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20

IMPACT OF STEM EDUCATION ON SOFT SKILL DEVELOPMENT IN IT STUDENTS THROUGH EDUCATIONAL SCRUM PROJECTS

IMPACTO DE LA EDUCACIÓN STEM EN EL DESARROLLO DE HABILIDADES SUAVES EN ESTUDIANTES DE TI A TRAVÉS DE PROYECTOS EDUCATIVOS SCRUM

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ABSTRACT

The purpose of the article is to analyze the influence of education in Science, Technology, Engineering, and Mathematics on group (project) work aimed at the development of soft skills in future specialists in the field of information technologies. The authors justify the relevance of introducing the pedagogical technology of education in Science, Technology, Engineering, and Mathematics for the development of soft skills in future specialists into the higher education process. Different approaches to the definition and features of education in Science, Technology, Engineering, and Mathematics are presented and various conditions for the formation of soft skills are examined. It is concluded that the use of the flexible model for the development of an educational project as a pedagogical technology for education in Science, Technology, Engineering, and Mathematics leads to the development of soft skills in future information technology specialists.

Keywords:

STEM, soft skills, project method, educational project, Scrum.

RESUMEN

El propósito del artículo es analizar la influencia de la educación en Ciencia, Tecnología, Ingeniería y Matemáticas en el trabajo en grupo (proyecto) dirigido al desarrollo de habilidades blandas en futuros especialistas en el campo de las tecnologías de la información. Los autores justifican la relevancia de introducir la tecnología pedagógica de la educación en Ciencia, Tecnología, Ingeniería y Matemáticas para el desarrollo de habilidades blandas en futuros especialistas en el proceso de educación superior. Se presentan diferentes enfoques para la definición y características de la educación en Ciencias, Tecnología, Ingeniería y Matemáticas y se examinan diversas condiciones para la formación de habilidades blandas. Se concluye que el uso del modelo flexible para el desarrollo de un proyecto educativo como tecnología pedagógica para la educación en Ciencias, Tecnología, Ingeniería y Matemáticas conduce al desarrollo de habilidades blandas en los futuros especialistas en tecnologías de la información.

Palabras clave:

STEM, habilidades blandas, método de proyecto, proyecto educativo, Scrum.

INTRODUCTION

Today's global socio-economic processes are associated with highly efficient nano- and biomaterials, new energy, and information networks; therefore, innovations are the key features of the existing stage in the development of society. The consequence of implementing innovations is the practical absence of restrictions in interaction, communication, and international scientific and applied work as well as the formation of a new integral scientific and technological field of knowledge and the corresponding scientific and technical and technological worldview (Freeman, et al., 2014).

One should note that the main participants in innovation are industry, business entities, the state, and universities, and their interaction takes place in four main areas: accelerating the commercialization of innovations, globalization of innovative initiatives, training of personnel for innovative technologies and industries, and forming a network of industrial innovations.

A special mission in the development of innovative technologies is assigned to universities, which, on the one hand, are centers of innovation, and on the other, rely on the support of the state and business circles, that form certain vertical-horizontal connections between developers and consumers of the latest developments. Thus, based on a flexible combination of fundamental and applied research, a new system of scientific and practical relations arises, and these relations form the innovation sphere in the economy of the state, which is a sign of its competitiveness.

With the development of the modern world, the task of training young IT specialists is becoming more complex and unconventional. According to Rudden (2021), since 2007, the number of technology startups has increased to 47 percent. From 116,000 businesses in 2007 to 171,000 in 2019, these startups are technology-driven. It is worth noting that 7.1% of startups in the world are in the financial technology sector. This is followed by 6.8% in life sciences and healthcare, 5.0% in artificial intelligence, 4.7% in games, 3.3% in advertising technologies, and 2.8% in Edtech. It is clear that modern startups are gravitating towards the Internet and digital technologies. The United States is likely to lead in the number of startups (63,703). India is second on the list with 8,301 startups, and the United Kingdom is third with 5,377 startups.

