Construction of an Education Model of Natural Disciplines' Students in the Distance Learning Conditions

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Abstract: For a number of reasons, in particular the introduction of urgent quarantine measures, a temporary change is taking place in the format of full-time studies on distance learning. This requires a quick reorientation of the teacher and students to use educational solutions to provide remote access to teaching material. The article studies the requirements for building a distance course in order to quickly adapt full-time education to distance learning. The features of the organization of distance STEM education are determined. The pedagogical and technological aspects of supporting distance learning STEM are established. The problems that may arise during the organization of distance learning are analyzed and models for overcoming them are considered. An example of constructing a course in accordance with established requirements is given.

1 INTRODUCTION

Distance education is an important factor in acquiring special competencies and a sufficiently powerful resource in the form of online learning skills (not just communication) for further career development of both students and teachers (Kuzminska et al., 2019).

The advantages of distance learning are obvious: to study anywhere and anytime, to determine the amount of information to be processed in a certain period independently, the opportunity to obtain quality, relevant knowledge, learning simultaneously in several areas or combining with work and more. But the effectiveness of these benefits must be ensured by a well-prepared course with different activities. The materials for such course are significantly different from the materials of the full-time course, where the teacher takes into account the characteristics of the audience that listens to him, can supplement the material with clarifications, make an analogy, emphasize the features. Distance courses are planned and prepared for a long time, have several iterative changes. The differences between a quality distance learning course and its hybrid replacement by "emergency" distance learning are described in (Hodges et al., 2020). So the issue of effective transformation of the educational process, which would ensure the construction of education in conditions of limited access to educational institutions, is relevant.

Distance STEM education has the prospect of going beyond traditional educational institutions, providing equal opportunities for students to master modern research skills (Sharko, 2017). Therefore distance STEM education can be considered as an alternative approach to learning that can provide solutions to the problems of science and mathematics learning. However, although the number of studies on distance education has been growing recently, the study of the possibilities of distance STEM education is insufficient. In addition, there is the issue of ensuring permanent access and effectiveness of distance STEM education.

2 LITERATURE REVIEW

The issues of distance education are sufficiently covered in scientific research. The study of the experience of developing distance learning courses has shown that the issue has a fairly wide range of solutions in organizational, methodological and resource areas.

In Ukraine there are scientific schools exploring the possibilities of distance education and the princi-

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ples of its organization. Works by Kukharenko and Oleinik (Kukharenko and Oleinik, 2019), Vakaliuk et al. (Vakaliuk et al., 2021), Yahupov et al. (Yahupov et al., 2020) and others devoted to the development of distance learning methodologies and the creation of distance learning systems. The issues of effective organization of distance learning and distance learning technologies are devoted to the works of Franchuk and Prydacha (Franchuk and Prydacha, 2021), Kravtsova et al. (Kravtsova et al., 2020), Kushnir et al. (Kushnir et al., 2020), Petrenko et al. (Petrenko et al., 2020), Polhun et al. (Polhun et al., 2021), Zinovieva et al. (Zinovieva et al., 2021) and others.

The organization of a distance STEM training course should notice the following features:

- Scientific approach to the study of the environment – the issues studied and researched by STEM education are among the phenomena for which it is necessary to develop a theory and find an answer about their essence, to give them an explanation.
- Availability of experimental and laboratory work – environmental studies provide empirical data that needs to be analyzed and explained.
- Data processing and analysis – research data are usually presented in tables or graphs and require visualization, interpretation and statistical processing.

Consideration of these features in the organization of a distance course of STEM education can be considered from the standpoint of two main aspects:

- Pedagogical – refers to understanding the principles of organization of STEM student training, the ability to apply research methods in future professional activities. Includes the desire to support different types of interactions in the learning process (Chi and Wylie, 2014; Osadchyi et al., 2019). This aspect defines learning as a social and cognitive process, not just as a matter of information transfer.
- Technological – mostly, refers to recommendations for the use of technologies, in particular, robotic, biochemical, programming environments; selection of technical means that best meet the solution of professional tasks; developing the structure of the course and its content and supporting the learning management system, creating multimedia, determining the content to be covered.

