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The development of a systems mindset in the first-year students studying online at a vocational pedagogical university while mastering the basics of working with digital technologies

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ABSTRACT

The purpose of the study is to show the possibility and feasibility of developing a systems mindset in the process of shaping competencies in information technology while the educational process is based on online learning. The features of the limitations of perception by first-year students in the field of systems that use digital technologies have been analyzed. An experiment based on the methodology for the development of a systems mindset in first-year students on the basis of a project-based approach in the process of online learning has been carried out. The study involved 250 students. The number of students who received average grades increased by 14.9 %; the number of students that received high grades increased by 15.65 % and 42.83 %, respectively. In the post-test of the experimental group, there were no participants who failed all tests. In the control group, there were no changes in the quality of a systems mindset. The novelty of the research concept is the fact that students learn the concepts of interactions in different systems in their first year of study that takes place in the online learning environment. The finding of the study can be useful for teachers of vocational universities that train first-year students.

1. Introduction

The development of a systems mindset is crucial in most jobs related to management, technological design, creation, implementation and support of complex technical systems. The development of technology and digital environment gives rise to the development of a systems mindset as a sign of professionalism in almost all jobs, including pedagogical ones (Pino-Fan, Guzmán Retamal, Font Moll, & Duval, 2017; Redmond & Macfadyen, 2020).

Systems thinking is required to adequately interact with the rapidly evolving digital environment, and becomes especially important in the context of the use of big data analysis and artificial intelligence in all major professions (Sajedi, 2018). In this regard, online learning is the most optimal environment for enhancing systems thinking skills, in particular, this refers to generations accustomed to the digital environment (Redmond & Macfadyen, 2020).

The issue is the time to introduce and teach systems thinking skills and their contribution to student development. Foreign publications devoted to education often focus on the earlier and comprehensive development of a systems mindset. This concept is often considered in the context of research on sustainable development, green thinking and business objectives (Lin, Shadiev, Hwang, &

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Shen, 2020). In Russian science, the problem is also described (Doronina, 2016; Zlatanović, Nikolić, & Nedelko, 2020).

(Pan, Valerdi, & Kang, 2013) consider systems analysis which relies on systems thinking as a toolkit for analysis and integrative synthesis. The researchers highlight the differences between the methods of developing a systems mindset in China and in the West and attach a special role to systems thinking in the formation of intuition used in decision-making.

In the education system, the systems approach is used as a guide for evaluating educational programs (Barrella, Cowan, Girdner, Anderson, & Watson, 2018). Almost all such programs involve online learning as an important factor that activates systems and critical thinking. It is important to train specialists to carry out this analysis.

The effectiveness of training that involves the development of a systems mindset is described by Hrin, Milenković, Segedinac, and Horvat (2017); they highlight the example of the effect of teaching chemistry to high school students based on the systemic approach. Specialized professional models of learning, in particular, in engineering, require the development of a systems mindset. Research devoted to its formation in engineering students is increasingly focused either on the full cycle of online learning, or on the introduction of strategic aspects of learning into the online learning environment. These include the development of systems thinking (Samarakou, Fylladitakis, Früh, Hatziapostolou, & Gelegenis, 2015).

Coombs and Bhattacharya (2018) suggests that the traditional system of education should be replaced with a system organized according to the principle of "a set of interacting knowledge". A learning system based on deep involvement can promote and facilitate the learning process.

A number of researchers emphasize the cognitive learning approach, which allows the student to be included in the system of "teacher-student-learning space". At the same time, the student's personality is the key systemic component of cognitive modeling. In order to focus on student personality, it is necessary to expand the vision of teaching activities in general, as well as their role in the life of society (Gilmeeva, 2018; Grohs, Kirk, Soledad, & Knight, 2018).

The development of cognitive skills is often considered more important than the actual acquisition of knowledge. The rapid development of technology and digital dominance contribute to the rapid obsolescence of information and the need for lifelong learning. In this process, the key role is played by online resources, which are more responsive to changes, and accordingly, the specialist should be ready for online training (Kulikov, Dron, & Kulikov, 2016; Tolstova, Suslova, Ryzhkova, & Yarina, 2018; Xiaofeng, Peng, & Yun, 2012). Popov (2019) also notes the importance of training based on a systemic-synergetic approach and analyzes the possibilities and nuances of its implementation.

Thus, we see that the development of a systems mindset in any education system is regularly considered as a priority and has recently been increasingly associated with online learning.