Due to the emergence of creative startups and new IT companies as well as the formation of an active professional community of programmers and business analysts, the industry is increasingly moving away from a monolithic corporate culture with its classical hierarchy of management and distribution of responsibilities. Effortless communication with any team member, direct communication with the customer, active participation in development planning, and direct influence on its global concept and vision – all these things are increasingly becoming available from the very first stages of their careers, allowing young specialists to quickly fulfill their ambitions and demonstrate their personalities.

However, the labor market built on such principles requires an individual to be versatile which would ensure the specialist's competitiveness already at the beginning of their career and would allow operating not only technical knowledge in their specialty but also the ability to quickly respond to market requirements, continuously take part in self-education, be able to communicate and take responsibility for the result of their own activities.

A critical factor in the innovativeness of the economy at present is the contradiction between the constantly growing shortage of specialists in high-tech industries capable of complex scientific and engineering work, and the existing training programs that do not give young specialists an understanding of business requirements. This is because high-quality teaching of the theory of fundamental sciences at universities is most often not accompanied by the development of personal qualities, the so-called soft skills, as to be a good specialist in one's field, today one needs to have another type of skills – the ability to negotiate, work in a team, lead people and work with objections.

We believe that to solve this problem, one needs to introduce the latest pedagogical technology of education in Science, Technology, Engineering, and Mathematics (STEM) into higher education, combining natural sciences, technology, engineering (design), and mathematics, readiness to solve complex tasks (problems), critical thinking, cognitive flexibility, cooperation, management, innovation, etc.

The acronym STEM (Science – natural sciences, Technology – technologies, Engineering – engineering, design, Mathematics – mathematics) denotes the characteristic features of the corresponding didactics, the essence of which is manifested in a combination of interdisciplinary practice-oriented approaches to the study of natural and mathematical disciplines. STEM unites disciplines into a single educational paradigm, which is based on the idea of the practical application of knowledge to solve social, economic, technical, and technological problems (Sekerin, et al., 2018).

Different authors propose varying approaches to the definition and features of STEM education (Table 1).

Table 1. Definitions and features of STEM education.

Source	Definition
Brown, et al. (2011)	in a broad sense: pedagogical technology for forming and developing mental-cognitive and creative qualities of pupils/students, the level of which determines the individual's competitiveness in the modern labor market
Hernandez, et al. (2014)	in a narrower sense: through the STEM approach to education, the content and methodology of natural sciences, technology, engineering, and mathematics and logical thinking are integrated into collaboration and research
Blackley & Howell (2015)	The STEM approach in education is based on structuring academic disciplines and individual didactic elements on an interdisciplinary basis (integrated learning according to certain topics, and not individual disciplines) using the latest educational technologies: cognitive, social, and knowledge transfer
Han, et al. (2015)	the defining goal of STEM education is, on the one hand, to ensure the integrated formation of scientific and practical knowledge by obtaining authentic practical experience (personality aspect), and on the other hand, prepare students for further education and employment in line with the requirements of the 21st century (social aspect)
Basham, et al. (2010)	STEM education goes beyond the educational institution as it involves the establishment and development of partnerships between pupils/students, teachers, researchers, innovators, industry professionals, and other stakeholders. This is necessary to work with real-life challenges and innovative ideas, including those related to moral and socio-economic problems
Knezek, et al. (2011)	to provide scientific and methodological support for the implementation of STEM education, it is of particular importance to develop integrated curricula for all types of educational institutions, elective courses focused on the formation of competencies necessary for modern scientific and professional areas of the latest technologies, etc.

At the same time, the interpretation of the essence and, most importantly, approaches to the practical implementation of the STEM education principles in the modern educational space remains a subject of discussion.

Thus, some scholars (Meyrick, 2011; Williams, 2011) see the efficiency of STEM education in the formation of four groups of skills: skills for mastering basic disciplines that form the content of knowledge and educational topics of the 21st century; learning and innovation skills with a focus on creativity, critical thinking, communication, and collaboration; skills for working with information, media and technology and skills for a successful life and career.

Other scholars (Wang, et al., 2011; Erdogan, et al., 2016) refer to the features of modern STEM education as integrated learning by topics, not by subjects; application of scientific and technical knowledge in real life; developing critical thinking and problem-solving skills; application of scientific and technical knowledge in real life; increased confidence; active communication and teamwork; developing interest in technical disciplines; creative and innovative approaches to project creation; the connection between education and career.

