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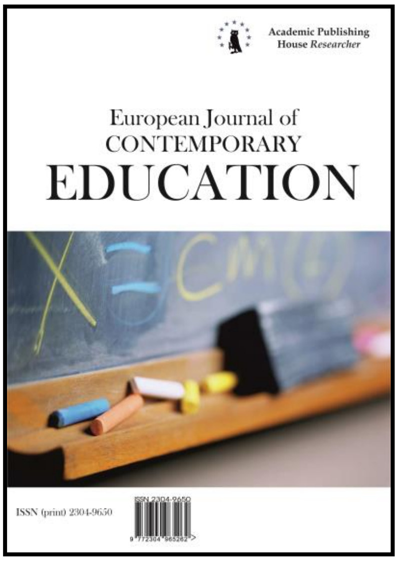

Characteristics of the Project-Based Teamwork in the Case of Developing a Smart Application in a Digital Educational Environment

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Abstract

The study is aimed at solving a problem generated by the necessity to change the organizational forms of digital learning to prepare graduates who meet the requirements of today's labor market; who are equipped with teamwork skills and skills of project-management under uncertainty which are especially relevant nowadays.

The purpose of the study is to provide a theoretical foundation for and experimentally verify the effectiveness of involving students in project teamwork on designing smart applications by means of modern digital technologies; project teamwork activities allow developing the skills and abilities characteristic of a strong research culture necessary for making future discoveries in science and technology.

The research methods are the analysis and generalization of psychological and pedagogical literature, of development strategies and education theories; mathematical methods of statistics, psychodiagnostics and survey methods. The pedagogical experiment is illustrated by the example of assessing the development of teamwork skills, project management skills, and programming skills which form the basis for professional self-realization of graduates.

The study results. The study specifies the concepts of the ability to work in a team and smart application in the context of training professionals for digital economy. The didactic potential of project team work in the sphere of self-realization of graduates is described. The authors reveal the characteristics, principles, and stages of team work on the project aimed at designing a smart application. They offer their recommendations regarding the process of planning and organizing team activities, specifying the skills and abilities necessary to help a person succeed in today's digital society and to get a profession which is in demand on the labor market.

The authors draw a conclusion that project teamwork meets the requirements of digital education and contributes to successful professional self-realization of university graduates if it is well designed, accurately planned, and monitored by the educator to the extent necessary.

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1. Introduction

1.1. Significance of the Research

The significance of the study is explained by the following:

1. The modern society has entered a new era – an era of transformation, which implies the creation of a digital space that can adapt to information and social technologies, meet the requirements of mobility and sustainability, and face the challenges of the future economy.

2. The ability to work with others, both individuals and groups of people (Shulgina et al., 2018), is one of the most demanded skills and competencies which employers expect to see in their future employees; which is necessary to introduce innovations (Kolesnikova, Doneckij, 2016), be competitive (Perelet, 2019), and develop high-tech production. Teamwork skills, the ability to working on large-scale cross-industry projects under uncertainty are a prerequisite and a priority for the "new-era" economy (Kuzminov, 2019).

3. The introduction of digital technologies in all spheres results in the introduction and use of intelligent systems in everyday life, technology, medicine, environmental protection: smart watches, smart utensils, smart lights, etc.

4. Taking the above into consideration, the primary focus of the Digital School project should be the development of team and project-based training. One more guiding principle should also be a more active use of mobile applications and digital technologies.

Nevertheless, despite the high didactic potential of the use of digital technologies in digital education which has been described by (Dezhina, Klyucharyov, 2018; Makarova et al., 2019), most teachers still use ready-made mobile apps (Soboleva, Fedotenko, 2019) which they mainly use to increase motivation, interactivity, and visualization (Terzidou et al., 2018). Teachers are not active enough in involving students in developing their own mobile apps to solve real-life problems (Soboleva, Perevozchikova, 2019). They give the following reasons for the existing situation: lack of time, lack of necessary knowledge and training, lack of skills of programming in appropriate environments (Cherniavskikh et al., 2019), inconsistency in the level of students' algorithmic thinking culture and complexity of a particular problem (Kocakoyun, 2017). The kind of training based on project team work has the resources to resolve these difficulties (Burgess et al., 2019).

Thus, there is an objective necessity to study the characteristics of organizing teamwork on a project aimed at developing a smart application to train skills that are now in demand on the labor market and necessary for successful professional self-realization of graduates.

1.2. Aims and Objectives of the Study

The aim of the study is determined by the necessity to involve students in project teamwork on designing smart applications by means of modern digital technologies. It helps graduates to meet the requirements of the labor market and master essential teamwork skills and skills of project management under uncertainty.

The objectives of the study:

– to specify the concepts of the ability to work in a team and smart application in the context of training professionals for digital economy;

– to demonstrate the didactic potential of project team work for self-realization of graduates;

– to describe the characteristics, principles, and stages of project team work on designing a smart application;

– to formulate recommendations regarding the process of planning and organizing team activities, specifying the skills and abilities necessary for a person to succeed in today's digital society and get a profession which is in demand on the labor market;

– to demonstrate experimentally that the suggested modifications are effective in upgrading the training process, in the development of skills and abilities that determine a high level of research culture and are necessary to introduce innovations in science and technology.