2. Literature review

Systems thinking as a category is regularly mentioned in the context of the lack of training of personnel who are ready to use this toolkit. The need for such specialists is observed in various sectors, such as politics (a theoretical study conducted at Corvinus University (of Budapest) (Király, Köves, & Balázs, 2017), life safety systems (Donovan, Salmon, & Lenné, 2015; Tetuan et al., 2017). Marshman, DeVore, and Singh (2020) introduce the concept of "holistic systems thinking", which can contribute to the development of a risk management system in economics and management. Each of these studies highlights the need for training aimed at the development of a systems mindset.

The choice of engineering solutions also depends on the level of systems thinking development, while the authors Xiaofeng et al. (2012) write about the increasing complexity of decision-making in engineering and the need to move away from traditional algorithms - basic decision equations (BDE). They have already emphasized that the search for non-standard solutions is usually reduced to the study of online resources, and it is necessary to highlight online learning as one of the important decision-making factors. When implementing software, the emphasis is placed not only on the importance of using software that allows managing more complex systems, but also people who can implement such systems and reveal the concepts of their operation (Cordeiro, de Vasconcelos, dos Santos, & Lago, 2020; Pill & Wotawa, 2019). In general, foreign researchers note that there is a shortage of personnel with developed systems thinking skills and offer various options for solving this problem, for example, the analysis of personal characteristics of thinking based on big data, etc. (Huang & Leng, 2019; Lin et al., 2020). Galiyev and Galiyeva (2017) consider systems thinking and analyze both methods and forms of education. They note the importance of using a variety of the forms of education to teach systems thinking skills. Some authors (Doronina, 2016; Redmond & Macfadyen, 2020) reveal the problems related to the ecological style of thinking which systems thinking is based on and formulate the problem of the lack of specialists in this area and the need to organize such training. Many researchers indicate that the process of making management decisions is associated with the appropriate analysis of the subject area, which implies a systems approach and the readiness of specialists to implement appropriate decisions (Lin et al., 2020; O'Konnor & Makdemott, 2017). A group of researchers rely on the extensive experience in the design and research of such systems and describe the concept of automating managerial decision-making as a mathematical model, which is, first of all, based on the readiness of managers for joint analytical activities with programmer analysts to update semantic links and data influencing decision-making (Kulikov et al., 2016).

The analysis of foreign research that considers systems approach in business as the most important element of building a successful business (Kerzner, 2017) revealed that the most significant factors that contribute to the development of a systems mindset are found in situational analysis, which is conveniently carried out in the online learning environment. Therefore, it is important to start teaching systems thinking skills as early as possible.

In Russian science, the theory of inventive problem solving (TRIZ) is considered as an example of the implementation of the concept of systems thinking. The theory is based on the works by Altshuller. He considered a model of inventive creativity. The researcher

described different levels of creativity; he believed that consideration of new principles of work was the highest level of creativity (Petrov, 2019). Therefore, the development of systems thinking requires a new vision of systems in education and professional field, as well as better awareness of their structure.

A number of modern researchers emphasize activity modeling when developing systemic perception of the object of cognition. It should be noted that if new knowledge does not fit into the current structure of activity, the cognitive effect will be poor. Therefore, students are not interested in cognitive activity unless they see the prospects for its use. This is a characteristic of the new digital generation (Pino-Fan et al., 2017). Consequently, it is necessary to include new knowledge in the system that precedes the discipline (daily life) and follows it (the system of higher educational institutions and professional activity).

A number of studies that describe the attractiveness of the course in terms of pedagogical design based on digital technologies are of particular interest (Redmond & Macfadyen, 2020; Samarakou et al., 2015). It is important that students have access to e-learning materials and can interact with the teacher in the online learning environment. However, there is a noticeable decrease in activity when working with these resources. At the end of the course, it is important to develop self-organization skills to work in the online environment and the ability to give adequate feedback.

It is noted that the development of creative thinking is a challenge in the training of vocational teachers (Rauner, 2019); therefore, the development of a systems mindset in the first year of study creates the basis for the further development of pedagogical and scientific creativity.

De Bono (2016) and his approach to the development of thinking and logic emphasizes not only the development of analysis, but also synthesis, design, and construction. It was found that 80 % of students cannot imagine themselves graduating from the university; most of them are focused on their assessments analyzing the reason they do this rather than the ways they can use it. New knowledge cannot be introduced into the current system of knowledge unless there is a long-term vector of knowledge development.

