Collaborative learning in the system of training future information technologies specialists as an educational strategy for the fundamentalization of the sustainable development of education

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Abstract

The article, based on empirical and theoretical research, reveals the place of collaborative learning in the system of training future information technology specialists in the context of the implementation of sustainable development goals. The authors of the article distinguish between the concepts of cooperative and collaborative learning, understanding the latter as a more psychologized, intellectualized learning, based on the disclosure of the synergistic effects of group work. In the work proposed a methodology for using collaborative learning in the system of training future information technology specialists to participate in team sports programming as one of the subtypes of subject competitions. The article presents a scheme of the iterative process of forming a sports programming team. It involves determining the primary team composition, defining roles, training, evaluating team success, changing team composition and redistributing roles. Considering the stages of training in the context of collaborative learning, it is proposed to use the following methods: pair programming, joint code development, code review, retrospective, code sessions. A survey was conducted of university lecturers involved in the training of future IT specialists. The results of the survey were processed using methods of system analysis, Natural Language Processing (NLP), statistical methods (Wilcoxon signed-rank test), computer modeling, and data visualization. It was found the common and different key characteristics of cooperative and collaborative learning in the opinion of computer science lecturers. The analysis of the results of the respondents' answers indicates that the respondents more often use cooperative learning compared to collaborative learning in the process of forming students' teamwork skills. At the same time, those university lecturers who constantly use collaborative learning in their activities note its positive impact on the formation of students' teamwork skills, the effectiveness of learning activities, which is manifested in solving tasks (simple and complex) and their better understanding, the formation of effective goal setting, effective emotional interaction and common values of group activities.

Keywords

collaborative learning, cooperative learning, teamwork skills, information technology education, sports programming, sustainable development goals, pair programming, code review, natural language processing (NLP), system analysis, computer modeling, data visualization, team formation, educational methodology, psychologized learning

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1. Introduction

Sustainable development in education is aimed at creating systems, strategies, and approaches that promote the development of education in harmony with the current needs of society, while ensuring that opportunities for future generations are preserved [1]. Sustainable development in education is aimed at creating a system in which future professionals gain knowledge and skills necessary for the development of a sustainable and responsible community, capable of acting in compliance with ecological standards, in collaboration, in harmony with the world, ensuring its well-being in the long term [2, 3, 4, 5]. One of these skills is communication skills, social interaction skills, the ability to collaborate and solve problems collectively [2, 3, 4, 5].

One of the approaches in which students work together in groups or teams to solve tasks and problems is collaborative learning [6, 7]. Collaborative learning can contribute to the sustainable development of education, because it promotes the development of critical thinking, tolerance and the ability to work together on global problems [6, 7]. In collaborative learning students can better understand the importance of sustainable development. This is achieved by working together on specific tasks or projects, including IT projects in the field of ecology, economics, society, etc. Therefore, collaborative learning can contribute to the training of professionals who understand the importance of sustainable development and have the skills to collaborate to achieve the goal.

One of the consequences of the mass informatization of society and the active use of information technologies in professional activities, education and leisure is the transformation processes in education [8]. They are also related to the requirements for training school and university graduates. At the same time, the system of graduates' professional qualities must meet the requirements of the modern digital society – a high level of information culture, the formation of key and professional competencies, the ability to self-learn, the ability to solve non-standard problems and adapt to changes in the environment [9].

Besides, a modern specialist must possess mental properties, professional skills and abilities that would help him or her to solve non-standard and atypical tasks, flexibly adapt to unexpected situations, rationally, creatively, independently solve a wide range of life and professional problems that may arise, generate new ideas, and be fluent in the latest technologies.

In the information society, the process of training information technology specialists is very important, because they take an active part in ensuring the smooth functioning of any information system, determining the level of development and penetration of information technology in all spheres of life, economy, and industry.

The global pandemic was one of the factors that influenced the quality of professional training of students in information technology [10, 11]. It led to the transition to distance or blended learning, raised many questions about the methodology of organizing educational activities and the selection of appropriate teaching methods and technologies [12, 13, 14]. It is very important to ensure the conditions for teamwork when training students in information technology, especially in the field of programming [15]. Therefore, teachers of higher education institutions were forced to find a new teaching technology and adapt to the conditions of distance learning, in particular, to actively use group methods of working with students based on collaborative learning.

