, knowledge object and competence relation [14].

Figure 7 presents the structure of the knowledge object. The knowledge object reflects the domain knowledge based on the different ontology types [22]. The knowledge object is divided into different portions of knowledge, which together form a competence. The knowledge object combines the theoretical, procedural, and project knowledge. The main condition for mastering the knowledge object is to perform the series of collaboration with teacher and e-learning system for each kind of knowledge. The repository is founded on the ontological model of the domain. It assumes that domain knowledge representation is based on the integration of theoretical, procedural, and project knowledge. Adding a new knowledge portion to the repository is means integrating the new piece of knowledge with the existing ontology. Each of the new knowledge portions can be added to theoretical, procedural, and project knowledge.

The production process for competence development is presented in Fig. 8. The student obtains from the repository new portion of theoretical knowledge in accordance with the course curriculum and arrangements with the teacher. When the processing of the new portion is finished the student moves to the servicing (execution) block in order to verify the theoretical knowledge. The student chooses one of the alternative tasks for new knowledge assessment. The same procedure is repeated for procedural and project knowledge as well. In the process of servicing each student's operation is interpreted as a student-teacher collaboration based on didactic materials contained in the repository. The specificity of this cooperation is as follows:

– The didactic material is presented in the form of an ontology divided into appropriate portions of knowledge, each of which covers a range of theoretical, procedural and project knowledge [24].
– The student uses self-education for knowledge acquisition and cooperation with the teacher for consultation.
– The time of cooperation is limited.

Each stage of knowledge processing can be finished in the following way (see Fig. 8): (−) return to appropriate decision block, (− −) exit from the production system, (+) departure from servicing block with positive assessment, (++) departure from servicing block with positive assessment and due to excellence of student's work new knowledge, generated by the student, is transferred to the repository (in the form of an approved knowledge model).

The competence development process can be presented in the form of a system (Fig. 8). The student's preference function, like the motivation function [5, 27], reflects the student's approach to the acquisition of knowledge. On one hand, a student can be focused on the routine task. In this case, after the stage completion the student is transfer to the next stage. If the student chooses a complex task, the knowledge acquisition process is hard and requires the student to use the creative approaches. However, the success of its completion not only allows the student to move to the next stage, but also the new knowledge is included in the repository. This event is recorded in the student's portfolio and is part of the student's intellectual capital after the completion of the learning process.

Figure 9 presents the structure of learning system for specific kind of knowledge. It represents one workstation of the discussed production process. Both students and teachers are characterized by the preference/motivation functions, which influence their actions [5, 27]. After the task execution the student and teacher cooperate in order to assess the task. As was said before, tasks of high-quality and complexity are placed in the repository.

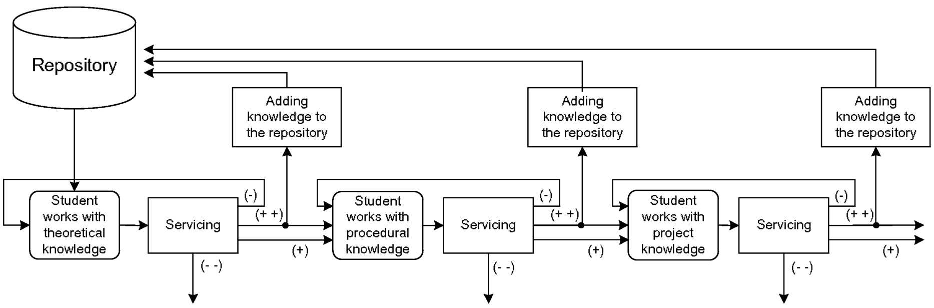

Fig. 8. Model of competence development as a production process [14].

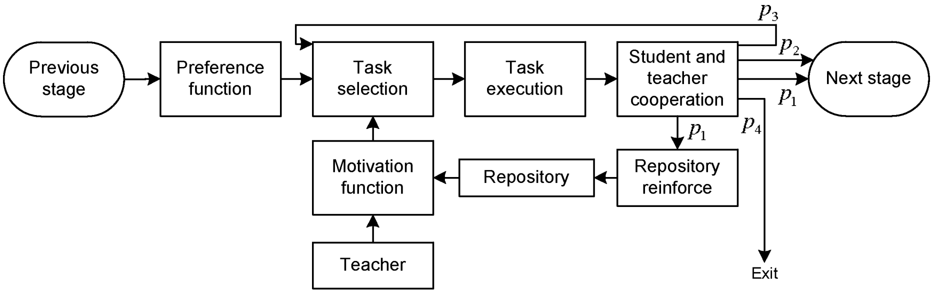

Fig. 9. Structure of the learning system for specific kind of knowledge transfer [14].