2. Discussion

2.1. Review of Russian Pedagogical Literature

The Strategy of the Information Society Development in the Russian Federation for 2014–2020 and up to 2025 in perspective (Strategiya razvitiya..., 2017) specifies the priorities of the digital economy taking into account the global trends of increasing competition, globalization, and automation. To implement these in practice, Atlas of the Future Jobs (Gohberg et al., 2019) describes key competencies for each economic sector. In particular, it is indicated that due to digital transformation there will be a reduction in professions where a person is required to perform routine monotonous actions (sorter, storekeeper, accountant, salesperson). Employers will prefer employees who can work in teams, or in collaboration with other individuals on multi-disciplinary projects. Ganseuer, Neretina, Korokoshko (Gansuar et al., 2015) consider that each team member should be able to act as both an executor and a leader. The project results should meet the challenges of the future, i.e. to offer a *smart* solution under conditions of uncertainty. Training of a new type of professionals having the necessary skills requires from digital education the introduction of innovative pedagogical ideas at all levels starting from pre-school education to further education courses. Karakozov and Ryzhova recognize the need for digital school changes in the content, organizational forms, methods, and teaching aids and provide well-grounded arguments (Karakozov, Ryzhova, 2019). The scholars study in detail the didactic potential of high-tech tools and changes in the way the participants of the digital educational environment interact.

Rogach, Frolova, Ryabova and Vetrova (Rogach et al., 2019) carried out the analysis of the labor market requirements for secondary school leavers; they also compared the expectations and requirements of employers and the students' competencies. The study provides specific cases illustrating the employers' interest in effective cooperation with educational institutions in the field of training professionals who can meet the requirements of the digital economy. The study also describes the problems that impede self-realization and prevent students from acquiring in-demand professional skills of the future. These problems are poor communication skills, inflated self-esteem, high salary expectations, unwillingness to work in a team, lack of responsiveness and responsibility.

The concept of a *team* is studied from different perspectives, more often as a sociological phenomenon as the features of a team are revealed in comparison with a group or body of people. From the point of view of management, scholars are interested in such notions as working in a team, teamwork principles, increasing the efficiency of a team. The psycho-pedagogical range of studies is also quite diverse, so we will narrow down on those which explore team training in relation to acquisition of in-demand professional or universal skills.

In its general sense, the concept of a team is defined as a group of people who can complement and replace each other while working to achieve the desired goal (Savva et al., 2018). Sidelnikova expands this definition stating that a team is a collective entity, and the main characteristic of a team is its ability to act as a whole in relation to setting goals, defining values and standards for action (Sidelnikova, 2018).

Considering teamwork as the basis for formation of the required skills, we should turn to the ideas formulated by Malysheva (Malysheva, 2017). The scholar characterizes the team activity as a set of skills including fast adaptation in a new team; performing activities at the same pace as others; an ability to build a constructive dialogue; being able to prove one's views to the team members in a convincing way; being able to admit to being wrong and accept a different way of thinking; being able to change roles depending on the goal; being able to constrain one's own claims and ambitions; readiness to help other team members; emotion management skills.

The digital economy prioritizes the trends of globalization, automation and competitiveness, so employers expect from graduates not just to be able to work in a team, but to act under uncertainty, to constantly self-develop, to be able to switch from one kind of activity to another, sometimes in a related sector. It determines the current understanding of teamwork skills as universal skills that include certain personality traits and professional competencies (Filatova, 2018).

Malysheva (Malysheva, 2017) offers a review of pedagogical technologies aimed at training skills required for working in a team, in a group of people or with other individuals. The results presented in her study are also taken into account as they confirm that the ability to work in a team on a cross-disciplinary research project is a universal competence necessary for future professionals.

To justify the fact that cross-disciplinary project work is effective for training for in-demand jobs of the future, it should be noted that digital economy follows the principle of division of labor. The activity within this system does not depend on the behavior of individuals; instead, it guides them in a certain way.

Sidelnikova (Sidelnikova, 2018) states that teamwork skills and communication skills are the competencies highly sought by employers. In this regard, she considers it necessary to use different group work training techniques, including moderation. The author points out that didactic and verified use of such forms of training will increase the attractiveness of teamwork for students and improve the quality of training contributing to their successful integration into the labour market.

Savva, Gasanenko and Shakhmayeva (Savva et al., 2018) studying the phenomenon of a team from the perspective of the didactic process define a team as a group of students corresponding to the following characteristics: maximum activity and responsibility in achieving a shared goal, being aware of the need for interaction and cooperation, comradery and flexibility, creative attitude to collaborative activities, integration of individual ideas and experience, making appropriate decisions in specific educational and professional tasks and situations. The study does not only list the essential characteristics of a team, but investigates this phenomenon from the perspective of professional activities. The researchers point out the necessity for the members of a team to possess cross-disciplinary knowledge and skills. To develop teamwork skills, educators should be able to organize special support activities including cognitive, target, value, and process components.

Ganseuer, Neretina, Korokoshko (Gansuar et al., 2015) generalize the experience in the field of project-oriented training and organization of teamwork activities among university students. They indicate that the global trends of globalization, automation, and competitiveness require qualitative changes in the education system of Russia regarding training of highly qualified specialists who meet employers' expectations. According to the scholars, modern university graduates are not ready for innovations in science and technology, as there is discrepancy between the knowledge they get at university and the required skills. As one of possible solutions, the experts suggest using the educational technology called "Learning by Doing" in the context of project-oriented training.

These ideas resonate with the opinion of Dul'zon (Dul'zon, 2013) who believes that any knowledge gained in the course of project and research activities should become a starting point for solving new problems.

Reshetnyak, Tarelin (Reshetnyak, Tarelin, 2013) describe their experience in organizing practice-oriented activities for students as a way to improve the quality of training. The scholars organize design studios and define them as an integrated component of the didactic process of cross-disciplinary nature in university education.