The introduction of project-based online learning that engages the student in professional activities in ICT disciplines in the first year of study should be considered. The novelty of the research is the new approach to the development of a systems mindset. The study is practice-oriented as its findings can be put into the practice of teaching ICT disciplines in the first year of study. It is assumed that within the framework of the projects it is possible to develop systems thinking as the projections of oneself into the future, not only at university, but also in the professional environment. This will speed up adaptation to the university environment, encourage students to master professional knowledge, as well as contribute to greater awareness in the process of mastering new knowledge and skills.

3. Materials and methods

3.1. Theoretical study of the development of a systems mindset in order to create a practical methodology

The research consisted of several stages. At the first stage, the literature on the development of systems thinking and the implementation of a systems approach in both educational and professional activities was analyzed. The structure of project activities has been developed. At the second stage of the research, the concept of the discipline design was implemented. The conversations with students aimed at the development of systems thinking were scheduled.

The focus is often placed on the development of systems thinking skills in senior students as they have already formed an idea of their future profession and the disciplines being studied are closely correlated. Therefore, most often it implies the development of interdisciplinary ties and the importance of the studied material for future professional activities.

3.2. An experiment based on the methodology for the development of a systems mindset in first-year students on the basis of a project-based approach in the process of online learning

The study took place at the Federal State Autonomous Educational Institution of Higher Education, Russian State Vocational Pedagogical University, Yekaterinburg, Russia. The Department of Information Systems and Technologies was involved in the research. The project was implemented within the framework of the Information Technologies discipline. First-year students of the vocational training program (by industry, namely "Design", "Music and computer technologies", "Translation and gist translation", "Technology and equipment of mechanical engineering", "Sports and health services", "Information Technology") participated in the study. A total of 250 first-year students (131 women and 119 men aged 18–20) took part in the study. They were divided into an experimental group (150 people) and a control group (100 people). Considering the size of the general sample, the admissible statistical error does not exceed 4.18; the research results can be considered statistically reliable.

The experimental group used the mechanisms for the development of a systems mindset based on online learning described in the present paper. Online learning elements involved the implementation by each participant of their own online project of switching to a more systemic vision of the future career. Communication between the teacher (the mentor) and the student took place on social media platforms at the mutual choice of the mentor and the student; the data were stored by Dropbox and Google Disk. Cloud-based online applications created intelligent maps of knowledge and training programs; student progress graphs and the trajectory of learning and implementing professional skills were developed from the perspective of the students; cognitive and educational information was provided at the individual request of the student in accordance with his or her interests. All student activities were supervised by a mentor. Also, all students regularly received logical problems within the studied disciplines focused on the development of systems thinking within their disciplines in accordance with the available methodology for the development of a systems mindset (Gray, 2018; Pill & Wotawa, 2019).

The System Reasoning Test (SRT) was carried out before the beginning of online training. This test assesses the skills of dealing with

conceptual and abstract problems that require an integrated approach. There are 4 types of problems in the test:

1 search for patterns in logical sequences;
2 search and analysis of patterns in structural diagrams;
3 analysis of diagrams and cyclic schemes (processes);
4 search for the relationships between elements.

A pre-test was carried out before the experiment began; a month later, a post-test was performed in each group. The test was conducted online using the individual account of each participant. It contained 30 questions and the time limit was 25 min. The assessment was based on a ten-point scale. Thus, the score of 10 points was given when all tasks were correctly solved within the given time limit while 0 meant the lack of correct solutions within the given time limit. When processing the results of the pre- and post-tests, the number of those who received a certain score in both groups was compared.

The results were statistically processed and visually presented in MS Excel 2014.

3.3. Ethical issues

All study participants were invited and agreed to participate on the basis of anonymity and voluntariness. No personal data of the participants was collected or used during the study. All participants received unique identifiers in the social network and for correspondence and assessment of knowledge, thus their confidentiality was guaranteed. The experiment did not affect the assessment of the learning process as a whole in the academic course and did not negatively affect the learning process of the participants.

3.4. Research limitation

The limitations of the study are related to their conduct in the educational context of only Russia, which requires expanding the context of the study to other countries, in particular, those using other forms and methods of developing critical thinking. Also, the study of the effectiveness and quality of the development of critical thinking is not structured according to separate gender, social and age groups and is concentrated only on first-year students.

4. Results

A theoretical study dedicated to the creation of a practical methodology of the development of a systems mindset has led to a number of models proposed below.