In the process of training modern information technology specialists, the issue of development of their teamwork skills through collaborative learning is very important. Among the scientific works devoted to the formation of teamwork skills in future information technology specialists, two areas of research can be distinguished: the first is researches devoted to the use of collaborative learning in the process of professional training of students in computer science, the second is the use of distance and blended learning technologies for the formation of teamwork skills.

Berglund [16] describes the process of formation of engineering students' skills to work in multi-disciplinary teams and solve social issues in distance learning. Tudevdagva et al. [17] describes the implementation of active learning methods (eduScrum, JigSaw, problem based learning, practical and team-based learning) in engineering courses. Sarrade and Lermigeaux-Sarrade [18] considered he process of integrating sustainability and ethics into team-based and project-based learning with computer

science students.

Dowdall et al. [19] pay attention to the development of communication and other soft skills among computer science students. The main focus in the training of future specialists in computer science is on the formation of professional competences, and the development of communication skills of future specialists remains in the shadows. The research has shown that the use of team projects based on a multinational, intercultural, multidisciplinary and intensive methodological approach contributes to the formation of interaction skills and effective teamwork in computer science students.

Matthíasdóttir and Loftsson [20] share their experience of implementing flipped classroom technology and team learning in the process of teaching programming computer science students. Based on experimental training and a survey, the authors conclude that students were interested in the flipped classroom technology, provided that there was a well-prepared distance course.

Xu et al. [21] consider pair programming, as a mode of collaborative problem solving in computer programming education (asks two students work in a pair to co-construct knowledge and solve problems). The research results suggest four models of cooperation in pair programming: a consensus-achieved pattern, an argumentation-driven pattern, an individual-oriented pattern, and a trial-and-error pattern.

Conte et al. [22] describes the results of an experiment on teaching parallel programming computer science students. The experiment used three different teaching methodologies: traditional, Problem Based Learning, and Team-Based Learning. The results of the research allow us to conclude that it is possible to teach parallel programming students without prior knowledge of computer science, while obtaining high scores and interest in such teaching.

Conte et al. [22] analyzes collaborative learning from different perspectives and concludes that collaborative learning can be applied to online learning, distance learning, and cross-cultural learning. The research shows that the effectiveness of collaborative learning can depend on a number of factors, such as the organizational environment of collaborative learning, the level of interdependence between group members, as well as the type of tasks performed, personal characteristics, etc.

Ramskyi et al. [23] considers the methodology of using massive open online courses in the process of training future information technology specialists. It proves the importance of attracting students to use open online courses as a means for self-education and self-development and formation of collaborative learning skills.

An important aspect of collaborative learning for information technology professionals is specific and meaningful interactions in the human-computer system [24]. In collaborative learning, this interaction can be considered as a “human-computer system small group”.

The review of scientific studies shows that they pay little attention to the description of the methodology of using collaborative learning in the training of future information technology professionals.

The purpose of the study is to find out the place and significance of collaborative learning in the structure of professional training of information technology students and the impact of its use on the development of students’ skills of interaction and effective teamwork, student training for team programming in the context of the implementation of sustainable development goals.

2. Selection of methods and diagnostics

In this research, we used a system of methods, among which the most important were: systemic, problematic, targeted, ecological (to understand the place and importance of collaborative learning as one of the ways to achieve the Sustainable Development Goals – №4 “Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all”), pedagogical, social and psychological (to reveal the phenomenology of group work which is used in the collaborative learning), cognitivistics (to understand the phenomenon of collective and individual minds), autopoiesis (to analyze the phenomenon of collaborative learning as a sociobiological and cognitive phenomenon), psychological (to analyze group dynamics and the phenomena of internal and external motivation in the process of implementing collaborative learning). The questionnaire method was used based on the developed own questionnaire.