The conclusions made by Semenykhina and Rudenko (Semenykhina, Rudenko, 2018) are also of significance for the purposes of this study. According to them, improving the quality of teaching programming is another way to modernize the education system and meet the challenges of the future and the requirements of the digital economy. Their study highlights a wide range of problems related to teaching programming and suggests ways to solve them. We see the value of their research in the fact that they give reasons why the ability to program is so important describing it as a kind of activity that improves intellectual training, develops the ability to concentrate on solving a task, facilitates algorithmic thinking and the ability to act according to a certain algorithm. Semenykhina, Rudenko summarize many years of teaching experience and conclude that including practice-oriented tasks of social and cognitive significance for students; verbal and non-verbal, external and internal means; communication attacks; stimulating tasks; gamification; teamwork, independent work and reflection activiities can significantly increase the effectiveness of teaching programming as the basis for training in-demand qualified professionals.

Soboleva, Perevozchikova (Soboleva, Perevozchikova, 2019) analyze the changes generated by the introduction of new digital technologies in the educational process. They show that a new digital tool does not guarantee any improvement in the quality of education. It is necessary to teach educators to use high-tech tools which should be used not only to increase interest and motivation, but also as a tool for acquiring new knowledge and competencies. Soboleva, Fedotenko (Soboleva, Fedotenko, 2019) specify the concepts of *mobile learning* and *mobile-based education apps*, explore the potential of mobile services as effective tools of the digital educational environment.

They also describe their own mobile application, which, in their opinion, corresponds to the requirements for a digital educational resource to the fullest extend.

Thus, the Russian literature review has shown that team work on a cross-disciplinary project allows us to take into account the fact that the economy of the future is oriented to economic system based on the division of labor. This activity does not depend on the behavior of individuals; instead, it guides them in a certain way. The use of digital technologies in the educational process should not be limited only to the use of ready-made applications, but it should contain programming components. The tasks connected with developing their own solutions should be based on a particular practical problem which is of value to both team members and future employers.

2.2. Review of Foreign Literature

Tocháček, Lapeš, Fuglík (Tocháček et al., 2016) consider that the need for innovation in science and technology determines the need for researchers who can integrate knowledge from different disciplines. The educational environment has all the possibilities to meet the challenges of the future. Teamwork/collaborative learning is one of the ways to achieve this aim. Parappilly, Schmidt, Ritter (Parappilly et al., 2015) describe the characteristics of team-based learning as an educational strategy identifying the following stages of collaborative activities: preparation activities, diagnostic testing and application activities.

Michaelsen, Richards (Michaelsen, Richards, 2005) formulate key factors for effective implementation of team-based learning: appropriate allocation of students to small groups on the basis of their academic performance and intellectual development; accountability for the result of the whole group and each member; the presence of a well-trained facilitator and provision of immediate feedback.

Hilliard, Kear, Donelan, Heaney (Hilliard et al., 2020) study the psychological aspect of collaborative learning activities: the problem of isolation, selfishness of modern adolescents (Z generation). Due to their deep immersion into the virtual world, the children of the digital society lose communication skills and fail to get socialization experience in collaborative activities. The new forms of training should take into account the potential of digital technologies (online learning), but at the same time they should equip students with the skills of working in a team/group and with other individuals.

Noguez, Neri (Noguez, Neri, 2019) describe a research-based learning (RBL) model for engineering students which is based on team-based research activities. The model includes 4 phases: a diagnosis of initial RBL competencies, an introductory workshop on research methodology by the teacher, developing the research project in teams and presentation of the results. The presentation is of key importance. It is made orally and takes the form of a group discussion guided by the instructor and illustrated with infographics and statistical calculations.

Lerchenfeldt, Mi, Eng (Lerchenfeldt et al., 2019) investigated the importance of communication with colleagues in the process of developing professional competencies. Their study proved that feedback and advice given by another team member contributes to one’s professional development.

Cherniavskikh, Borisov and others (Cherniavskikh et al., 2019) consider that project-based training contributes to the development of analytical, creative thinking; independent acquisition of necessary knowledge from various sources; theoretical thinking based on knowledge of facts and laws of science; teamwork skills. Doorman et al. (2019) conclude that to elicit collaboration skills students should be involved in problem-solving activities based on the use a context that is meaningful for students and meets their needs and interests.

The study by Montrieux, Vanderlinde, Schellens, De Marez (Montrieux et al., 2015) shows that mobile technologies open up new ways to motivate and develop cognitive interest, have an impact on teaching methods making teachers rethink didactical practices. The use of mobile applications allows eliciting feedback, providing access to multimedia data, providing learning tips, organizing productive discussions. In addition, there is a large number of software tools available to develop applications which students can use to create their own mobile portfolios for both training and further professional development.

The study by Fabic, Mitrovic, Neshatian (Fabic et al., 2017) shows that mobile tutors are effective for learning. It is also suggested that university students can use Java (in addition to Python, AppInvertor, Scratch, C++ tutors) to develop their own applications. The study by

Kocakoyun (Kocakoyun, 2017) gives reasons why a highly qualified specialist should be able to use Java and Eclipse tools to develop mobile applications. The scholar provides detailed information on how to develop and test a mobile application and describes the steps of creating a project from scratch. At the same time, it is noted that there is a wide range of problems associated with teaching programming, but some of the ways to solve them are suggested. We see the value of this study in the fact that it proves the importance of the programming skills in intellectual education; they contribute to the development of the ability to concentrate on solving a task, algorithmic thinking and the ability to act according to an algorithm.

To conclude, there is some disagreement in understanding the phenomena of teamwork and project management, however, most foreign researchers recognize the didactic potential of these training methods in providing educational-instructional support. Mobile application programming practices used in a collaborative environment provide additional resources for decision-making in a digital community. It is also revealed that there is a need for educators to master new competencies for organizing teamwork activities in the context of global digital transformation.