Based on a thorough analysis of academic works, scholars (Stohlmann, et al., 2011) point out that STEM education contributes to the formation of readiness to solve complex practical problems; the formation of critical thinking and creativity; organizational skills, teamwork, and problem assessment skills; the ability to make independent decisions and efficiently interact; negotiation skills, cognitive flexibility.

Recently, scholars (Sampurno, et al., 2011) have been inclined to expand the boundaries of STEM education and turn it, for example, into STEAM education (A – Arts skills, skills acquired in the process of studying the humanities), that is, from a purely technical to something that can encompass other specialties.

An analysis of the works by modern pedagogical practitioners also shows that most of the researchers into the problems of training students in IT specialties agree to consider the development of soft skills as a necessary component of training for IT specialists (Tang, 2011). Already, 77% of executives believe that soft skills are no less important than hard skills (Schleutker, et al., 2019).

However, scholars have not agreed on the most efficient mechanism for forming these skills. Some authors believe that soft skills form in the context of the student's active participation in various courses, unions, public associations, scientific societies, student self-government... Such activities help to improve communication skills and take responsibility for one's decisions. Others agree that on-the-job training and internship can become the basis for the formation of the students' non-technical skills. Part of the academic community is generally inclined to believe that the development of soft skills does not require a separate form of work and requires a revision of existing practices, enriching them with active dialogues with students, examination of real examples, presentations, and discussions.

Employers are looking for candidates not only with work experience but also with soft skills, in particular, the six most demanded of them are flexibility/adaptability; communication skills; the ability to solve problem situations; creativity; interpersonal skills and teamwork skills.

Soft skills include the ability to solve problem situations, skills in working with clients, writing and oral communication skills, presentation skills, etc. Since the educational process is rarely aimed at contributing to the development of these skills (for example, conducting seminars that will include student presentations), employers have to spend a lot of money on the development of these skills. One of the most widespread and popular practices of pedagogy, which, according to scholars (Tang, et al., 2015), forms professional independence and the ability to creatively solve not only educational tasks but also those that will arise further in one's career in real production, is project work. It is a way of organizing the activities of students, in which the teaching material and methods of interacting with it are not provided by the teacher, and the student, under the teacher's guidance, independently finds the necessary information, works with various information, masters the planned methods of action in the process of solving their own or team problem.

Considering the trends of teaching disciplines in recent decades, researchers (Sheffielda, et al., 2018) note that it is the use of STEM education that will expand the possibilities of efficient and high-quality professional training of future specialists, the formation of their "soft skills".

Summarizing the above, the modern scientific-pedagogical community recognizes and actively studies the problem of the need to develop non-technical skills of future specialists, however, the problem of finding the optimal methodology for the development of soft skills in the context of training future IT specialists, in our opinion, remains unresolved.

Research hypothesis: the use of a flexible model for the development of an educational project as a pedagogical technology of STEM education leads to the development of soft skills of future specialists in the field of IT.

Research objectives:

To achieve the goal of the study, the following objectives were set:

1. Conduct a theoretical analysis of the features of STEM education and the formation of soft skills.

2. Choose a model for project development and substantiate the efficiency of the chosen methodology in the development of soft skills of future specialists in the field of IT.

3. Formulate a list of the most relevant soft skills in the project activities of a future IT specialist.

4. Analyze the use of soft skills during project activities at each stage of the project implementation according to the chosen model, consider in detail the processes and team roles of the methodology.

The article consists of an introduction, a literature review, research methods, research results, a discussion of the results, and a conclusion.

MATERIALS AND METHODS

To achieve the goal of the study, we used the following research methods:

theoretical methods: theoretical generalization, analysis, and synthesis were used for choosing a model for project development;

empirical methods:

- the expert survey method was used to define and classify soft skills used and formed during the implementation of the project;

- project method was used to determine the soft skills that are most actively used during each of the stages of project development.

Procedure and research tools

1. Choosing a project development model

A project development model is a structure that systematizes various types of project activities, their interaction, and sequence in the process of project development. The choice of a particular model depends on the scale and complexity of the project, the subject area, available resources, and many other factors. The choice of a project development model directly affects the workflow, determining the composition of the team, the choice of strategy, the work schedule, the necessary resources, and the requirements for the participants.