Model of intangible production network for single competence development based on the Queuing Theory approach

The presented system can be modeled in different ways (e.g. discrete models). However, the open aspect of the learning-teaching process has features that demand a special modeling approach. The ODL student can enter the system at any moment. The students' basic levels of knowledge are different and can differ in both the content and the context of possessed knowledge (different educational background). The students' expectations regarding the educational system, their motivation and learning preferences are different as well. The resources of the educational system are limited. In case of a large amount of students, the students will be waiting in queues. In consequence, the queuing system is the best approach to modeling the stochastic nature of the ODL learning-teaching process. Only in the ODL conditions the queuing system approach to the learning-teaching process is valid.

Let's describe the intangible production network for single competence as a chain of queuing systems (Fig. 10). At every chain's stage, the special kind of knowledge is transferred to the student. Each stage consists of a task selection block (S) and a task execution (servicing) block (U). At the task selection stage the student can select [16]:

- A – a simple task (consolidation problem valuable for the student due to pedagogical reasons),
- B – a hard task (complex problem the solution of which is valuable for the educational organization and for the student as well).

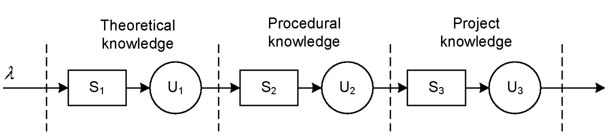

Fig. 10. The stages of the intangible production network (S – task selection block, U – task execution (servicing) block).

We can formalize the students input flow in the following way:

λ – rate of the input flow of students.

$\lambda=\lambda^A+\lambda^B$ – students input flow decomposition (Fig. 11).

λ^A – rate of the input flow of student who selected a simple task.

λ^B – rate of the input flow of student who selected a hard task.

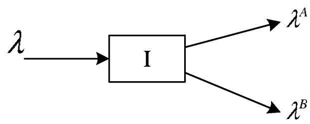

Fig. 11. The input flow decomposition.

At every stage theoretical knowledge or procedural knowledge or project knowledge is transferred to the student. Each type of knowledge can be transferred based on the simple or hard task respectively. The hard task's stage structure is presented in Fig. 12. The stage of knowledge processing can be finished in the following ways:

1. finish the task with a positive result of assessment,
2. return to the decision block,
3. exit from the production system,
4. finish the task with a positive result of assessment; the task's solution is transferred to the repository, due to the excellence of the student's work, and it is treated as a new organization's knowledge.

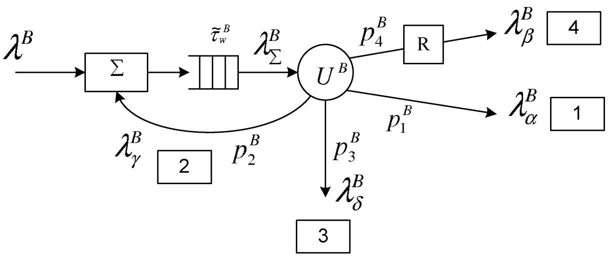

Fig. 12. Hard (creative) task's stage structure.

The hard task's stage structure (Fig. 12) has the following description:

p_1^B – probability of finishing the task with a positive result of assessment (the task is too easy to put it into the repository),
p_2^B – probability of returning to the selection block (new task selection),
p_3^B – probability of escaping from the system,
p_4^B – probability of finishing the task with a positive result assessment and having the task recorded in the knowledge repository (R).
$p_1^B + p_2^B + p_3^B + p_4^B = 1$ – normalization condition,
$\lambda_{\sum}^B = \lambda^B + \lambda_{\sum}^B p_3^B$ – input rate.

Traffic equations for the creative task stage:

$$\begin{cases} \lambda_\alpha^B = \lambda_{\sum}^B p_1^B, \\ \lambda_\beta^B = \lambda_{\sum}^B p_4^B, \\ \lambda_\delta^B = \lambda_{\sum}^B p_2^B, \\ \lambda_\gamma^B = \lambda_{\sum}^B p_3^B. \end{cases}$$

The simple task's stage structure is presented in Fig. 13. The student can finish this stage in the following ways:

1. finish the task with a positive result of assessment,
2. return to decision block,
3. exit from the production system.