The above circumstances determine the significance of this research.

3. Materials and methods

3.1. Theoretical and empirical methods

Theoretical methods (review of psychological, pedagogical, scientific and technical literature) were used to specify the concepts of teamwork skills and smart application taking into account the need for changes in the sphere of training specialists for the digital economy; to describe the principles and components of teamwork on a project on a mobile application.

The didactic potential of project-based teamwork for graduates' self-realization was revealed through the analysis of the design programs developed by subject teachers, cross-disciplinary projects, and the experience of organizing collaborative and teamwork activities.

The analysis of the practices of incorporating mobile technologies into the digital educational environment was based on praximetric methods; it provided the description and assessment of the methods, means, and forms of organization and control.

The expert assessment method allowed us to comprehensively analyze the results of teamwork activities in a project on developing an application (Shihov, Shihova, 2015). The participants, the tutor, and the prospective employers (customers) played a role of experts. A criteria-based matrix was developed to assess the competencies in question: project management skills, teamwork skills, programming skills, cross-discipline communication skills.

The empirical methods (observation, analysis of the project results) were used to obtain the feedback concerning the knowledge acquired and competencies trained. These methods made it possible to obtain information about the changes in reflection, motivation, involvement in a problem situation, the students' degree of involvement in the learning activities, development of research skills and independent work which are important skills for successful professional self-realization.

The statistical significance of the qualitative changes was verified by means of G test and using the Pearson's chi-square test.

3.2. The base of the research

The pedagogical experiment was used to organize students' teamwork activities in the projects on development of smart applications by means of mobile technologies and assess the development of skills and abilities that characterize a high level of information culture and prepare students for a successful professional career. 50 students were involved in the experiment. They are students of the Faculty of Informatics, Mathematics and Physics of the Vyatka State University, Russia.

3.3. Stages of the research

The study had three stages.

At the preparatory stage, it was specified what and by what criteria would be assessed. The tutor made an initial list of experts (project owners). The primary survey and evaluation of educational results of students for experimental and control groups was conducted. Training in both groups was conducted on the same equipment, by the same teacher. The team of experts was also one for both groups. A list of skills most relevant to the needs of the digital society was created (teamwork, cross-sector collaboration, project management, programming), and the appropriate tasks were designed. As a result, a criteria-based assessment matrix was obtained. At the same time, a test was drawn up; it included 10 tasks, each rated 2 points. Thus, the maximum number of points for each competency was 20.

The second stage was devoted to methodological activities; the tutor explained to the participants the rules and criteria of the experiment; the students were divided into teams; the topics of projects were specified. The list of external experts was also elaborated at this stage.

The third stage of the study is experimental learning and updating the main ideas of teamwork training in relation to the requirements of the digital economy and the development of key cross-professional competencies. The learning process and the results of the students' research projects are continuously monitored, which allows improving the suggested methodological ideas. The research findings have been published in scientific journals and presented and discussed in the form of reports at the conferences of various levels.

4. Results

4.1. Specifying the main concepts

Working with people. The following forms of classroom interaction were used when developing mobile applications:

Student – Student. The team working on an application is characterized by the distribution of roles between a pair of students: one student assumes the role of a designer engaged in the development and improvement of the device, and the other one is responsible for creating the model behavior management program. At the first stage, the students discuss the expected results, agree on design features: which blocks, graphic design, algorithmic designs, screens, sensors of Android devices (accelerometer, GPS, databases, etc.) should be used. Further they work independently without close interaction and mutual assistance. At the last stage, they evaluate the application as a result of work of both team members. Close interaction is required at this stage again; it involves discussion, error finding and correction in the design of the model and/or program, improving the efficiency of the model or its technical characteristics, expanding functional capabilities, etc.

Teacher – Student. In class, the teacher acts as a tutor supervising and guiding the work of students in accordance with the task. The teacher should inspire the students' interest, foster their research activities, suggest ways of improving the model, for example, by demonstrating how the application may function under different conditions.

Student – Computer. Learning activities involve the ability to program, i.e., to control the model's behavior. In case of the absence of expensive equipment, a student can do homework using special programs that allow creating programs not for a real device, but for the cloud, emulator, virtual device and evaluating the outcome in real time. This enables the students to learn the basics of programming even at home, without having an opportunity to program in the required environment. Working at the computer, the student studies the materials provided by the teacher (video lecture, synopsis, presentation), answers the questions (for example, doing an online test), and performs practical tasks in a software environment.

Group – Pair of students. This kind interaction takes place during presentation of the project by the team (most often it is presented by a pair of students). The rest of the students and the tutor ask questions. This way of interaction prepares students to participate in contests and olympiads training the skill of public speaking. The students defend their projects presenting the developed applications and demonstrating their capabilities. They also discuss the results in the form of a press conference during which students exchange opinions, try to prove their point of view, and conduct discussions.

In this study, teamwork training is understood as an educational strategy aimed at developing teamwork and communication skills. This form of training should be preceded by surveying and analyzing both individual students and the group of students as a whole. Team work on a project means that there is mandatory task distribution between team members; each participant solves/performs specific subtasks; the result of the team work, however, is a whole; everyone in the team is responsible for the project; there is a motivation scheme and unity. We consider understanding of the practical value of the project and sharing the goal and the method of project implementation by all team members as key conditions for effective team work on the project. Students should understand why the task is solved by means of teamwork project-based activities, why this kind of activity is useful for them, what result they are to get in the course of teamwork activity. Our understanding of the ability to work in a team, or a group and with other individuals also means that the tutor and the students should understand how team work is going to be organized: what principles will be taken into account when forming the teams, the algorithm of activity, the form of presentation of the results, assessment rules and criteria.

