The dynamics simulation of knowledge potentials of agents including the feedback

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Abstract. The conceptual and mathematical models of the agents’ knowledge potential redistribution considering their constituent components are constructed in the paper. A nonlinear model describing the dynamics of agents’ knowledge potentials is developed taking into account the feedback effects (agent → student) on the source of knowledge (teacher / lecturer). In particular, the procedure of constructing a multicomponent two-dimensional array of discrete values of the knowledge potential constituent components for generating procedures to enhance (improve) the professional competences of knowledge sources, is generalized and specified.

1. Introduction

In a changing and closely interconnected world, everyone needs a wide range of skills and competences that need to be developed throughout their lives [18]. Therefore, one of the contemporary visions is to analyze and study the formation of a person-oriented educational trajectory that is a personal educational (training) program of a person, which provides with the acquisition of professional competences that correspond to their abilities, interests, motivation, psychodynamic and emotional characteristics, age and level of knowledge potential (for example, in the form of hard skills and soft skills, etc.) [15].

Thus, the construction and analysis of mathematical and information models of the formation of teachable and measurable abilities (hard skills) that can solve complex problems, is a necessary and urgent task.

2. Brief literature review

An analysis of studies [6], [13], [14] have showed that a lot of scientists focused to develop models that reflect the interaction processes between the objects of the educational sector and the labor market and the modernization of educational programs. Nowadays, these results cannot be used in practice in all cases.

Despite the rapid research development of knowledge dissemination modeling, it is known a little about how knowledge potential is created and transmitted. Since the processes of knowledge dissemination between individuals (agents) are characterized by complication, dynamics, adaptation, and nonlinearity, they are heavy for empirical research. It means that computational (computer) modeling can be a useful tool to study the dynamics of knowledge transfer between agents ([1], [11]).
An agent-modeling approach to study the knowledge dissemination was used by Morone and Taylor, Xuan, Hirshman, Giacchi and others. These researches mainly concerned the influence of network (agent group) properties on knowledge dissemination within that network (organization). In particular, Morone and Taylor, using a cellular vending machine model, studied how knowledge is transferred through a network where agents interact through direct communication. Their scientific works represents the effect of network structure on the learning process ([10], [16], [19]).

Xuanet and others have explored the impact of the knowledge relation structure on knowledge transfer in this network. They have shown that the diversity of knowledge facilitates their dissemination.

A lot of scientists used agent-based modeling formed on the mechanism of homophily to study the effects of the social connection level. They have positioned the society where agents interact with their counterparts ([2], [9]). Their works propose that simulation of the emergence of multilevel social relations using a homophilic model is possible, and the simulation results are up to the models observed in real human networks.

In the model proposed in scientific work [10], agents (nodes) transmit knowledge based on two criteria, namely knowledge distance and confidence. They display that in a more distributed network configuration, the dynamics of knowledge discussion and confidence level are much greater than the centralized structure [19].

Generally, in the studied knowledge dissemination models, knowledge is represented in several ways as a stock (each agent has a primary knowledge level, which is an integer selected randomly from a given range), as a tree where a little potential knowledge corresponds to each node or as a set of facts that characterizes the agent’s knowledge matrix [7].

As result, the purpose of this work is to analyze and develop a mathematical model of the redistribution of potential of knowledge processes in the derivation of the agent’s professional competence system.

3. The problem formulation

The numerical characteristic that helps fix a some level of agent’s knowledge, gathered during training, life experience, etc., has been suggested in our previous works ([3], [4], [5]) to call as knowledge potential $\phi$.

It has been constructed the so-called diffusion-like models of information processes of knowledge potential redistribution in the educational social and communication environment of the city and focuses on the description (simulation) of processes of knowledge potential redistribution in the system formation of professional competences. The competence usually means a functional combination of intelllection, ways of cogitative, views, evaluates, skills, capacity, and other private properties of that determines a person’s capability to successfully pursue professional and further educational activities [5].

It is estimated that a particular competence is described by a definite of components of knowledge potential and their constituents.

Using $\phi_{q,l,k,m,e}$, it is denoted the value of $q$ constituent of $l$ knowledge potential component of $k$ agent at $m$ time ($l = 1, l^r$, $q = 1, q^r$, $k = 1, k^r$).

For example, figure 1 presents some characteristics of competence formation based on the constituents and components of the knowledge potential.

In general, as in [5], the set of all possible components of the knowledge potential constituents at a given time situation can be characterized by a matrix (two-dimensional array (with the size $l \times q$)):

$$
\begin{pmatrix}
\phi_{1,1,k,m,e}, & \phi_{2,1,k,m,e}, & \cdots, & \phi_{q,1,k,m,e} \\
\phi_{1,2,k,m,e}, & \phi_{2,2,k,m,e}, & \cdots, & \phi_{q,2,k,m,e} \\
\cdots, & \cdots, & \cdots, & \cdots, \\
\phi_{1,l,k,m,e}, & \phi_{2,l,k,m,e}, & \cdots, & \phi_{q,l,k,m,e}
\end{pmatrix}
$$

where $e$ is any small variable that will characterize further disturbing effects on the learning process. The complex of potential subsets of such an array will be joined with the set of competences gained by agents during educational.
Figure 1. Components of competencies.

It is shown some examples of such subsets on figure 2.

Figure 2. Schematic image of competence.

It is set out to form such subsets to satisfy certain optimal conditions for training costs and program outcomes, with regard to the needs dictated by stakeholder conditions.