To achieve the goals of the study, a questionnaire was developed for teachers using Google Forms. University lecturers were asked the following questions in the questionnaire that we developed:

1. Please indicate which specialties you are currently teaching (or have teached in recent years) at your higher education institution.
2. What modern educational technologies do you use in teaching students?
3. What do you understand by cooperative learning?
4. What do you understand by collaborative learning?
5. Do you use cooperative learning methods in your teaching practice? (Answer options: yes, often; yes, seldom; no.)
6. Do you use collaborative learning methods in your teaching practice? (Answer options: yes, often; yes, seldom; no.)
7. Have you involved students in team project work? If yes, in what form was the project work carried out? (Answer options: yes (auditory classes); yes (optional work); yes (students' practice); no.)
8. Do you prepare student teams for participation in team programming? (Answer options: yes; no.)
9. If you have prepared student teams for competitions, what methods or technologies did you use for training (If not, put "–")
10. When you used collaborative learning, did you observe an increase in the effectiveness of learning activities, which was manifested in solving relatively simple tasks? (Answer options: yes; I cannot decide; no; I do not use collaborative methods in teaching.)
11. When you used collaborative learning, did you observe an increase in the effectiveness of learning activities, which was manifested in solving relatively complex tasks? (Answer options: yes; I cannot decide; no; I do not use collaborative methods in teaching.)
12. Did the use of collaborative learning contribute to a better understanding of the tasks and the formation of effective goal setting? (Answer options: yes; I cannot decide; no; I do not use collaborative methods in teaching.)
13. Did the use of collaborative learning contribute to the formation of effective emotional interaction in the group? (Answer options: yes; I cannot decide; no; I do not use collaborative methods in teaching.)
14. Did the use of collaborative learning contribute to the formation of effective cognitive interaction in the group? (Answer options: yes; I cannot decide; no; I do not use collaborative methods in teaching.)
15. Did the use of collaborative learning contribute to the formation of common values in the group? (Answer options: yes; I cannot decide; no; I do not use collaborative methods in teaching.)
16. Rate on a scale from 1 to 10 the impact of cooperative learning on the development of students' teamwork skills. 1 – no impact at all, 10 – great impact.
17. Rate on a scale from 1 to 10 the impact of collaborative learning on the development of students' teamwork skills. 1 – no impact at all, 10 – great impact.

To analyze the survey results, we used system analysis methods, statistical methods (Wilcoxon signed-rank test, analysis of standard deviation and mean values), NLP methods [25], digital modeling, and data visualization. The research results were processed using Google Sheets [26], Google Collaboratory [27], and the Python programming language [28].

Natural language processing (NLP) was implemented using the Python programming language [28], the Natural Language Toolkit (NLTK) open-source library [25]. The sequence of processing respondents' answers was as follows (figure 1):

The data were statistically processed using the Wilcoxon signed-rank test [29, 30]. It was used to find out whether there is a statistically significant difference between the respective estimates of the impact of cooperative learning and collaborative learning on the development of students' teamwork skills. In this case, we consider a "Typical" shift to be a shift towards an increase in the value of the score when

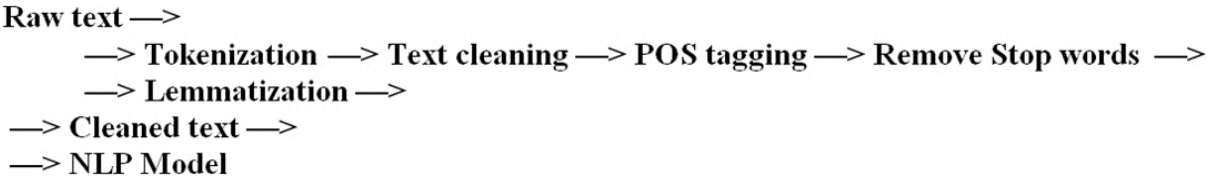

Figure 1: The sequence of processing the respondents' text answers.

finding a difference between the respondent's assessment of cooperative and collaborative learning, and an "Atypical" shift to be a shift towards a decrease in the value of the score. Differences between the respective respondents' assessments of the impact of collaborative learning and cooperative learning on the development of students' teamwork skills that are equal to zero are ignored when applying this test. At the same time, we formulate the following hypotheses:

H1: the intensity of "Typical" shifts is statistically significant at the level of significance $a < W$ does not exceed the intensity of "Atypical" shifts.

H2: the intensity of "Typical" shifts statistically significantly exceeds the intensity of "Atypical" shifts at the level of significance $a < W$.