A mobile application is understood as a component installed on a mobile device under a specific platform that controls the user interface and the logic of the device.

A smart solution is the solution of the educational environment that meets the priorities of the digital transformation of the society. The development of a smart application implies the use of the didactic potential of the modern digital technologies in respect of providing science and technology with innovative tools. A smart application can support a healthy lifestyle, manage costs, provide comfort, automate routine processes, minimize danger and risks, i.e., improve the quality of life in the digital society.

4.2. Project-based teamwork on developing a smart application

As it is mentioned above, the students were asked to design a cross-disciplinary project for developing a smart mobile application in the course of their on-the-job training program. The choice of implementation tools remained with the students. The following project tasks were given:

1. A smart project called *City Monuments*. The project idea: there is a list of monuments with pictures and GPS coordinates. The user selects from the list the monuments which are of interest to him, ticks them and offers the app to build a virtual route. After the selected monuments and their history are studied and visited, the application offers the user a set of questions about these attractions. Then the application issues a certificate (for example, Beginner, First Class City Expert) based on the results of the virtual tour.

2. A smart virtual assistant providing career guidance in respect to in-demand future jobs. The project idea is to develop the information model to guide a student in choosing a career; it is designed on the basis of the Atlas of New Professions and available psychological and pedagogical tools for identifying the student's cognitive style, intellectual style, the style of cognitive attitude to the world.

The stages of the team project:

1. Identifying the problem. This stage takes place in the first classes; the problems are identified in the course of discussion of the real tasks with the students. The teams are formed (taking into account the students' choice and preferences). One task can be performed by more than one team (working independently or competing with one another).

2. Setting the goal and objectives. In accordance with the goal, the image of the future model is selected; its structure and content are discussed, the set of functions is specified. The result of this stage is the Requirement Specification, which is drawn on behalf of the Customer and reflects the main requirements for the features of the smart application. Further, the Requirement Specification should be submitted in paper (electronic) form to the experts and the tutor for assessment. In addition, each team should write a review of the Requirement Specification of some other team (the reviewers are appointed at random) and estimate its compliance with the requirements, analyze errors and inconsistencies, whether it is complete, and assess professional expertise. The Tutor does the same identifying the most common errors and shortcomings, and these are subsequently discussed with the teams.

3. Developing a Solution. Students choose a design method in accordance with the requirements for the framework, design and functions described in the specification. The result of this stage is the Technical Project, which is drawn up on behalf of the App Developer (the team of students) taking into account the requirements of the Customer stated in the Requirement Specification. The Technical Project (in paper or electronic form) is submitted to the Tutor for assessment.

4. Creating a demo version. The teams install the chosen programming environment and create a test version of their smart solution using available tools. They select the settings, modify the design, etc. It often turns out that the standard libraries and modules do not have enough capabilities to implement a particular function; in this case the teams have to create their own modules/libraries. The next step is content development and development of a unique copyright sign. The stage ends with presentation of the Project. The teams give a demonstration of their mobile solution (using PowerPoint presentation, infographics, an oral report). The application

itself may not be functional yet at this time. It is assessed how the smart solution may eventually look and function. In other words, it is the project that is assessed, not the real mobile application.

5. Maintenance and implementation stage. The participants modify their application and fill it with the necessary content taking into account the comments made during the Presentation of the Project. Sometimes, the concept itself and/or the programming environment are changed for various reasons. The final version of the smart solution is put into the public domain for all teams and external experts. Since the projects are implemented as part of their on-the-job training program, all teams must do it at the same time which is agreed upon in advance (the date and time).

The tutor and all the teams do not just visually evaluate each other's applications, but also check their functionality and performance on a compulsory basis (they get registered, ask questions in the feedback forms, post reviews, etc.). In this case, the teams act as internal experts. External experts (prospective employers) do the same optionally, if so desired, guided by their own professional interests. At the end of the training program, the external experts fill in the assessment tables assessing specific or all participating teams. The final outcome of the Project is evaluated at this stage.

6. Application operation. If it is a real project, it can be delivered to the Customer for further use after all the above steps. However, it is necessary to organize reflection activities after implementing the Project. Thus, all the teams write a review (in free form) at the end of their work (but before the results are announced) of what, in their opinion, they have succeeded in and what they have failed to implement (taking into account the Requirement Specification/Technical Project) and why. If the team has changed the programming environment, it is necessary to indicate the reasons. If the Customer's problem/the training task has not been solved to the full extent, or, the final Project has excessive functionality that is not required by the Customer, it is necessary to state why and at what stage this happened, and also try to indicate possible ways to resolve these contradictions ("*if we had started the Project again, we would have done so and so* ... ").The last lesson is devoted to the discussion of general and particular problems that the teams have faced, the technical difficulties, the ways to overcome them, development prospects and/or prospects connected with implementation of educational projects, exchange of information about useful resources, etc.

It should be noted that some students continue to work on the application even after the on-the-job training program is over: some of them are offered a job connected with the project and they develop the product. The improved and completed mobile service is often presented and defended as the Bachelor's thesis. Anyway, participation in the Project provides sound practical experience, a basis for the development of professional and universal competencies.