Today there are numerous model varieties and methodologies for project development, but in general, two categories can be distinguished: monolithic and agile.

One of the classic monolithic models is the waterfall model which is now more of historical interest since the model is rarely used in modern projects. The model involves a single execution of each of the project phases, which, in turn, strictly follow one after another. In a very simplified way, it can be said that within the framework of this model, at any given time, the team moves only from the preliminary to the next phase, ignoring the overall vision of the project and not moving a step away from the previously created plan. The waterfall model is often used intuitively for relatively simple tasks where communication between team members is minimized and the amount of work and dependencies are known in advance and remain unchanged.

The iterative-incremental model is the foundation of a modern approach to project development. The key feature of this model is the division of the project into relatively small intervals (iterations), each of which, in the general case, can include all the classical stages inherent in the waterfall model (Figure 1).

As the name implies, the model is characterized by a certain duality: from the life cycle perspective, the model is iterative since the model implies multiple repetitions of the same stages; from the perspective of product development (increasing the useful functions of the product), the model is incremental. The length of the iterations can vary depending on many factors but the principle of multiple repetitions ensures that both testing and demonstration of the product to the end customer (with feedback) will be actively applied from the very beginning and throughout the entire development of the project.

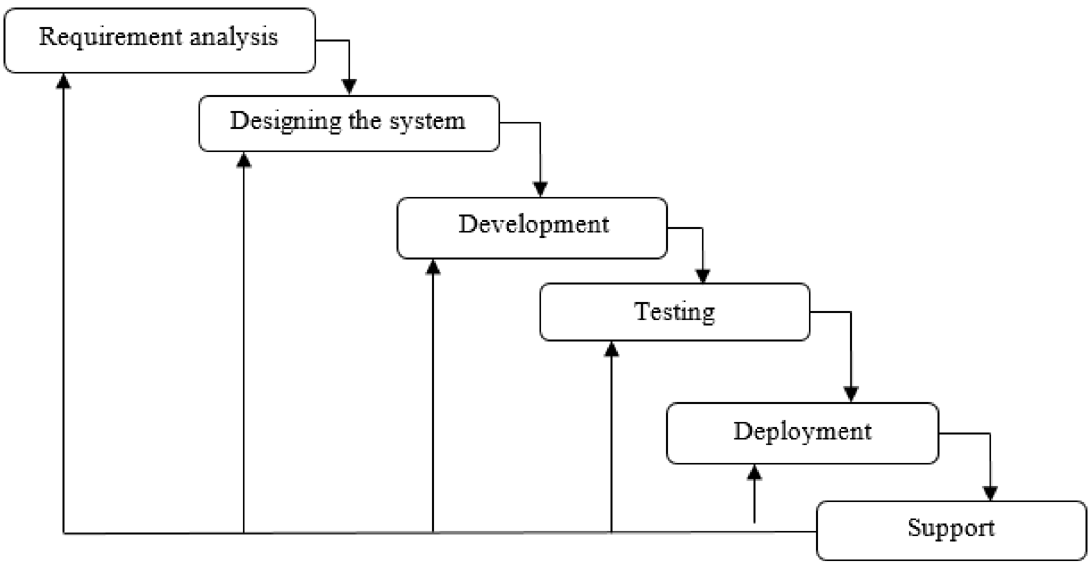

Figure 1. The iterative-incremental model of project development.

Due to the factors described above, monolithic project development models set relatively low requirements for non-technical skills and personal qualities of team members. The models only require successive execution of pre-planned tasks and do not participate in high-level planning and adaptation to change.

Unlike classical monolithic models, agile methodologies define people and their interaction as the main priorities in project management to create a product based on cooperation with the customer. Their agility is ensured by constant openness and willingness to change. Such technologies are aimed at overcoming the expected incompleteness of requirements and their constant changes, offering an agile iterative-incremental approach as a result of the constant interaction of teams that self-organize and consist of versatile specialists.

All flexible project development models are based on an informal list of basic principles: people and interaction are more important than processes and tools; a working product is more important than comprehensive documentation; cooperation with the customer is more important than negotiating the terms of the contract; readiness for change is more important than following the previous plan.