Fig. 1 shows a model that describes system complexity that is positively associated with the size of the system. Thus, the child initially learns a very small structure - the family, its way of life and the rules of interaction. Family values are not universal; they vary significantly. This leads to highly individualized personal attitudes (preschool institutions do not affect the formation of a child to the extent that schooling does). At the next stage, the child becomes a student of the first complexity level (a pupil). The child learns more

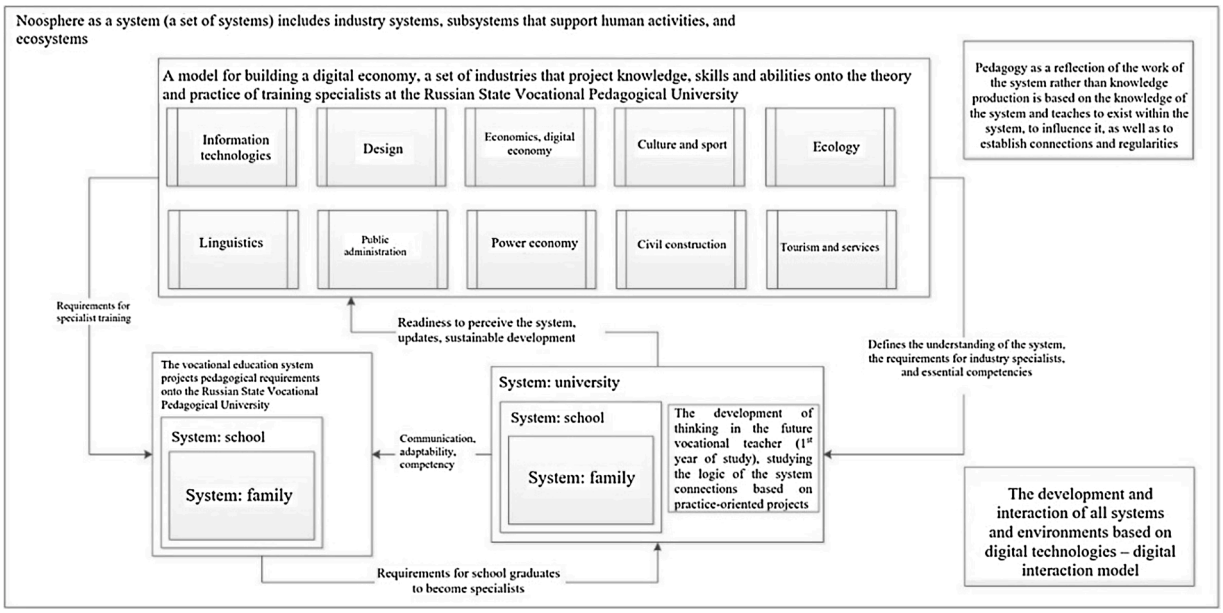

Fig. 1. Model of interdependent systems in which the learner can interact in contrast to the noosphere model.

about the world outside, the noosphere as a system, society as a whole; however, the family structure is still important for him or her as there has been no separation from the family yet and the outside world is perceived as something alien. At the next stage, being a teenager, a person enters the university environment. At a vocational pedagogical university, the student gets acquainted with the two systems: the noosphere, in which the emphasis is placed on sectoral activity, and the system of vocational training, which is studied from the perspective of being trained to conduct professional activities within the system. Due to the fact that the concept of digital society affects human ontogenesis, shapes a new image of a person, as well as a new way of life, digital technologies must harmoniously fit into project activities.

Let us consider the statement that it is important to develop systems thinking in order to form a holistic perception of the environment as a starting point.

Consistency in higher education is often perceived as an interdisciplinary relationship. However, the study highlights that there are no disciplines in the noosphere, as well as in the real system; therefore, it is necessary to shift the emphasis on the development of a systems mindset through the search for the connections between the ontological, scientific and professional space.

Therefore, teaching systems thinking in the first year of study at a vocational pedagogical university is a rational step. This becomes possible when projects focused on both the familiar system (ontological space) and new knowledge that expands the concept of this system (professional layer) are included in the educational process. The project involves students in the mini-infrastructure development that generally corresponds to training or the immediate environment. The semantic load allows students to make a conscious transition from being obsessed with the tasks of small systems to the tasks of large systems, to realize the scope of university education, and to summarize the pre-university experience in terms of its usefulness for solving business problems.

At the first stage, the implementation of end-to-end projects by senior Economics students was generalized. Fig. 2 shows that senior students become more aware of industry-specific activities; that is, they are ready to consider higher-level systems rather than a system representing a set of disciplines.