The sum of the ranks of the differences in respondents' estimates characterizing the "Atypical" shift (R_{atyp}) is calculated by the formula (1).

$$R_{atyp} = \sum_{i=1}^{k} r_i, \tag{1}$$

where:

- k is the number of respondents' answers with a shift value that is not equal to 0 (the number of atypical shifts);
- r_i is the rank of differences in respondents' answers that characterize the "Atypical" shift;
- i – index, $i = 1, \ldots, k$.

We find R_{cr} in the table for the Wilcoxon signed-rank test for a given n (the number of "Typical" and "Atypical" shifts) at the significance level W, W is defined as 0.05 or 0.01, that is, $a < 0.05$ or $a < 0.01$. If $R_{atyp} >= R_{cr}$, then at the level of significance W, the intensity of "Typical" shifts is statistically significant at the level of significance $a < W$ does not exceed the intensity of "Atypical" shifts, we accept the hypothesis $H0$. If $R_{atyp} < R_{cr}$, the intensity of "Typical" shifts statistically significantly exceeds the intensity of "Atypical" shifts at the level of significance $a < W$, the hypothesis $H0$ is refuted, we accept the hypothesis $H1$.

We also used the following formulas to compare the mean values ($\bar{X}$) and standard deviations (σ) of the estimates of the impact of cooperative learning and collaborative learning on the development of students' teamwork skills. σ – the standard deviation is calculated by the following formula (2).

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n}}; \tag{2}$$

where:

- n is the number of respondents' answers;
- x_i is the value of the assessment given by the i-th respondent, $i = 1, \ldots, n$;
- $\bar{X}$ – the expected value (arithmetic mean) (formula (3))

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n}. \tag{3}$$

3. Results and discussion

Nowadays, there is a need to train a competitive information technology specialist who is able to navigate the changing information society and is capable of self-learning. To do this, it is necessary to ensure that future specialists develop knowledge of the theoretical foundations of information technology, general competencies (ability to learn, communicate in a foreign language, work in conditions of uncertainty, plan their workload and effectively distribute work, maintain high performance, etc.) and professional competencies (the ability to quickly and easily learn new information technologies, apply new standards in the field of information systems and technologies, analyze and select the necessary data among the existing information collapse in the global network, form new competitive ideas and implement them in projects, develop business solutions, evaluate new technological proposals, etc.).

The requirements for training IT specialists are laid down in the state standard of higher education. They provide for the formation of a system of general and professional competencies in students, some of which are formed in the process of collaborative learning:

- Ability to work in a team.
- Skills of interpersonal interaction.
- Ability to act in a socially responsible and conscious way.
- Ability to apply knowledge in practical situations.
- Ability to develop and manage projects.
- Ability to develop business solutions and evaluate new technological proposals.
- Ability to participate in the design of software, including modeling (formal description) of its structure, behavior and processes of functioning.
- Ability to formulate and ensure software quality requirements in accordance with customer requirements, technical specifications and standards.
- Ability to formalize the obtained work results in the form of presentations, scientific and technical reports.
- Ability to formulate new competitive ideas and implement them in projects (startups).

Collaborative learning is defined as the joint organization of learning activities in which students with different abilities work in small groups to complete a project or solve a task.

A distinction should be made between cooperative and collaborative learning. During cooperative learning, each student in the group performs the task assigned to him or her. At the same time, cooperation requires the distribution of tasks among all members of the working group, and each is responsible for a separate part of the task in order to combine them effectively to achieve the goal. Collaboration involves the mutual involvement of group members in interaction through coordinated efforts to solve the task. The main focus is on the dynamics of cooperation within the collaborative group rather than on the individual completion of the task [31].

In collaborative learning, multifaceted subject-subject relations are created that influence the course and outcome of learning activities. Students are exposed to the idea and practice of equality, given the opportunity to acquire competence in professional interaction, learn to accept or reject the position of another participant in the training, coordinate their actions with his or her actions, develop volitional traits, assert themselves, defend and protect their own opinions and academic achievements.