Ensuring a scientific approach to environmental research by students sometimes faces problems if the distance learning course has not noticed pedagogical principles and provisions. For example it could be finding the right information for research. Lewis and Contrino (Lewis and Contrino, 2016) conducted a study of students' online courses and determined that among the most common models of information retrieval by students for educational purposes are:

- Misconception about the research process. Most students chose a linear research model, i.e. they added materials to their work using keywords and direct links, using them as "facts". The search for already adapted information to the requests and needs of students is conducted, and the set of information and its analysis is not analyzed. However, research projects must contain a critical understanding of the information, which requires combining different sources of information into an abstract idea expressed in their own words. The use of linear research models, the authors note, can lead to the use of unreliable information as a "fact".
- Misconception about the semantic search for information on the network. Instead of entering keywords and phrases, students often used direct questions and waited for answers online. The authors note that this model is easily adjusted by learning using a variety of sources of information, including statistics, directories, and research reports of a scientific nature.
- Finding a single source for research or hoping that the teacher will simplify their search and provide everything they need to complete the task.

The lack of students' readiness to search for information and scientific approach to research independently requires to change the organization of their search activities and pay more attention to adjusting the process of designing a distance course so that it contributes to the development of their independence skills. One of the ways to overcome such problems, the authors see in the creation of special interactive sections of the course, instructions on how to search for information. The course itself can also include dynamic links to databases where you can quickly and efficiently find the material you need.

To address these issues, the University of Plymouth has developed an ACE framework – adaptability, communication and equity – to manage decision-making and professional development planning in the context of distance learning (DeRosa, 2020). Each of the frameworks has three levels of distance learning organization: at the level of teaching, at the level of course organization, at the level of the educational institution.

- Adaptability.
  - At the level of a task tutors can set up more nasty task doing terms for the students, because it is clear that they will face difficulties or uncertainty, and it is possible to join students to creating tasks or let them choose tasks from several variants.
  - At the level of a course you can set courses allowing students to pick up the available online and full-time options, as well as to consider the circumstances, and to break the programs on the smaller modules, which can be set up in different modalities depending on different scripts of technical availability of distance learning.
  - At the institutional level it is possible to acquire technology and infrastructure based on the needs of the tutors and students and to provide culture in the university which would help students not to not to continue studying despite difficult circumstances.
- Linking.
  - At the task level tutors can create a task, giving students the opportunity to bring their work to communities, for whom such help would be useful or important, and to understand Internet not just as a channel for exchanging but like a portal which connects studying students.
  - At the course level you can connect an open mind from the reality of life while crisis by asking students to see the links between their abilities and needs. You can use open platforms and give to the masses the corny servants and to prevent the demands of done work using them.
  - On the basis of the mortgage it is possible to reserve additional help from the designers of the studying materials for tutors support. There is also a need for additional help in integration at the training courses of the ways which help to establish the progress in the community, for example, including examples of local and global real life problems' solving in the teaching context.
- Availability.
  - At the task level, tutors can learn the basic principles and universal design tools for learning to ensure the availability of the course as much as possible, and it is allowed to propose a number of advertising channels, so that students could take part with any technology at any time.
  - At the course level, you can quickly go to free educational resources to ensure the availability of the text in the course and reduce cost of the teaching materials.
  - On the basis of the mortgage, it is also possible to set the basic information about the resources and to pay attention of the community to the studying program, and to ensure that the integrated support of the basic education requirements is provided.

The technological course building aspect of distance learning has its own rules. Whereas distance learning course is the supremacy of electronic content, there is the possibility of organizing its elements in relation to the rules used in functional design. These recommendations were made in (Davidson et al., 1999):

- Simplicity – studying is not guilty of "pushing", but "leading" after itself (Malamed, 2015). Each question in a topic can be represented or complemented by short videos (5-10 minutes), overmotivating (motivational) events or by awards (badges). Create a library of "micro lessons". You may be able to compose in the right sequence and to pick it up easier
- Familiarity – each theme must rely on the forefront knowledge, perhaps the model of analogies or journalistic method can be used, which is closed by practical tasks. Analogies see one or more points of similarity between two other things. For example, it can be a part of the function of a cell and a factory (sciencenetlinks.com, 2021). But the analogy method using must have a point, where analogy may be destroyed (Aubusson et al., 2006). The journalistic method is using: breathtaking headlines, teasers in the menu, informative graphics, motivational phrases or history for the completion of the course, which will reflect the essence of the course (Veglis and Pomportsis, 2014).
- Accessibility – the course may not only have enough links on additional resources, but also the doing terms, variants of consulting with the tutor, the possibility of asking questions to classmates or a tutor. Directions are also an important element. Students need strict instructions how to move forward and what progress they achieved.
- Flexibility – the course can be adjusted to the choice of task-doing tools, or the material learning algorithm or doing time independence with meeting the deadlines. Flexible studying program: in the individually determined studying environment student is a doer in creation of flexible studying program defined by a student: students make a studying map and the instructors are like a compass (Hase and Kenyon, 2007).