One of the most widespread and popular agile development methodologies in the industry today is Scrum which allows the team to select tasks to complete considering business priorities and technical capabilities and decide how to efficiently implement them. This allows one to create an environment in which the team enjoys the work and is as productive as possible. Scrum focuses on continuously prioritizing tasks based on business goals which increases the usefulness and profitability of a project in its early stages.

Since it is almost impossible to determine its profitability when initiating a project, Scrum suggests focusing on the quality of development and by the end of each iteration have an intermediate product that can be used, albeit with minimal functionality.

The SCRUM project development model is shown in Figure 2.

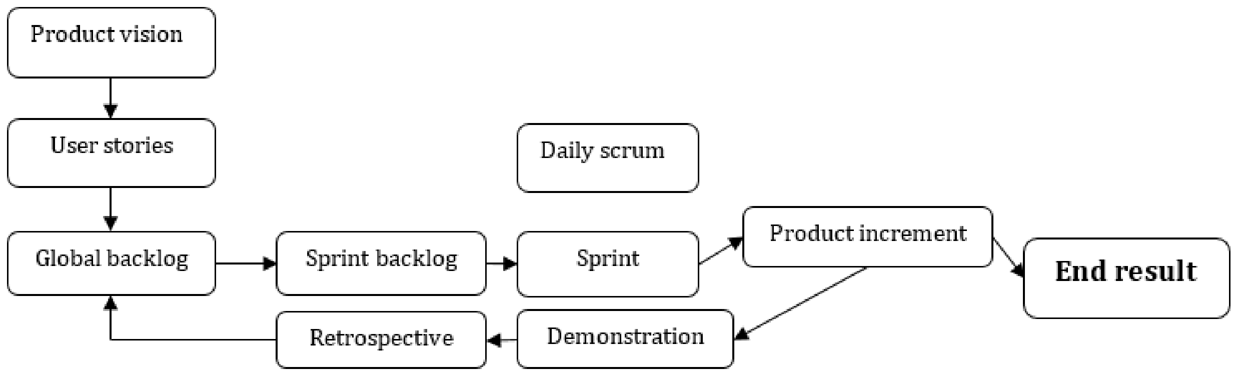

Figure 2. SCRUM project development model.

2. Expert survey.

A total of 33 experts, university professors with experience in teaching in the field of project activities took part in the expert survey.

The experts were asked to identify and rank the soft skills required in the implementation of an IT training project.

All participants were informed about the purpose of the survey and the organizers' plan to publish the summarized results of the study.

Statistical analysis

During the mathematical processing of the research results, the percentage of expert references of soft skills was determined.

The ranking of the entire set of soft skills consists in their arrangement by each of the experts in descending order. Moreover, each of the opinions is evaluated by the rank (number) under which they are located in the given sequence. The final rank is the arithmetic mean of all expert ranks in the sample of experts.

RESULTS AND DISCUSSION

For a deeper understanding and analysis of the soft skills used and formed during the implementation of the project, there is a classification of soft skills in Table 2 developed based on the expert survey.

Table 2. Soft skill classification.

Set of soft skills	№	Soft skill	%	Ranking
Personal skills	1	Decision making and problem-solving	85%	3
	2	Clear task setting and goal formulating	82%	4
	3	Creative thinking and optimism	76%	5–6
	4	Orientation towards the client and the final result	58%	12
Communicative skills	5	Clearly formulate thoughts (messages)	76%	5–6
	6	Friendly communication and good manners	73%	7
	7	Interact with different types of people	67%	8
	8	Structure and moderate the meeting (discussion)	55%	13–14
	9	Listen to and take into account all perspectives	55%	13–14
	10	Give reasoned, timely and polite answers	52%	15
	11	Prepare and hold high-quality presentations		16

Management skills	12	Be a team player	97%	1
	13	Unite and motivate the team	91%	2
	14	Accurately plan and manage time (time-management)	64%	9
	15	Foresee and prevent risks	61%	10–11
	16	Educate and train team members	61%	10–11

The classification is not exhaustive and nor does it include absolutely all soft skills but only those that are necessary for project work. The use of soft skills, according to experts, also implies the ability to use different models of behavior even in the same situations, deeply understand one's own interests and stakeholders' interests, set priorities quickly and clearly, make the best choice when there are alternatives, quickly adapt to new challenges and circumstances, be stress-resistant and be able to achieve the set goal. The skills can be better mastered, as a rule, in specialized expensive MBA programs or after employment in leading companies.