Traffic equations for the simple task's stage:

$$\begin{cases} \lambda_\alpha^A = \lambda_{\sum}^A p_1^A, \\ \lambda_\gamma^A = \lambda_2^A p_2^A, \\ \lambda_\delta^A = \lambda_2^A p_3^A. \end{cases}$$

The task selection and execution (servicing) block for the consolidation and the creative task is presented in Fig. 14. We can notice that the execution block for the simple (**) and the hard (*) task can be interpreted as a M/M/1 system. The process of knowledge and competence acquisition during learning is a stochastic process. Its nature is reflected in the queuing analytical and simulation methods:

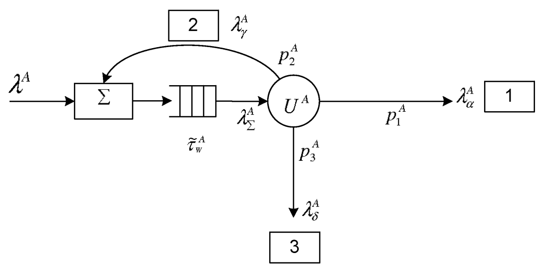

Fig. 13. Simple task's stage structure.

Student arrival is a stochastic process. In case of a large number of students and students independence the process can be interpreted as a Markovian one.

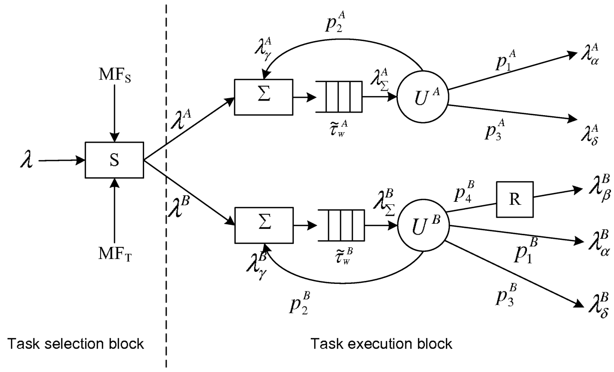

Fig. 14. Generalization of the stage structure.

Student's servicing: time sharing approach for teaching resources, software and repository resources. Due to the limited nature of resources, queues appear at different stages of the learning-teaching process.

Servicing discipline: the teacher can establish priorities (static or dynamic) in the students' servicing process.

The M/M/1 system approach is a simplification for clarity of the model. The students' arrival and servicing time can be interpreted as a Markovian one in case the students have similar basic knowledge and the servicing time is similar. For the M/M/1 system the average time of the simple and the hard task's servicing is the following:

$$\tilde{\tau}^A = \frac{1}{\mu_A}, \qquad \tilde{\tau}^B = \frac{1}{\mu_B}.$$

The student chooses the task in the selection block. The selection process is based on the motivation model for the student and the teacher [5, 6, 27]. The motivation model belongs to the class of incentive models and is oriented towards maintaining control of social economic systems [28]. The teacher's interest is in maximizing the level of repository filling with tasks of different complexity for every considered educational situation in a given domain [5]. The student's interest lies in individual preferences and can be described using opposing groups of creators [5]: (1) achieving a minimal acceptable success level, meaning meeting only the basic requirements for obtaining a positive opinion about the task (low complexity of the task, minimal acceptable quality) and saving maximal amount of their time; (2) providing the repository with the maximal possible success level, implying creating and editing contents of high complexity in order to produce the best overall quality.

Let's define the parameters of the task selection and execution (servicing) process for the structure in Fig. 14:

$\widetilde{\tau}^A$ – average time of simple task execution;

$\widetilde{\tau}^B$ – average time of hard task execution;

$\widetilde{\tau}_W^A$, $\widetilde{\tau}_W^B$ – average waiting time of hard and simple task respectively;

$\widetilde{T}_S^A = \widetilde{\tau}^A + \widetilde{\tau}_W^A$ – average time during which the simple task (A) stays in the system;

$\widetilde{T}_S^B = \widetilde{\tau}^B + \widetilde{\tau}_W^B$ – average time during which the hard task (B) stays in the system;

$N^A = \lambda_\Sigma^A \widetilde{T}_S^A$ – average number of simple tasks (A) in the system;

$N^B = \lambda_\Sigma^B \widetilde{T}_S^B$ – average number of hard tasks (B) in the system;

$\lambda = \lambda^A + \lambda^B$ – input flow decomposition.