The expected meta-subject/regulative learning outcomes are the ability to independently set the learning objectives; the ability to choose from the available options and independently seek for resources to solve the problem/achieve the goal; the ability to describe your experience adapting it to be transferred to other people in the form of a technology for solving specific practical problems; together with the teacher and team members to determine the criteria for the planned result and the evaluation criteria for the educational activities; the ability to observe and analyze one's own educational and cognitive activities and the activities of other students in the process of peer checking; the ability to compare planned and obtained results and draw conclusions.

The suggested project-based team work on the development of a smart application also involves meta-subject/cognitive actions performed by the students: they learn to identify and name the causes of the event or phenomenon specifying the possible/most probable causes, to predict possible consequences, to independently carry out the cause-and-effect analysis; to build a model/scheme in accordance with the problem data and/or find the way to solve the problem; to work out a plan or algorithm of action, to correct or restore a previously unknown algorithm on the basis of given information about the object where the algorithm is applied.

In regard to the communicative component of teamwork activities, it should be noted that it develops the following skills:

– organizing educational cooperation and collaborative activities with the teacher and peers; working individually and in a group: making a joint decision and resolving conflicts on the basis of coordination of opinions and interests;

– stating, reasoning and defending one's opinion;

– accepting and understanding the point of view of your partner, being able to identify in his speech: the opinion (point of view), evidence (arguments), facts; hypotheses, axioms, theories;

– defending one's point of view in a right and reasonable way, being able to submit objections in the discussion, to paraphrase one's thoughts (mastering the mechanism of equivalent replacement);

– identifying possible roles in collaborative activities, playing a certain role in collaborative activities;

– submitting a detailed plan of one's own activities orally or in writing;

– observing the standards for public speaking, the order and procedure in monologues and discussions in accordance with the communicative task;

– being able to use computer technology (including selection of appropriate software and hardware tools and services relevant to the task) to solve information and communication training problems.

4.3. Experimental estimate

4.3.1. The ascertaining stage of the experiment

The main goal of the experiment was to verify the effectiveness of team work on a cross-disciplinary project aimed at developing skills that are in demand on the labor market and necessary for successful professional self-realization. It was decided at the preparatory stage that the project product itself (smart application) as well as the development process would be evaluated too. A list of skills was compiled (teamwork skills, cross-sector communication skills, project management skills, programming skills), which was most relevant to the needs of the digital society market, and appropriate tasks were drawn up.

After that the criteria were set according to which the tutor, external experts (customers, prospective employers), and participants would conduct an assessment of the team project. A test was carried out before the start of the experiment; it consisted of 10 tasks, each given 2 points by the external experts. For example, to diagnose the skills of the students to work in a team or with other individuals, they were given tasks to develop a dialogue program model or develop a game strategy and select characters. Here is an example of the task: *Professor Dumbledore has to draw up the results of Hogwarts Cup. Four faculties (Houses) participate in the Cup in total: 1. Gryffindor, 2. Slytherin, 3. Ravenclaw, 4. Hufflepuff. The Professor has to choose the House with the highest and least points. Professor Dumbledore must inform Professor McGonagall of the number of the winning House, so that the House is awarded with the Cup. He must also inform Mr. Filch, caretaker of Hogwarts, of the number of the House with the least points, so that Mr. Filch prepares sweets for this House. You should develop an appropriate model.*

The experiment involved 50 students, of which the experimental (26 people) and control (24 people) groups were formed. All subjects are senior students of the faculty of computer science, mathematics, and physics. The average age of students was 21 years. The learning was conducted in the same classrooms, on the same equipment (software, mobile platforms).

4.3.2. Forming stage of the experiment

The tutor carried out methodological work during the forming stage informing the students about the criteria for assessing the project. The teams were formed by the tutor and external experts, but the preferences of students were taken into account. The topics of team projects were formulated together with students taking into account their needs and professional interests either on the basis of a specific problem situation described the customer, or on the basis of a training task. The projects were implemented as part of a three-week on-the-job training program. The expert assessment method (external experts, tutor, students themselves) was used to process and interpret the results of the team work activities aimed at developing a smart solution.

The ability to work in a team was evaluated on the basis of a 5-point scoring scale according to the following criteria: rhythm of work of each member of the team and of the team as a whole, constructive nature of disputes and discussions; argumentation of ideas and decisions in the process of discussion; error correction by each member of the team and the team as a whole; distribution of powers; emotion management, the ability to subordinate their ambitions to the common goal.

Programming activities were evaluated on a scale from 0 to 5 according to the following criteria: software selection; efficiency compliance of the result with the set goal; sustainability, originality, ease of solution; technical design.

The project activities were evaluated on a scale from 0 to 5 according to the following criteria: functionality, replicability of the project, applicability, producibility; visual expression, aesthetic qualities, attractiveness; novelty, creative approach, originality, uniqueness; effectiveness, efficiency, practicability, ease of use, availability; relevance, up-to-dateness, room for improvement.

Cross-sector collaboration was evaluated on a scale from 0 to 5 according to the following criteria: content, completeness of the material; correct wording of concepts and definitions; application of scientific laws, notions and concepts; use of formulas, models; range of economic sectors where the application can be used.

If the project got more than 17 points according to the results of expert assessment it was given an excellent mark; the projects rated in the range from 9 to 17 were given a good mark. The projects were marked as satisfactory if the experts assessed them from 5 to 8. Other projects were rated as "unsatisfactory".

4.3.3. Control stage of the experiment

The test was carried out again at the control stage of the experiment. It also contained 10 tasks designed according to the principles described above. The tutor took into account the difficulties that the participants faced when formulating the tasks in the final test. For example, to determine the redundant functionality of the application, to indicate the minimum required team composition for the project, to decide which digital technology to use, etc.