At the second stage, the results were interpolated into the first year program. The level of proficiency was taken into account. The involvement of students in the discussion of problems and tasks in this area expands the awareness of the principles of learning new system elements. Thus, university studies can be viewed as a system of interaction with teachers, who are the people having a set of professional competencies, in order to acquire systems skills. Students also get an idea of greater freedom when communicating with teachers and develop a new attitude towards mistakes; they learn to position themselves differently - an attempt to position oneself as a leader or a business owner is also a position of responsibility. The introduction of a system and criteria for assessing the quality of work makes people to consider the results of educational activities as an acquaintance with the principles of professional activities.

In the first year of study, it is most reasonable to implement a project based on the ideas that students already have and to draw analogies between the financial and economic, administrative and documentation activities of companies gradually expanding students' ideas about the issue under study and introducing additional connections and elements into the system of existing knowledge linking them with the future professional activity.

Computer skills of the first-year students are made up of formal experience gained at school and spontaneous informal learning; therefore, it is necessary to identify their percentage. The knowledge gained in the process of formal learning, according to the survey

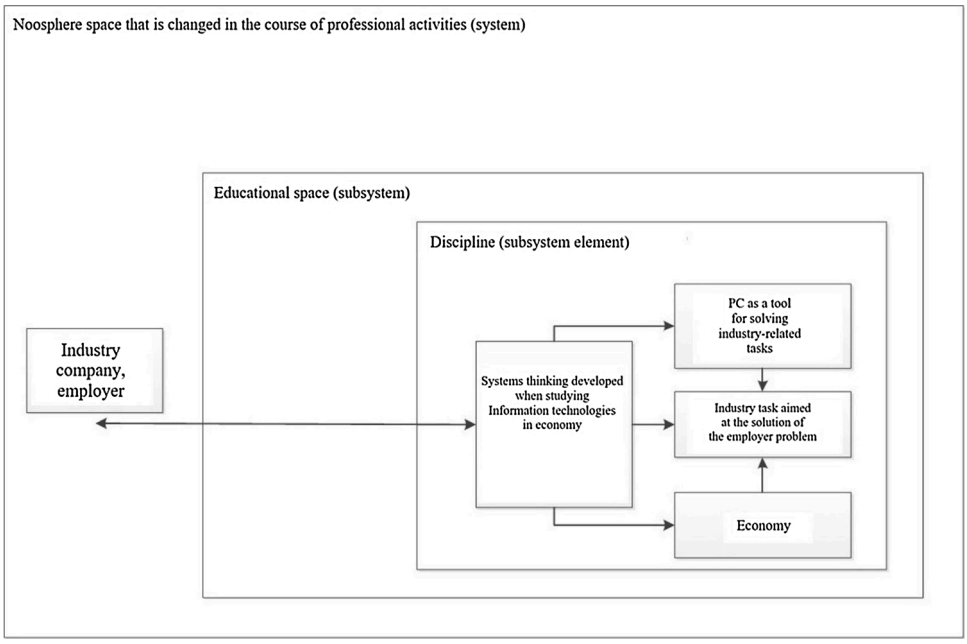

Fig. 2. Modeling of the educational process that involves quasi-professional project activities for senior students (systems thinking in the context of the industry as a system).

results, makes up 30 % of the total computer skills of 70 % of students.

An educational project allows first-year students to get a general idea about the digital economy within the framework of online learning, the interaction with a future employer online, and industry-specific tasks (Fig. 3) when considering company activities as a system

While working with the groups (more than 250 people), the following information was collected based on observations, interviews, and questionnaires:

- students try to introduce new knowledge into their developed world view when interacting with the teacher and studying a new topic (an increase from 2% to 20 %);
- students initiate a conversation about the need to study a particular function and try to introduce this knowledge both in the educational activity and future professional activities (from 1 % to 30 % of students);
- students consider their activities through the lens of objective reality (solving common everyday issues); professional activities (at the initial level, sometimes through the occupation or the level of a specialist); through professional activities beyond their vision - from the position of a manager, head of the department, business owner (from 2 % to 40 % of students);
- students do not consider professional activities in the context of digitalization (60 % of students); project activities make them review the role of PCs in professional activities and the involvement in activities that require the use of personal computers (70 % of students do not see themselves as PC users).