Based on the Little's law for M/M/1 system characteristic, the following parameters can be formulated for the discussed system of the hard and simple task transferring:

Average number of tasks in the system:

$$N = N^A + N^B,$$

where:

$$N^A = \frac{\lambda_\Sigma^A}{\mu_A - \lambda_\Sigma^A} = \frac{\lambda_\Sigma^A \widetilde{\tau}_O^A}{1 - \lambda_\Sigma^A \widetilde{\tau}_O^A};$$

$$N^B = \frac{\lambda_\Sigma^B}{\mu_B - \lambda_\Sigma^B} = \frac{\lambda_\Sigma^B \widetilde{\tau}_O^B}{1 - \lambda_\Sigma^B \widetilde{\tau}_O^B}.$$

Average time during which a task stays in the system:

$$\widetilde{T}_S^A = \frac{N^A}{\lambda_\Sigma^A} = \frac{1}{\mu_A - \lambda_\Sigma^A} = \frac{\widetilde{\tau}_O^A}{1 - \lambda_\Sigma^A \widetilde{\tau}_O^A};$$

$$\widetilde{T}_S^B = \frac{N^B}{\lambda_\Sigma^B} = \frac{1}{\mu_B - \lambda_\Sigma^B} = \frac{\widetilde{\tau}_O^B}{1 - \lambda_\Sigma^B \widetilde{\tau}_O^B}.$$

Average waiting time for a task to be executed:

$$\widetilde{\tau}_W^A = \widetilde{T}_S^A - \widetilde{\tau}_O^A; \qquad \widetilde{\tau}_W^B = \widetilde{T}_S^B - \widetilde{\tau}_O^B.$$

Average number of tasks in the waiting queue:

$$N_W^A = \lambda_\Sigma^A \widetilde{\tau}_W^A; \qquad N_W^B = \lambda_\Sigma^B \widetilde{\tau}_W^B.$$

Knowledge in the repository is increasing over time due to hard (creative) tasks analysis. In the best cases, the student finished the task in the manner that the task's solution can be transferred to the repository. The business model of such interaction can be found in [8]. The dynamic of the repository growth ΔK in the time unit $K(1)$ characteristics based on the traffic equation for the create task:

$$\lambda_\beta^B = \lambda_\Sigma^B p_4^B \quad \text{where} \quad \lambda_\Sigma^B = \frac{\lambda^B}{1 - p_3^B}.$$

$\Delta K(R, r_i) = \Delta\widetilde{K}\Delta K$ – average increase of knowledge in the repository as a result of task r_i execution.

$K(1) = \dfrac{\lambda^B}{1 - p_3^B}\Delta\widetilde{K}$ – knowledge increase in the time unit $K(1)$.

$K(T) = \dfrac{\lambda^B}{1 - p_3^B}\Delta\widetilde{K}T$ – knowledge increase in the time interval $[0, T]$.

The presented model is simplified in order to present the model's features and characteristics. The model can be adapted to real conditions using ontology [24] and knowledge modeling [5]. The model supports the social network level due to the student's and teacher's motivation functions' integration.

Conclusion

Information technology entirely changes methods of human communication and production processes. Information technology and communication networks play the role of the neural system of a global human being, whose intellect and knowledge are formed by distributed memory. Intangible production becomes an important component of this system. As was presented in the article, the concept of production changes continuously. Currently the most important challenge for manufacturing systems is production of knowledge. The new intangible products are aimed at developing competences among the clients.

References

[1] Kipphan H. (Ed.), *Handbook of Print Media – Technologies and Production Methods*, Springer, Heidelberg, 2001.

[2] Różewski P., Małachowski B., *Competence Management In Knowledge-Based Organisation: Case Study Based On Higher Education Organisation*, In: R. Goebel, J. Siekmann, and W. Wahlster (Eds.), KSEM 2009, Lecture Notes in Artificial Intelligence, vol. 5914, pp. 358–369. Springer, Heidelberg, 2009.

[3] Sampson D., Fytros D., *Competence Models in Technology-Enhanced Competence-Based Learning*, In: Adelsberger H.H., Kinshuk, Pawlowski J.M., Sampson D. (Eds.): Handbook on Information Technologies for Education and Training, 2nd edition, Springer-Verlag, Heidelberg 2008, pp. 155–177.

[4] Kusztina E., Zaikine O., Różewski P., Małachowski B., *Cost estimation algorithm and decision-making model for curriculum modification in educational organization*, European Journal of Operational Research, 197 (2), 752–763, 2009.

[5] Różewski P., Kusztina E., Tadeusiewicz R., Zaikin O., *Intelligent Open Learning Systems: Concepts, models and algorithms*, Intelligent Systems Reference Library, Vol. 22, Springer-Verlag Berlin Heidelberg, 2011.

[6] Różewski P., Kushtina E., *Motivation Model in Community-Built System*, In: Eric Pardede (Ed.), Community-Built Database: Research and Development, Springer-Verlag Book, 2011, pp. 183–205.

[7] Różewski P., *Model of Community-Build System for Knowledge Development*, P. Jędrzejowicz et al. (Eds.), ICCCI 2011, Part II, Lecture Notes in Computer Science 6923, Springer-Verlag Berlin Heidelberg, 2011, pp. 50–59.