Here is an example of the task: *There is an order to design a mobile application which helps the user choose a theater and a performance in a particular city. The developer started to describe the functionality of the application, but stopped work for some reasons. Continue the description of the required functionality highlighting the necessary minimum and application development options.*

1. The application contains a list of city theaters.
2. The application can switch to the selected theater, provide its address, location, the news; a list of the theater productions and a list of actors upon request.
3. The application should display the theatre guide for the current month (or months in accordance with the information on the site) …

The results of the assessment of the required competencies by the external experts and the tutor before and after project-based teamwork activities are presented in Figure 1.

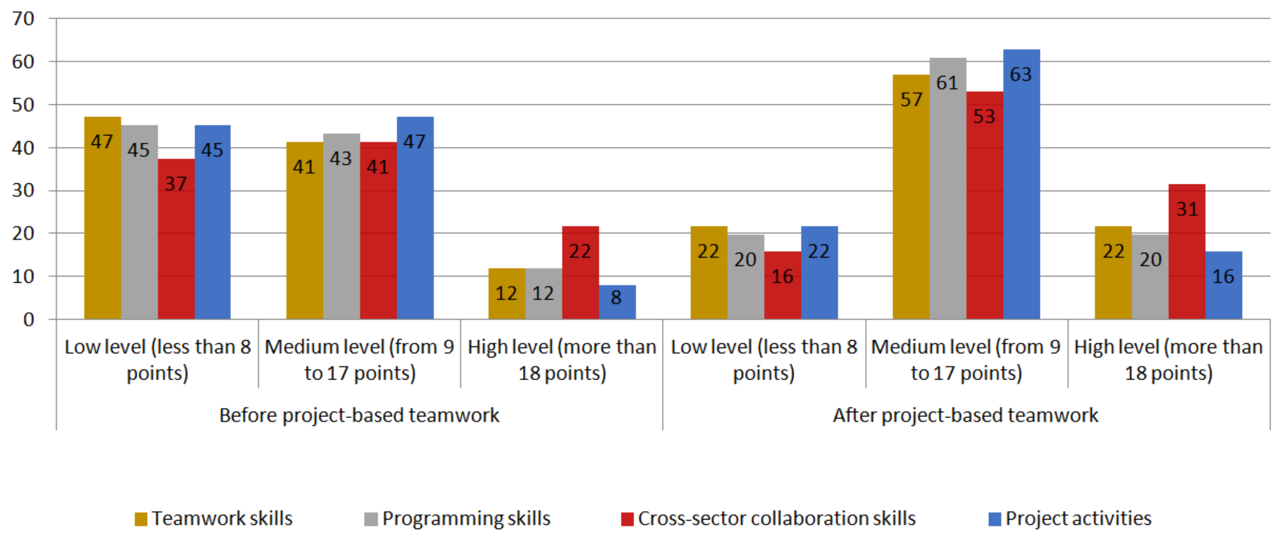

Fig. 1. Dynamics of changes in the level of competencies

The analysis of the obtained results allows us to conclude that the least difficulties, both before team work on the project (37 % of the participants show a low level of proficiency), and afterwards (16 %) were caused by cross-sector collaboration. As for the ability to work in a team/a group or with other individuals, this indicator had the lowest values before teamwork activities (37 % of students show a low level). In our opinion, this is explained by the fact that the formation of these competencies is a long and complex process which should have a systematic and fundamental nature. However, after the experiment, there was a significant improvement in this universal competence (only 22 % of the students had a low level). Thus, the conclusions made by other scholars are confirmed: training students to participate in collaborative activities requires from the educator serious methodological work.

The medium level demonstrated the highest growth in values for all indicators.

G test was used to assess the effectiveness of the suggested form of training. It allows evaluating random/non-random nature of the changes that take place. The method assumes tracking the shift that reflects the changes in the results of the same student after and before being engaged in project-based teamwork. The values are presented in Table 1 taking into account the sign. According to the table, we have 1 "zero" (discarded), 24 "positive" (typical), 1 negative (atypical) shifts. The methodology takes into account only positive and negative shifts, the zero ones being excluded. The calculation was made using special statistical tables.

Table 1. Assessment Results

Shift	-1	0	1	2	3	4	5	6	8	11
Number of shifts	1	1	6	5	4	3	2	2	1	1

We shall formulate the hypothesis:

H0: the shift in increasing the level of skill formation after the project-based team work on the development of smart applications is random.

H1: the shift in increasing the level of skill formation after the project-based team work on the development of smart applications is not random.

Next, we analyzed the values in the table of G signs and the data of online calculations (Ostapenko, 2010). We see that for n = 24 (according to the number of typical shifts), the calculated $G_{emp} = 1$ and the critical statistical value given in the tables the following is fair:

$$G_{cr} = \begin{cases} 7, \text{when p} = 0.05 \\ 5, \text{when p} = 0.01 \end{cases}$$

As $G_{emp} < G_{cr}$, the hypothesis drifts towards H1 hypothesis, so the shift in increasing the level of skill formation after the project-based team work on the development of smart applications can be considered not random.

The results of the control testing before and after the experiment are given in Table 2 and Table 3 respectively.

Table 2. The results of the test before the experiment

Groups	Mark				
	5	**4**	**3**	**2**	
The experimental group	0	4	14	8	26
The control group	1	3	13	7	24
	1	7	27	15	50

Table 3. The results of the test after the experiment

Groups	Mark				
	5	**4**	**3**	**2**	
The experimental group	8	10	6	2	26
The control group	3	4	12	5	24
	11	14	18	7	50

Let us accept the following hypotheses. H0: the level of development of skills in demand in the labor market in the experimental group is statistically equal to the level of skills and abilities of students in the control group. H1: the level of development of skills of students in the experimental group is higher than the level of students in the control group.