Thus, systems thinking is developed based on the combination of organization-pedagogical, didactic, and mainly psychological and pedagogical factors (Donovan et al., 2015; Galiyev & Galiyeva, 2017). The emphasis should be placed not only on interdisciplinary ties, but also on professional and pedagogical activities (Sclater, 2018). This contributes to better understanding of the need to study a particular issue, especially in the field of IT. One of the problems that teachers face is the lack of student involvement in the learning process and lack of student-teacher communication (Jalinus, Nabawi, & Mardin, 2017; Neupokoeva & Chapaev, 2016). Such projects will help first-year students to solve the problems of adaptation, to accept a new system for assessing the quality of work, and interaction with the teacher.

The test results for the experimental group are shown in Fig. 4. As for the use of the elements of online learning in the project-based approach to the development of systems thinking in the experimental group, the post-test results showed a significant improvement in systems thinking. Despite the short period of the experiment (one month), there were no students who could not complete any test task; the number of those who received the minimum grade (1–4 points) decreased by 60 % (from 25.34 % to 14 %); the number of students who received higher grades increased. The number of students who received average grades (5–6 points) increased by 14.9 %; the number of students that received high grades (7–8 and 9–10 points) increased by 15.65 % and 42.83 %, respectively.

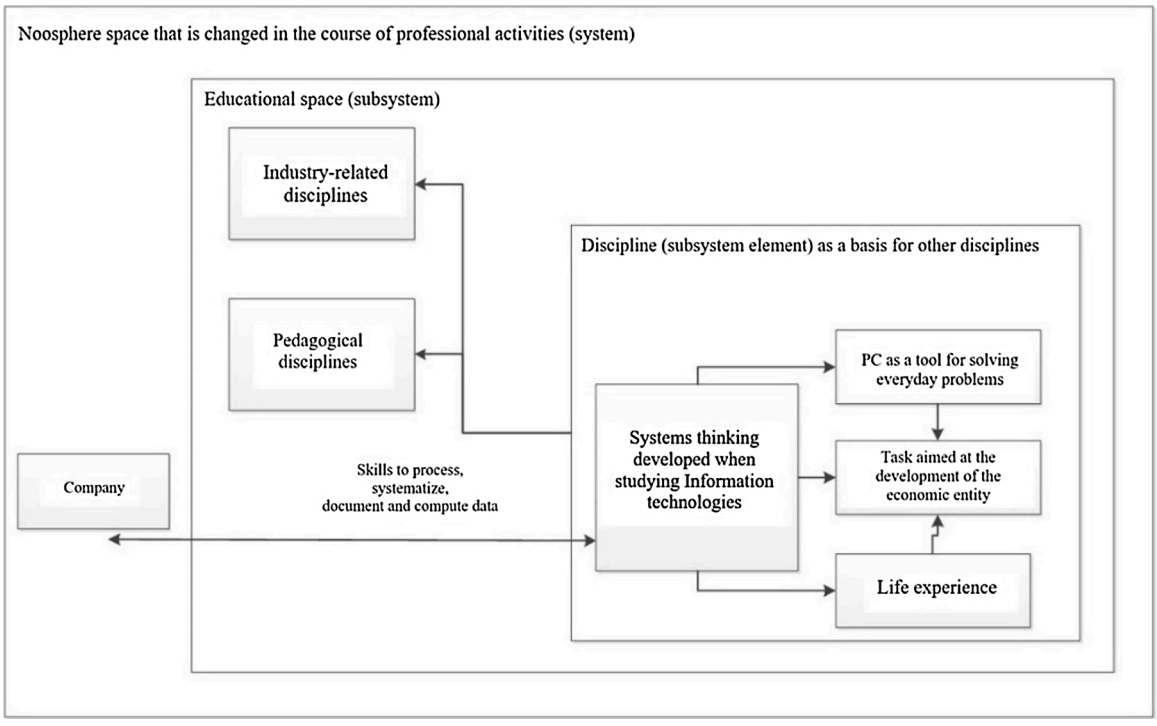

Fig. 3. Modeling of the educational process that involves quasi-professional project activities for first-year students (systems thinking in the context of the acquaintance with the industry and pedagogical activities, as well as at the level of interdisciplinary ties).

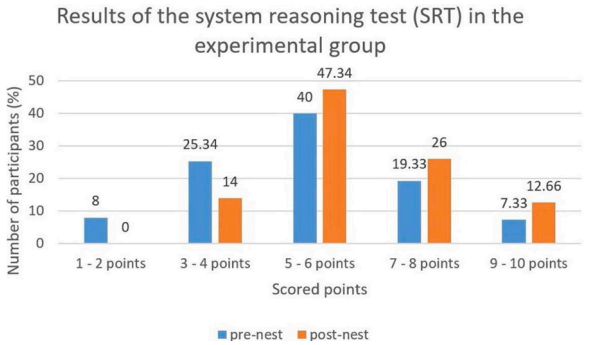

Fig. 4. Results of the system reasoning test (SRT) in the experimental group.