[8] Różewski P., Ciszczyk M., *Model of a collaboration environment for knowledge management in competence based learning*, In: Nguyen N.T., Kowalczyk R., Chen S.-M. (Eds.), ICCCI 2009, Lecture Notes in Artificial Intelligence, vol. 5796, Springer, Heidelberg 2009, pp. 333–344.

[9] Berkhout F., Hertin J., *De-materialising and re-materialising: digital technologies and the environment*, Futures, 36 (8), 903–920, 2004.

[10] Zaikin O., *Queuing Modelling Of Supply Chain In Intelligent Production*, Informa, Poland, Szczecin, 2002.

[11] Lahti R.K., *Identifying and integrating individual level and organizational level core competencies*, Journal of Business and Psychology, 14 (1), 59–75, 1999.

[12] Nemetz M., *A Meta-Model for Intellectual Capital Reporting*, In: U. Reimer and D. Karagiannis (Eds.), PAKM 2006, Lecture Notes in Artificial Intelligence, 4333, 2006, pp. 213–223.

[13] Korytkowski P., *Optimization Of Production Capacity In Intangible Flow Production Systems*, In: Dolgui, Morel, Pereira (Eds.), Information Control Problems in Manufacturing, Vol. 3, Elsevier Science, 2006, pp. 627–632.

[14] Różewski P., *Model of Intangible Production Network for Competence Development*, KSEM 2011, Lecture Notes in Computer Science, Springer-Verlag Berlin Heidelberg (in press).

[15] Korytkowski P., Zaikin O., *The management of production capabilities in Intangible production*, In: W R. Kulikowaki et al. (Eds.), Operational and Systems Research, Exit, Warszawa, Poland, 2004, pp. 207–218 (in Polish).

[16] Różewski P., Małachowski B., *System For Creative Distance Learning Environment Development Based On Competence Management*, In: Setchi R., Jordanov I., Howlett R.J. and Lakhmi C. Jain. (Eds.), KES 2010, Lecture Notes in Artificial Intelligence, vol. 6279, Springer 2010, pp. 180–189.

[17] Kärkkäinen M, Holmström J., Främling K., Artto K., *Intelligent products – a step towards a more effective project delivery chain*, Computers in Industry, 50 (2), 141–151, 2003.

[18] Meyer G.G., Främling K. Holmström J., *Intelligent Products: A survey*, Computers in Industry, 60 (3), 137–148, 2009.

[19] Van Belle J., Saint Germain B., Valckenaers P., Van Brussel H., Bahtiar R., Cattrysse D., *Intelligent Products in the Supply Chain Are Merging Logistic and Manufacturing Operations*, In: Proceedings of the 18th IFAC World Congress, Volume 18, Part 1, 1596–1601, preprint, 2011.

[20] McFarlane D., Sarma S., Chirn J.L., Wong C.Y., Ashton K., *Auto id systems and intelligent manufacturing control*, Engineering Applications of Artificial Intelligence, 16 (4), 65–376, 2003.

[21] Ventä O., *Intelligent products and systems*, Technical Report, VTT 2007.

[22] Gomez-Perez A., Corcho O., Fernandez-Lopez M., *Ontological Engineering: with examples from the areas of Knowledge Management, e-Commerce and the Semantic Web*, Springer-Verlag, London, 2004.

[23] Paquette, G., *An Ontology and a Software Framework for Competency Modeling and Management. Educational*, Technology & Society, 10 (3), 1–21, 2007.

[24] Zaikin O., Kushtina E., Różewski P., *Model and algorithm of the conceptual scheme formation for knowledge domain in distance learning*, European Journal of Operational Research, 175 (3), 1379–1399, 2006.

[25] Różewski P., *A Method of Social Collaboration and Knowledge Sharing Acceleration for e-learning System: the Distance Learning Network Scenario*, In: Yaxin Bi and Mary-Anne Williams (Eds.), KSEM 2010, Lecture Notes in Artificial Intelligence, 6291, 148–159, 2010.

[26] Gibson G. A., Alawneh J. Y., *Time-bounds for production networks*. International Journal of Production Economics, 102 (1), 149–166, 2006.

[27] Kusztina E., Zaikin O., Tadeusiewicz R., *The research behavior/attitude support model in open learning systems*, Bulletin of the Polish Academy of Sciences: Technical Sciences, 58 (4), 705–711, 2010.

[28] Novikov D.A., Shokhina T. E., *Incentive Mechanisms*, Automation and Remote Control, 64 (12), 1912–1921, 2003.