The soft skills that are most actively used during each of the stages of project development with the Scrum methodology are shown in Table 3.

Table 3. The use of soft skills in project work.

Stages of a Scrum project	Utilized skills
Project vision	1, 2, 3, 4, 7, 9
Backlog development	5, 12, 13, 15, 16
Sprint planning	5, 12, 13, 15, 16
Development. Daily scrum	1, 2, 3, 5, 6, 8, 9, 10, 13, 14, 15, 16
Sprint demonstration	3, 4, 7, 10, 11
Retrospective	6, 8, 9, 12, 13, 14

Let us consider in more detail the SCRUM model and its stages chosen for developing a project at the university.

In classic Scrum, there are 3 basic project roles:

- "Product owner" – this role is played by the teacher during the development of an educational project.

- "Scrum master" – "service leader". When developing a training project, this role is played by all students – members of the project team in turn.

- "Development team" – when developing an educational project, their role is played by students – members of the project team.

The first step in the implementation of any project is to create a vision of the final product by its "owner" (teacher). Next, the "product owner" meets with the "scrum master" and the team to provide them with information about what the final product should be in the "user story" format – algorithms for using the final product by the target user.

After processing the vision of the project results, all project members (students) sort, prioritize and group the resulting user stories to understand which elements are mandatory for implementation and which can be changed or postponed. As a result of this process, a "backlog" is created – a list of formalized and structured requirements and wishes regarding the results of the project, which are sorted in order of importance.

The basis of Scrum is "sprint" – a fixed period during which work is done. The next stage after the formation of the backlog is its distribution between sprints. Before the start of each sprint, "sprint planning" is held - a meeting at which the "sprint backlog" is formed – a separate list that contains tasks that must be completed in the current sprint. Each sprint should have a goal that is a motivating factor and is achieved by completing the tasks in the sprint backlog.

Every day, there is a short daily scrum meeting where each student member of the team answers the question "what did I do yesterday?", "what am I planning to do today?", "what obstacles have I encountered in my work?". The goal of the daily scrum is to determine the status and progress of work on the sprint, early identification of the obstacles that have arisen, and the development of solutions to change the strategy necessary to achieve the goals.

After the end of the sprint, the team presents the "owner" with the result of the work at a meeting which is aimed at monitoring the intermediate results of work on the project.

At the retrospective phase which takes place after the end of each sprint, the team analyzes the problems encountered during the sprint and suggests actions to prevent similar situations in the future.

Such iterations (planning, development, demonstration, retrospective) are carried out until the backlog is completely exhausted and the completed project meets the initial requirements.

For the successful operation of a Scrum project when implementing a STEM methodology, a team should be capable of self-organization, that is, the team itself decides how to achieve the goal. Each team member must play an active role at every stage, from idea formation, software development, testing, to the deployment and support phase. However, Scrum requires a high level of both individual and team autonomy. This project development methodology most fully utilizes the specialist's soft skills since the efficiency and high productivity of the team are directly supported by communication skills, management skills, thinking skills, teamwork skills, leadership skills – all the most relevant soft skills for an IT worker.

When planning work and choosing tasks for implementation, the team must act as efficiently and seamlessly as possible. Understanding the speed of work of each of the team members and awareness of the possible risks will allow the team to be confident in the future performance of their work.

The daily work of a member of a scrum project is associated with processing a large amount of information and the need for constant communication with colleagues. A tight schedule and frequent conflicts require the ability to constantly change the pace of work and switch between tasks.

After completing the set amount of work, the team must present the results, which requires the ability to emphasize the strengths of the project in a concise and understandable form, and further analysis of the tasks already completed at the retrospective stage will become efficient only due to the ability of team members to have open and conflict-free dialogue.

The above order of work clearly illustrates that working in a Scrum team is actually a testing ground for the soft skills of IT specialists – the work stimulates them for continuous improvement and evolution.