Fig. 5 compares the pre- and post-test results in the control group, where there were no changes in the learning environment, and the online methodology for the development of systems thinking was not introduced. The differences in the results of the pre- and post-test fall within the range of the statistical error (Fig. 5).

Thus, it can be argued that the introduction of the online learning methodology for the development of systems thinking based on the implementation of an individual project significantly improves the quality of systems thinking skills in first-year students. It seems that further research should be aimed at the study of individual trajectories of learning and professional development of students who demonstrated the improvement of the quality of their systems thinking skills. The long-term effect of these changes, as well as the ways to consolidate and systemically implement them in professional activities throughout the period of study and professional life, should be studied.

5. Discussions

Foreign and Russian studies, first of all, describe the importance of systems thinking in vocational training. Ateskan and Lane (2018) note the task of professional development of teachers in the context of the formation of readiness for sustainable development. They focus on the fact that sustainable development is impossible without the development of systems thinking. Due to the fact that the study of the discipline relied on the metropolis infrastructure as the noosphere element, the answers to the question of why a certain toolkit is studied resides in two planes: training students to solve problems of the educational process and implement projects in the space of sectoral activity, or the noosphere (Figs. 3 and 4). Therefore, when discussing the tasks of training vocational teachers, we need to remember that the ability for sustainable development is formed due to systemic knowledge, the stability of which is supported by systems thinking (Grohs et al., 2018; Pino-Fan et al., 2017).

O'Konnor and Makdemott (2017) emphasize the importance of changing mental models in relation to familiarity with systems thinking. The mental model of first-year students, according to the results of the study, has a large number of limitations; thus, it is important to expand the horizons of students.

We discuss the issue of the intersection of educational trajectories, which corresponds to the realities of life. At the same time, it is necessary to create individual educational trajectories implemented through the development of elective electronic content (Hohlova & Starikova, 2018), as well as introduce business games and case studies.

The famous Russian researcher Shchedrovitsky considered the systemic-structural activity approach as the leading approach to the development of systems thinking and called this process *the formation of mental activity*. The author referred to hermeneutics to analyze the transposition of experience into "situations occurring in life". In fact, the author considered the process of distorting person's vision of the situation based on the current experience, frameworks, clichés; he analyzed obstacles to creative problem solving, realizing the

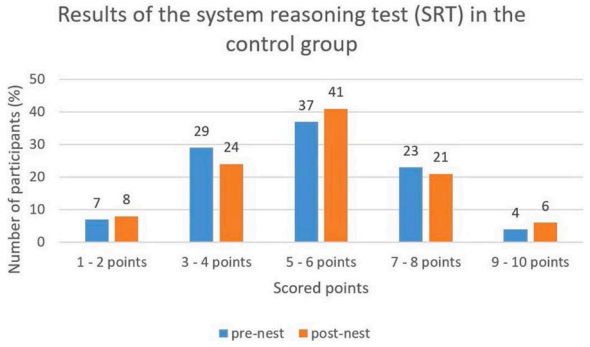

Fig. 5. Results of the system reasoning test (SRT) in the control group.

system operation logic and finding ways to solve systemic problems (Stol, 2020).

Due to the fact that the development of systems thinking involves soft skills, primarily communicative ones, we were focused on the research devoted to their development. Ngang, Chan, and Vetriveilmany (2015) highlight the importance of integrating soft skills into each discipline (course project) in teacher training. At the same time, the researchers note that the factors hampering the development of soft skills are the large size of the audience to ensure interaction and the short study period. Other authors indicate that the solution to both problems is online learning; thus, the development of critical systemic knowledge and skills should partially take place in the online learning environment (Akpur, 2020; Samarakou et al., 2015). It can be concluded that the development of soft skills when studying Information technologies is acceptable and desirable as speech (written or oral) is an essential element that reflects the processes of thinking.

The approach described in the present paper correlates with the study by Sajedi (2018), who examined numerous teaching practices and found that the style of thinking is directly related to pedagogical creativity. Due to the fact that creative thinking is mainly based on systems thinking (Neupokoeva & Chapaev, 2016), students are placed in the environment where they can "expand their mental horizons." The idea to develop micro-businesses in micro-infrastructure makes it possible to discuss a range of issues related to the digitalization of society, the economic sector, and, most importantly, personal contribution to the process. It has been mentioned that student thinking evolves from the interaction in small systems (family, school) to the interaction in large ones (vocational training, university). The integration of business activities and economy into the online environment requires the development of a large-scale strategic vision of a professional in this environment. The best decision is the early introduction of the elements of project-based online learning, at least, in higher education, which is also highlighted in the study.