- Questions directed to the studying and discussion which follows after the questions – that orients students and works as the mechanisms, which help the students to understand the course, to make the idea clear and contribute individual and group reflection.
- Feedback – is a prerequisite for successful learning, the course should provide constant communication about the tasks performed and the results of actions. This allows students to evaluate the results of their work and be more motivated for further study. Assessment should include measurable forms of assessment of understanding the content, determining whether the student has achieved the desired competencies (Hase and Kenyon, 2007, 2001). One example is the use of student assessment by other students, followed by the publication of reviews and discussion. This helps to critically comprehend the evaluation criteria and the presented material, as well as to evaluate one's own achievements (Kushnir et al., 2013).
- Safety – students should feel comfortable taking the course, knowing that they can return to the study of the topic, repeat the material passed, retake the test. Assessment, discussed and defined by students, improves their motivation and involvement in the learning process, as well as makes students feel more protected from the teaching control of their learning process (Canning, 2010).

But despite the sufficient attention of scientists to the problems of building distance learning the issue of distance STEM education and the study of the peculiarities of its organization remains unresolved. One of the advantages of distance STEM education is its accessibility not only to teachers, students, but also to everyone, from scientists, technicians, mathematicians and engineers, to ordinary people who want to study or improve their skills, or can not go to institutions. education due to restrictions (e.g., quarantine).

The *purpose* of the article is to clarify the pedagogical and technical features of educational approaches to building a model of distance STEM education for students of natural sciences.

3 RESEARCH RESULTS

The basis of STEM education is the integration of natural-mathematical and engineering areas of education. The natural component provides a context for combining the study of different disciplines. The engineering component is a unifying category that contributes to a better study of science and mathematics. But integration must take into account their different epistemological characteristics (Herschbach, 2011; Sanders, 2008; The PEAR Institute: Partnerships in Education and Resilience, 2019; Williams, 2011). When planning and building a model of STEM education, these characteristics must be taken into account to preserve the integrity of each industry.

The model of distance learning should correspond to the model of preparing students to study STEM disciplines. It takes into account the relationship of such components as: value-motivational (worldview, the formation of a system of personal development); content-organizational (formation of conceptual connections between theory and practice, planning the study of fundamental disciplines, creating a field of interaction); applied cognitive-activity (implementation of project activities: independent reflection, analysis, work with the teacher); evaluative reflexive-analytical (study of best practices, development of innovations).

The purpose of the system of preparing students to study STEM disciplines is the formation of worldview, which is the result of value-motivational system of personality development (Osadchyi et al., 2020a). Any activity is the result of the action of "value" regulators, which determine the motives and behavior of the individual. Based on the value attitude to technology, the following requirements can be distinguished (Sipiy, 2018):

- awareness of the place and role of technology in human life;
- effective use of equipment (competent, rational, timely, effective;
- safe use (both for yourself and others);
- environmental consequences of use.

The system of preparing students for the study of STEM disciplines is based on didactic and pedagogical principles of teaching and their system integrity:

- the principle of accessibility and awareness of cognitive activity, which provides the actualization of scientific knowledge and activation of cognitive activity through the differentiation of educational tasks and the use of modern teaching aids;
- the principle of scientificity, as a basis for the fundamentalization of knowledge and the formation of the content and organizational component of the model of personality-oriented system of student training. The leading idea of this principle is not the simplification of "scientificity", but the

provision of knowledge that corresponds to the objective reality, in accordance with the age and knowledge levels;

- the principle of systematization, as a basis for the integration of disciplines in order to form logical thinking and a holistic scientific career of the world, taking into account the already formed ideas about the functioning of the environment;
- the principle of linking learning with the needs of real life, as a basis for the formation of skills in demand in the XXI century (Gray, 2016);
- the principle of student-centeredness and personality-oriented learning, as the appropriate direction of the educational process from the needs and level of development of the applicant, through the construction of an individual educational trajectory, in order to implement the tasks of STEM education;
- the principle of emotional participation, as a basis for further involvement in solving educational problems and project activities related to real life situations. The leading idea of this principle is the formation of a value-motivational component of the model of personality-oriented system of student training;
- the principle of cooperation and mentoring, as an opportunity to organize teamwork and support continuity in the system of knowledge transfer.