The approach to organizing STEM training in the development of educational projects for IT students using the Scrum methodology can bring several positive aspects at once to modern methods of student project work.

First, the approach accumulates and retains all the advantages of project-based teaching methods. Second, the approach radically changes the role of the teacher who acquires a new position of not only the organizer but also a direct participant in the students' activities which is even more important for the educational process. As the teacher takes the position of a product owner in the Scrum methodology, their function is not only reduced to monitoring the progress of the process and understanding of the content of education but also consists in playing an important and, above all, realistic role, the students' interaction with which will provide them with relevant experience for their further career.

However, according to experts, the most important is continuous practice and systematic development of the soft skills of future IT specialties. Systematically being in an environment that is as close as possible to real conditions, future specialists will be able to cultivate the skills of teamwork, decision-making, presentation, planning, time management, and many other qualities required by the modern IT market, while understanding the methodology from the inside and practical experience in a modern business project model will help them become competitive candidates for the positions of young professionals.

It should be noted that modern pedagogical technologies (problem-based learning, differentiated learning, project learning, flipped learning, gamification, web quest, case studies, etc.) make it possible to improve the educational process in a higher education institution but it is not enough to only apply them. One of the urgent areas of modernization and innovative development of natural and mathematical education is the STEM-oriented approach to teaching. STEM education is based on interdisciplinary approaches to structuring curricula at various levels, individual didactic elements, the study of phenomena and processes of the world, and solving problem-oriented tasks. The usual form of teaching when the lesson is built around the teacher changes. In STEM, the focus is on a practical task or problem. Future specialists learn to find solutions not in theory but practice through trial and error.

The analysis of the results of the study made it possible to select and adapt the following features of STEM education for implementation in the training of specialists:

1. Integrated learning based on the activity approach through partial search and research methods; the result of such training is specific original scientific inventions that can be used in practice.

2. The ability to solve specific scientific problems by organizing research which increases motivation for professional training, contributes to mastering a wide range of practical skills.

3. Formation of a stereotype of a specialist which encompasses innovative work skills, the ability to think critically, communication and cooperation, the ability to work in a team, and the skills of cognitive flexibility. This stereotype orients the student towards successful self-fulfillment not only in the future profession but also in other spheres of social life.

CONCLUSIONS

Summing up the results of the study, it should be noted that the STEM direction in education emerged as a means of resolving contradictions deeply related to the convergence of innovative technologies, radical changes in the requirements for specialists in the labor market in the 21st century and the passivity of the education system in the formation of relevant competencies and skills.

It was discovered that the main feature of STEM education is integrated training in the application of scientific and technical knowledge in real life. The scientific and methodological foundations for creating a model of this approach to the organization of education consist in the transition from traditional education to innovative through project-oriented teaching methods.

STEM technology aims to comprehensively form young people's key professional, social and personal competencies that determine competitive ability in the labor market: the ability and readiness to solve complex tasks (problems), critical thinking, creativity, cognitive flexibility, cooperation, management, innovation, etc.

Key issues in the development of STEM education are reliable targeted support for effective professional training of STEM educators, initiatives aimed at attracting and maintaining talented STEM teachers, developing high-quality standards in STEM industries, prioritizing the development of STEM-oriented projects, programs, and curricula which include classroom and extracurricular learning activities.

In the study, we chose a model for the development of an educational project, the focus of the research was on the most common representative of agile methodologies – Scrum. The classification of soft skills and a list of the most relevant ones in the project activities of a future IT specialist are presented. The use of soft skills in the process of performing each of the stages of a project using the Scrum methodology has been investigated.

The results of the study confirmed the hypothesis that the use of a flexible model for developing an educational project as a pedagogical technology of STEM education leads to the development of soft skills of future specialists in the field of IT.

Prospects for further research consist in the dissemination of the best STEM educational practices, further research of STEM education should be carried out in vertical-horizontal directions: from the development, testing, and implementation of innovative interdisciplinary curricula, establishing a system of reliable criteria and indicators of the quality of STEM education to state support as one of the national priorities which should be reflected in educational reform, innovation policy, which should be based on evidence, supported by partnerships with society and stakeholders: government and business representatives, employers, research institutions and educational organizations.

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