In an ideal scenario, the university should develop large-scale thinking in students (organization or enterprise, industry, country, noosphere). It is impossible to expand the scope of thinking without setting large-scale tasks. Thus, the simultaneous focus of students on the two systems - the university environment and the noosphere - contributes to the solution of the problems of the activities that students are taught to conduct and thereby initiates a greater degree of memorization of the educational material and greater strength of the skills and abilities formed (Akpur, 2020; Lin et al., 2020; Rajagopalan, 2020).

Some researchers focuse on the use of project-based learning to solve problems related to the future professional context and links theory with practice. He emphasizes that the project-based approach complies with the requirements of the Bologna Process for European higher educational institutions (Dunn, Farquharson, & Mann, 2020; Jalinus et al., 2017).

We believe that it is feasible to link the project structure to the systemic connections inherent in professional activity; it reveals the possibilities for discussing both pedagogical and industry-specific tasks, issues, and problems. Jokonya (2016) considers the issue of training analysts capable of implementing information technologies in company activities, which requires an interdisciplinary approach. Digitalization raises the issue of combining digital and information and communication training and the development of critical and systems thinking skills.

Foreign researchers are trying to create universal patterns for the development of systems thinking (York, Lavi, Dori, & Orgill, 2019) and challenge this practice (Vesty, Dellaportas, Oliver, & Brooks, 2016). We agree that certain thought patterns can facilitate system state analysis, but they will never replace the importance of the comprehensive vision of the system with due regard to its states, both possible and unlikely. This approach was not used in the present paper; however, further research should be focused on the effectiveness of the thought patterns for the development of critical and systems thinking skills.

In higher education, there is an approach to designing the educational process that is based on interdisciplinary ties (Sclater, 2018). However, the approach has a limitation; it considers consistency only within the framework of university education, that is, it teaches “to think in disciplines”. We believe that we should think more broadly and consider not only the "student-university" system, but also the "graduate-employer", "graduate-industry training", "young specialist-career" systems, etc.

The analysis of the scientific interest in systems thinking in the Russian scientific community shows that most studies on systems thinking are related to secondary education, which is confirmed by the review work by Galiyev and Galiyeva (2017).

Methodological techniques for the development of systems thinking, in particular, on the basis of online learning, in higher educational institutions are not described in the Russian scientific literature, in contrast to the Western sources. The exception is healthcare industry; annually, there are about 5 publications on the development of systems thinking when teaching disciplines in medical universities, but for obvious reasons, these sources were not included in the references.

6. Conclusions

The study reveals the concept of the educational process structure aimed at the development of systems thinking in first-year students of a vocational pedagogical university based on a project-based approach implemented in the online learning environment. The research can contribute to the study of the development of systems thinking. An experiment based on the methodology for the development of a systems mindset in first-year students on the basis of a project-based approach in the process of online learning was carried out. The study involved 250 students of the Federal State Autonomous Educational Institution of Higher Education, Russian State Vocational Pedagogical University, Yekaterinburg, Russia. The experiment lasted for a month. The results of the pre- and post-test procedures of System Reasoning Test (SRT) revealed an increase in the experimental group results. The number of students who received average grades (5–6 points) increased by 14.9 %; the number of students that received high grades (7–8 and 9–10 points) increased by 15.65 % and 42.83 %, respectively. In the control group, there were no changes in the quality of a systems mindset. The research also examines the key aspects of the methodology for implementing project activities by first-year students in the online learning environment taking into account the development of the systemic perception of the skills acquired. The novelty of the research lies in the use of an interdisciplinary integrative approach in the program for preparing critical thinking, consistent with the

global context of developing students' critical thinking skills. The program is focused on adjusting the existing educational paradigm and eliminating the conflict between the educational practice existing in Russia and other countries and professional requirements.

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CRediT authorship contribution statement

Elena Neupokoeva: Conceptualization, Data curation, Writing - review & editing. **Nikolay Chapaev:** Formal analysis, Funding acquisition. **Irina Suslova:** Investigation, Methodology, Visualization. **Natalya Khokhlova:** Project administration, Supervision, Validation. **Aleksandr Sosnin:** Resources, Software, Writing - original draft.

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