Formal features of the structure of students' preparation for the study of STEM disciplines define (Valko, 2019):

- the existence of an educational environment, part of which are professional communities that adhere to the norms of introduction of new technologies in the professional activities of students, and is a center of support and dissemination of innovation;
- the presence of disciplines in training, the principle of organization of which is based on integration and project activities;
- availability of scientific problems, the solution of which is based on the integration of scientific methods and innovations into educational activities;
- availability of tools and technologies that will ensure the use of innovative approaches.

The concept of preparing students for the study of STEM disciplines is based on the following methodological approaches: personality-oriented, competence, integrative, axiological, activity.

Personality-oriented approach is the basis of the educational process and determines the forms, methods and means of developing the professional qualities of the student, gaining their own experience. It is closely related to the axiological approach and embodies the student's subjective choice of forms, means, and methods of teaching in future professional activities. Therefore, the issue of proper organization of personality-oriented educational process is gaining importance, in order to stimulate important patterns of life of students. Behavioral models, in the context of STEM education, are the ability to choose their own educational trajectory and be active in the application of STEM technologies.

The *competency approach* directs the process of professional training to the formation of the student's readiness and ability to effectively use external and internal resources (informational, human, material, personal). This approach allowed identifying the components of student training and presenting them as a holistic system of professional, personal and social orientation.

The *integrative approach* is part of the process of fundamentalization of the system and performs the function of system integration of all components as a whole, taking into account the interconnectedness of all components of student training (Semerikov, 2009).

The *activity approach* serves not only as a basis for practical training of students, development of its cognitive forces and creative potential. It can also be a criterion for choosing possible areas of activity and influence the forms, methods and means of cognitive activity.

The *axiological approach* builds the value-motivational component of the student training system. It defines the guidelines of professional activity and contains social, psychological and ethical principles of behavior, which are related to the integration of technology and research into the educational process, determining their pedagogical value.

Based on these provisions, we can formulate the task of professional training of students to study STEM disciplines as the integration of these components, which are expressed in the formation of his skills and abilities to:

- independent construction of teaching your subject using modern technological and engineering knowledge with the help of modern technological tools;
- preparation of the individual for the decision of global questions with application of technological decisions in the course of training and being based on innovations in the field of technologies;

- identify trends in the modernization of world technologies and their impact on educational activities,
- involvement of students in research activities and management of their project activities using innovative technologies;
- dissemination of innovations and knowledge about them in the professional circle and in everyday life.

We will distinguish between different levels of formation of the value-motivational component depending on the activity that underlies such a division, and, consequently, the purpose of such activities. The initial level is characterized by activities aimed at forming an environment of communication and developing interest in the study of STEM disciplines. The next level is based on quasi-professional activity, the value of which is determined by the degree of conscious use of STEM technologies. The third level is characterized by awareness of the value of knowledge through the prism of scientific and technological picture of the world and readiness for such activities. The final level is the formed need and ability to transfer experience, knowledge, values in the process of communication.

The purpose of the *content and organizational component* of the system of preparing students to study STEM disciplines is to form conceptual links between theory and practice, planning the study of fundamental disciplines, creating a field of interaction between participants in the educational process. The structure of the unit is compiled in accordance with industry standards, educational programs and curricula: technical and fundamental disciplines, special elective courses and participation in extracurricular activities. Accordingly, an educational environment for STEM oriented learning should be formed, which would ensure the implementation of this unit. Resource components of the content-organizational stage are software and hardware, educational and methodological support of the educational process and influence the formation of the educational environment of STEM oriented learning.