We calculate the value of the statistic of the criterion before ($\chi 2_{emp\ 1}$) and after ($\chi 2_{emp\ 2}$) the experiment, using the online resource http://medstatistic.ru/calculators/calchit.html (Ostapenko, 2010). A significance level is α = 0,05. In this case c = 4, which means that the number of degrees of freedom is $\nu = c - 1 = 3$. According to the distribution tables χ^2 for ν = 3 and α = 0,05, the critical value of the statistic is 7,82. Thus, we obtain: $\chi 2_{emp\ 1} < \chi 2_{cr}$ (1,49 < 7,82), a $\chi 2_{emp\ 2} > \chi 2_{cr}$ (8,55 > 7,82). According to the decision rule, this means that the hypothesis H_o is true before the experiment, and the hypothesis H_1 is true after the experiment.

5. Discussion

The sample was not probabilistic, since the initial stage of the experiment took into account the results of a survey of students, previous educational achievements, and the opinions of a team of experts. The training was conducted in the same classrooms, by the same teacher. The expert assessment method was used to process the results of team work on the project. The teamwork tutor had to select external experts, develop a criteria-based matrix for assessing the projects, choose a method for processing the results in order to obtain feedback on the formed competencies. It was decided to visualize the data about the competencies in the form of a diagram to demonstrate the dynamics.

The experts also determined the average values for each indicator. The calculations showed that the average value of the control measure calculated before and after the team activity on the project was higher at the end of the experiment by 1.1 (the indicator increased from 2.9 to 4.0). At the same time, the final control tasks were more complex than the initial tasks.

The participants of each team worked in the process of the project development in the following way: all the team members worked together during the discussion of the problem situation, reflection activities and preparation for the defense of the project; participants worked individually in accordance with the technical requirements doing programming and individual tasks during the project implementation, programming and the implementation of independent tasks. The competencies necessary for participating in the project include: basic knowledge and skills of writing the program code according to the algorithm, programming in the environment; receiving and processing information; the ability to connect external libraries in programming environments; the ability to carry on multiple operation tests aimed at studying and improving specific characteristics of the created application.

The set of skills and abilities that are developed through the involvement of students into collaborative activities includes: the ability to generate ideas; the ability to listen to and to hear the other person; the ability to defend one's point of view; the ability to search for information in free sources and to structure it; the ability to carry out independent research activities aimed at designing a new application or improving the characteristics of the old one; ability to combine, modify and improve ideas; teamwork skills; the ability to formulate your thoughts in writing; the ability to position oneself in the field of professional tasks; the ability to assess the necessary amount of professional knowledge and skills necessary to solve a particular problem; the ability to assess the aesthetic qualities of a particular solution and its compliance with the public morals; reflection skills and the ability to evaluate the result of one's own activities; basic public speaking skills.

In general, the pedagogical experiment has shown that involving students in teamwork on a cross-disciplinary project to develop smart applications can improve the quality of training in relation to the competencies most demanded by today's society, economy, and education. However, to organize teamwork on a cross-disciplinary project requires from the teacher a lot of preparatory and organizational effort. As for methodological tips, we recommend that the tutor should use the projector to submit the task description for the teams; the project assessment criteria can be given in the form of a criteria matrix. One can also use infographics and show how the teams are located in the classroom schematically. It is recommended to prepare handouts for the participants: manuals, a list of questions, a list of information resources, assignments, etc.

6. Conclusion

The analysis of the results of the students' cognitive activity allows us to insist that teamwork activities facilitate deep meaningful learning. The practice of developing smart applications in the form of teamwork shows the main didactic advantage of the suggested method which is the fact that it makes it possible to solve really serious problems and practice-oriented tasks and to develop in-demand professional skills. The main condition is that teamwork should be carefully planned and designed and supported by the tutor to the extent necessary.

It is of importance that project-based team work should contain an element of reflection. Therefore, meta-subject/regulative learning outcomes are the most significant ones:

–the ability to independently determine the learning goals, to set and formulate new tasks, to expand motives and interests of one's own cognitive activities;

–the ability to choose among available options and independently seek the means/resources to solve the problem/to achieve the goal;

–the ability to describe your experience in the form of technology making it proper to transfer to other people for solving practical problems in a particular sphere;

–the ability to work out, together with the teacher and peers, the criteria for the planned results and the criteria for evaluating educational activities;

–the ability to set your actions against the goal and, if necessary, correct the mistakes;

–the ability to observe and analyze one's own educational and cognitive activities and the activities of other students in the process of cross-check;

–the ability to correlate real and planned results of collaborative activities and draw conclusions;

–the ability to define the reasons for success or failure and find the ways out of the situation of failure.

The findings of the study make it possible to formulate the following recommendations to help teachers unlock the educational potential of teamwork projects:

1. The tutor should decide at the planning stage what will be assessed: the Project itself, the process of creating the product, or all these things as a whole.
2. The task for the team should be quite complex and multidimensional, allow different solutions requiring different skills and actions; it should create conditions for different members of the team to show their worth.
3. Teamwork assessment procedure should be designed prior to its implementation. All participants must know the assessment criteria before they start to solve the problem.
4. The project can be assessed by the tutor, experts and the students themselves.
5. Evaluation should not be a goal in itself. It's not obligatory to give a mark. The priority in organizing teamwork activities should be given to getting feedback on the knowledge obtained and the competencies trained.

The projects designed in the process of teamwork are smart solutions developed in a digital educational environment and aimed at providing science and industry with innovative competitive resources to meet the challenges of the future.

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