4. Mathematical model of the reverse influence process

The acquisition of professional competences and the implementation of program learning outcomes are the result of three forms of interaction ([12], [17], [8]):

Agent / Knowledge Source (teacher / lecturer);
Agent / Agent;
Agent / Educational Content

In this paper, it is described not only the interaction between agents (learners), knowledge sources and learning content, but also the feedback between teachers and agents, as well as the educational content used to enhance the level of knowledge potential (figure 3).
As mentioned in [4], the process of knowledge potential redistribution (including the acquired knowledge) at the next time stage without considering the knowledge redistribution between agents is represented as:

$$\phi_{q,t,k,m+1,e} = \phi_{q,t,k,m,e} + \sum_{m=1}^{m+1}(f_{q,t,k,m} + \epsilon \alpha_{q,t,k,m} f^*_{q,t,k,m} \phi_{q,t,k,m+1})$$  \( (1) \)

where \( f_{q,t,k,m} \) is the main part of the characteristic of the knowledge source (teacher), and \( \epsilon \alpha_{q,t,k,m} f^*_{q,t,k,m} \) is the corresponding correction (disturbing influence) on the traditional nature of the knowledge presenting by the teacher / lecturer, depending on the final needs (requirements) of the agents \( (f = f + \epsilon \alpha f^* \) is the general characteristic of the knowledge source).

It can also be directly formed redistributions in time of the constituents of knowledge potential components, for example, as follows:

$$\begin{align*}
\phi_{q,t,k,0,e} &= \phi_{q,t,k,0,e} + f_{q,t,k,0,e} + \epsilon \alpha_{q,t,k,0} f^*_{q,t,k,0} \\
\phi_{q,t,k,0,e} &= \phi_{q,t,k,0,e} + \sum_{m=1}^{m+1} f_{q,t,k,m} + \epsilon \alpha_{q,t,k,m} f^*_{q,t,k,m} \\
\phi_{q,t,k,0,e} &= \phi_{q,t,k,0,e} + \sum_{m=1}^{m+1} f_{q,t,k,m+1} + \epsilon \alpha_{q,t,k,m+1} f^*_{q,t,k,m+1}
\end{align*}$$  \( (2) \)

If the requirements for teacher’s / lecturer’s advanced training, can only be characterized by a set of final knowledge (program outputs) of pupils / students, then the corresponding dependence can be represented as:

$$f^*_{q,t,k,m} = f^*_{q,t,k,m} (\phi_{q,t,k,m}; k = 1,k, \tilde{m} = 1,m + 1) = \sum_{k=1}^{K} \beta_{q,t,k,m+1} \phi_{q,t,k,m+1}$$  \( (3) \)

where \( \beta_{q,t,k,m+1} \) are some weight coefficients.

If all the other constituents and components at different time moments are used, then the formula can be generalized as follows:

$$f^*_{q,t,k,m+1} = \sum_{q=1}^{Q} \sum_{l} \sum_{k=1}^{K} \phi_{q,t,k,m+1}$$  \( (4) \)

Taking into account the final components of competence, the parameters \( \alpha_{q,t,k,m} \), \( \beta_{q,t,k,m} \) will be selected optimally depending on the form of agents’ requests (regarding the professional qualification of knowledge sources) to the goals and program results of the training, which characterize the required professional competences, as well as the optimal costs. In the simplest case, the following conditions can be formed in the form of inequalities:

$$\phi_{q,t,k,m+1} < \phi_{q,t,k,m+1,e} < \phi_{q,t,k,m+1}$$  \( (5) \)
where $\phi_{q,l,k,m+1}$, $\overline{\phi}_{q,l,k,m+1}$ are certain thresholds of components and their constituents of knowledge potential, which should satisfy the program results of training of the corresponding specialty. In this case, each of the elements A, B, C, etc. (sets of elementary competences and their constituents) will be characterized by the initial and final indices of the corresponding matrices, for example:

$$A = A_1 = A_{(1,1)(2,2)}, B = A_2 = A_{(2,2)(3,3)}, D = A_3 = A_{(5,6)(5,6)}, \ldots$$

In general:

$$A^t = A^t_{(k_1,j_1)(k_2,j_2)}.$$  

Then the inequalities of type (5) can be applied only to the elements of the corresponding subsets $A_i$. For example, the appropriate restrictions for $B = A_2$ can be presented in the form:

$$\psi_{2,2} < \alpha_{2,2,k,m} \phi_{2,2,k,m} + \alpha_{3,2,k,m} \phi_{3,2,k,m} < \overline{\psi}_{2,2},$$

$$\psi_{2,3} < \alpha_{3,3,k,m} \phi_{2,3,k,m} + \alpha_{3,3,k,m} \phi_{3,3,k,m} < \overline{\psi}_{2,3}.$$  

As a result of solving the optimization problem of certain functionals (for example, cost optimization), under the conditions as in (5), it is found the parameters and according to formulas (1-4) the characteristics of the corresponding “disturbances” of educational programs are considered, for example, needs, dictated by stakeholder conditions.

5. Conclusion

The characterization of the agents’ knowledge potential, taking into account the units of its components and the interactions in the learning process, provided an opportunity to specify these models (consideration of dependencies between the parameters characterizing interpersonal relationships), and, consequently, modeling of more real situational states that has considerable practical value.

In particular, a mathematical model was developed to describe the dynamics of the components and their constituents of the agents’ knowledge potentials, taking into account the feedback (agent – student) on the knowledge source (teacher / lecturer) and the achievement of program results, in particular regarding to the needs dictated by employers.

To identify the relevant parameters (according to their further use in the creation of individual training trajectories of a person), it might be used the procedure of their step-by-step fixations (block iterations), similar to our previous works.

The prospect of further research is the introduction of objective functions (as functions whose arguments are subsets of the proposed two-dimensional array), the solution of various kinds of nonlinear optimization and control problems.

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