The content and organizational component of the system of student training is determined by the plan of studying fundamental disciplines and the formation of a knowledge base for further study. It is formed under the influence of both objective and subjective factors. Objective factors are the educational regulatory framework, these are: industry standards, updated educational programs, curricula of specialties. The subjective ones include cognitive activity, the choice of which depends on the student himself: special elective courses, master classes, extracurricular activities. Each of these factors is crucial for meeting the requirements for student learning outcomes and indirectly affects the formation of their professional behavior. These factors can both promote and hinder the formation of self-determination and training.

The *cognitive-activity component* has an applied character and is directly related to the training of future specialists. This block reflects the process of learning and includes both formal and non-formal and informal education: basic knowledge, project activities, cooperation with research centers and communities.

We conducted a survey aimed at establishing the experience of using different teaching methods in students. We interviewed students of natural sciences and mathematics. The questionnaire consisted of two types of questions: choose one or more answers, as well as questions with a score on the Likert scale. The questionnaire also provided the opportunity to add your own comments to the questions, in case there were no answers in these options.

The process of preparing future teachers of natural and mathematical disciplines for the application of STEM technologies in their professional activities takes place in the course of the sequential implementation of five stages, namely: initial, introductory, quasi-professional, professional-practical and resulting. Moreover, each of the defined stages has its own goal and objectives.

So, the purpose of the *initial stage* is to determine the initial state of readiness of future teachers of natural and mathematical disciplines to use STEM technologies.

The objectives of this phase include:

1) preparation for experimental work;
2) involving future teachers of natural and mathematical disciplines in experimental work;
3) determination of the initial state of readiness of future teachers of natural and mathematical disciplines to use STEM technologies.

The *introductory stage* of preparation is aimed at actualizing future teachers of natural and mathematical disciplines as the main providers of STEM education to schools and initiating their interest in the use of STEM technologies.

The main tasks of this stage are:

1) awareness by future teachers of the importance of their professional activity as a teacher of natural and mathematical disciplines for STEM education;
2) awareness of the complexity and multidimensionality of the professional activity of a teacher of

natural and mathematical disciplines in the context of STEM education;

3) initiation of the interest of future teachers of natural and mathematical disciplines in the application of STEM technologies in professional activities by preliminary acquaintance with the means of STEM education;

4) providing students with the opportunity to express their own experience and impressions received during their acquaintance with their future profession and STEM education;

5) actualization of future teachers of natural and mathematical disciplines as the main providers of STEM education in schools.

The *quasi-professional stage* of preparation should ensure the formation of knowledge, skills and value-motivational guidelines for future teachers of natural and mathematical disciplines, necessary for the application of STEM technologies in their future professional activities.

At this stage, the main tasks are:

1) theoretical training of future teachers of natural and mathematical disciplines for the use of STEM technologies in professional activities;

2) the formation of pedagogical and technological components of the readiness of future teachers of natural and mathematical disciplines and their content components;

3) the direction of the cognitive activity of future teachers of natural and mathematical disciplines to acquire a quasi-professional experience of using educational information in situations that imitate professional activities;

4) the formation of value orientations among future teachers of natural and mathematical disciplines, united around the conscious use of STEM technologies;

5) the formation of future teachers of natural and mathematical disciplines of a holistic understanding and vision of their future professional activities in the context of STEM education.

The *professional-practical stage* of preparation provides for testing students in the role of teachers of natural and mathematical disciplines and the correction of ineffective behaviors using STEM technologies.

The objectives of this stage are:

1) testing students in the role of teachers of natural and mathematical disciplines;

2) testing the pedagogical readiness of the future teacher of natural and mathematical disciplines;

3) testing the technological readiness of the future teacher of natural and mathematical disciplines;

4) the awareness of future teachers of natural and mathematical disciplines of the value of the knowledge, skills and quasi-professional experience acquired by them for further professional activity in the conditions of STEM education;

5) the awareness of future teachers of natural and mathematical disciplines of their own readiness to use STEM technologies in their professional activities.

The goal of the final stage is to determine the final state of readiness of future teachers of natural and mathematical disciplines to use STEM technologies in their professional activities.

The objectives of this stage are:

1) determination of the final state of readiness of future teachers of natural and mathematical disciplines for the use of STEM technologies in professional activities;

2) summing up the results of the experimental work and drawing conclusions regarding the effectiveness of the developed model of the system of future teachers of natural and mathematical disciplines for the use of STEM technologies in professional activities;

3) if it is necessary to adjust the developed model of the system of future teachers of natural and mathematical disciplines to the use of STEM technologies in professional activities.