The fundamental ancient Greek educational concepts of self-knowledge ("know thyself") and self-care ("take care of yourself") were developed in the interpretation of M. Foucault [32, 33]. Based on these concepts, we consider the student as a person who independently builds his or her educational trajectory, acquires knowledge, gains practical experience in their application, and realizes himself or herself as part of a team, solving common problems. The art of teamwork, leadership, creativity, and critical thinking are one of the 21st century skills needed to achieve success in the professional field and ensure sustainable development [2, 3, 4, 5, 7].

An important way to acquire collaboration skills is to prepare for subject competitions and participate in them. Here, collaboration can be implemented as interaction with a mentor and as teamwork.

Subject competitions provide an opportunity to develop students' cognitive activity and contribute to the formation of their analytical thinking. Team sports programming is one of the subtypes of subject competitions in which students of information technology can participate.

Collaborative learning tools (as opposed to traditional ones) contribute to the efficiency of the team's work. That is why it is appropriate to use collaborative learning in the process of preparing for competitions in team sports programming.

Here are some specific examples of how collaborative and cooperative learning can be used in training sports programming teams.

It often happens that in a sports programming team, each team member specializes in a certain type of task. An example of cooperative learning would be a process in which each team member works on the tasks that best suit their knowledge. That is, team member M_1 develops a solution for task T_1 on a computer, team member M_2 develops an algorithm for solving task T_2, and M3 works on task T_3. Team members work on their own parts and collaboration between them is minimal.

Below are a few examples of how cooperation described above can transformed into collaboration:

1. While team member M_1 is programming task T_1 on the computer, team members M_2 and $M3$ work together on the algorithm for task T_2.
2. Team member M_1 writes the code to solve problem T_1, while M_2 monitors this process (which can help to detect errors at an early stage). At the same time $M3$ works on the algorithm for task T_2.
3. Team member M_1 writes the code to solve problem T_1, while M_2 spends some time developing input data sets (tests) for T_1 and then M_2 monitors the coding process of M_1 (which can help to detect errors at an early stage). At the same time $M3$ works on the algorithm for task T_2.

We suggest the following stages of preparation for competitions in team sports programming:

1. Formation of the team.
2. Defining the roles and fields of specialization of each participant (for example, one team member may have the most experience in dynamic programming, while the other team member may have experience in solving problems using graph theory methods).
3. Training (acquisition, improvement, and development of knowledge in algorithmization and programming, development of creativity, critical thinking, problem solving, communication skills, negotiation skills, empathy, adaptation, initiative, presentation skills, etc.)

This process is usually not linear; at any stage of the process, there may be a need to return to the previous stage, and it may be iterative (for example, the composition of teams may change during the preparation process). This is shown in figure 2.

Let's take a more detailed look at the training stage from the perspective of collaborative learning. During training, it is advisable to use the following collaborative methods:

- pair programming is a programming methodology in which two programmers work on the same task using the same computer. One programmer writes the code, while the other analyzes it, controls the quality, and provides advice and assistance;
- collaborative code development is a program code development process in which several developers work together on the same program or project, using special tools and collaborative development technologies to help improve efficiency and quality of work;
- code review – the process of checking program code performed by another developer or development team to ensure quality, identify errors, and ensure code compliance with best practices and standards;
- retrospectives – a team (or several teams) meet once in a certain period of time (a week or two) to evaluate the work done, highlight strengths and weaknesses, and develop an action plan for the future;
- code sessions – programmers get together to solve complex problems or improve the code of already solved problems, discuss problems that arise and share knowledge.