The developed model takes into account a set of organizational and pedagogical conditions that ensure the effectiveness of the implementation of the system of training future teachers of natural and mathematical disciplines for the use of STEM technologies in professional activities, namely:

1) updating the content of professional training of future teachers of natural and mathematical disciplines to use STEM technologies;

2) implementation of STEM projects in robotics by future teachers of natural and mathematical disciplines;

3) ensuring during the training of future teachers of natural and mathematical disciplines their social interaction in a professional environment.

In terms of the organization of environmental research and analysis of empirical data, it is necessary to ensure the study of STEM disciplines by means that effectively help: conduct research, create models to describe systems, organize experimental activities, conduct statistical processing of empirical data. The theory and practice of research can be linked through the use of simulators and virtual laboratories (Osadchyi et al., 2020b).

As part of the creation of a distance course "Fundamentals of Robotic Systems" for undergraduates, we used the above provisions regarding the technological and pedagogical aspects of the course. To do this, the following elements were introduced into the course:

1. Short motivational videos about the achievements of modern technologies and robotics. The motivational component is crucial for the formation of the worldview of future professionals, which is the result of the formation of value-motivational system of personal development. Any activity, including professional, is the result of the action of "value" regulators, which determine the motives and behavior of the individual. One can use the following topics to form a valued attitude to technology:
   - awareness of the place and role of technology in human life;
   - effective use of technology (competent, rational, timely, effective;
   - safe use of technology (both for themselves and for others);
   - environmental consequences of the use of technology.

   The value-motivational component has different levels of formation, depending on the type of activity and its purpose. The initial level is characterized by activities aimed at forming an environment of communication and developing interest in the study of STEM disciplines. The next level is based on quasi-professional activity, the value of which is determined by the degree of conscious use of STEM technologies. The third level is characterized by awareness of the value of knowledge through the prism of scientific and technological picture of the world and readiness for such activities. The final level is the formed need and ability to transfer experience, knowledge, values in the process of communication.
2. The content of training is a decomposition of elementary topics of connection of robotic devices. Execution of such elementary task allows to carry out activization of cognitive activity on related subjects: physical properties and laws, designs and algorithms of programming, engineering of designs, etc. Each of the tasks has a clear practical significance. The purpose of such construction of the material is to form conceptual connections between theory and practice, to plan the study of fundamental disciplines, to create a field of interaction between the participants of the educational process. Due to the unavailability of robotic designers for the quarantine period, the Tinkercad environment was chosen to perform the work. A number of projects were created that simulated various robotic systems in a virtual environment.
3. Each completed task was available for discussion in the team through a system of links in the course. Thus, students could get acquainted with the work of classmates and make suggestions for improving the presented projects. Such social expertise proved to be effective enough to form a critical view of their own projects and to analyze and discuss the results of modeling robotic systems.

Thus formed STEM training course provides the implementation of the functioning of distance STEM education. Resource components of the distance STEM course for teaching undergraduates the basics of robotics – software, hardware, teaching and methodological support (Valko and Osadchyi, 2021) – were adapted to the distance educational process in order to form an educational environment for distance STEM learning.

4 CONCLUSIONS

As a result of the study, it was found that the transition to distance learning requires teachers and educational institutions to change approaches to teaching and building courses. Such changes must be justified not only at the technological but also at the pedagogical level. Based on the various models of distance learning, the article identified the features of distance learning STEM disciplines. The components of the system of teaching students to study STEM disciplines are determined: value-motivational, content-organizational, cognitive-activity for the implementation of project activities, reflexive-analytical. The distance learning model must take these components into account and ensure their integrity. The principles of preparing students for the study of STEM disciplines were taken into account in the organization of distance learning in STEM specialties. Pedagogical and technological aspects of distance learning construction are considered. Pedagogical aspects are the activation of cognitive processes and active involvement in the cognitive process. The technological aspect is a set of rules for organizing the elements of the distance course. The skills that should be formed as a result of such training are singled out.

Therefore increasing the efficiency of the distance educational process and solving the pedagogical aspect is possible through the correct technical organization and structure of the distance course.

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