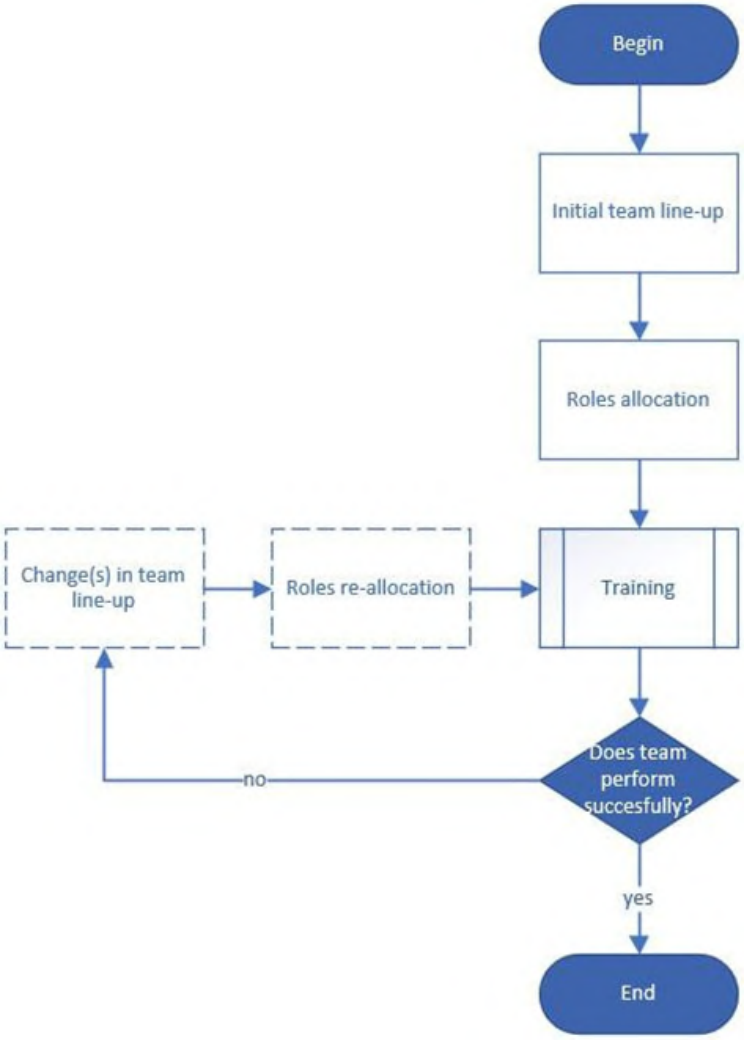

Figure 2: The iterative process of forming a sport programming team.

This allows each team member to contribute to the solving of a problem, receive feedback from other members, and improve their skills.

The team can also use online resources and platforms for collaborative programming, such as GitHub, GitLab, Bitbucket, Jira, Confluence, and others. These platforms allow the team to work on a project together, share knowledge and experience, use a version control system, assign responsibilities, create documentation and implement other useful features.

Future IT specialists must not only have the necessary knowledge, but also be ready to develop independently and easily adapt to changes. This is due to the rapid development of this industry. Let's demonstrate this on the example of developing business applications that work in browsers and are developed using the .NET web development stack. In the last 10 years alone, it has been completely updated several times (table 1).

Table 1
Backend and frontend technologies for developing business web applications using the .NET development stack.

Backend technologies	Frontend technologies
ASP.NET	HTML/CSS + JavaScript
ASP.NET MVC	RAZOR + frameworks like jQuery
ASP.NET WebAPI	TypeScript VueJS, Angular, React

As you can see from table 1, front-end and back-end developers need to update their knowledge on a regular basis. In addition, their roles and contributions to the final product are being rethought. It should also be noted that IT specialists must be a "team player", that is, they must work effectively on the overall result as a team member.

We conducted a survey of information technology lecturers using the questions presented above in the following higher education institutions: Dragomanov Ukrainian State University (Kyiv, Ukraine), Borys Grinchenko Kyiv Metropolitan University (Kyiv, Ukraine), State University of Trade and Economics (Kyiv, Ukraine), Institute of Pedagogy of the NAES of Ukraine (Kyiv, Ukraine), Higher educational institution "University of Educational Management" of the NAES of Ukraine (Kyiv, Ukraine), Vinnytsia Mykhailo Kotsiubynsky State Pedagogical University (Vinnytsia, Ukraine), Public Higher Educational Establishment "Vinnytsia Academy of Continuing Education" (Vinnytsia, Ukraine), Communal institution of higher education "Vinnytsia Humanitarian Pedagogical College" (Vinnytsia, Ukraine), Ternopil Volodymyr Hnatiuk National Pedagogical University (Ternopil, Ukraine), Drohobych Ivan Franko State Pedagogical University (Drohobych, Ukraine), Zhytomyr Ivan Franko State University (Zhytomyr, Ukraine), Pavlo Tychyna Uman State Pedagogical University (Uman, Ukraine), Taras Shevchenko National University "Chernihiv Colehium" (Chernihiv, Ukraine), Berdyansk State Pedagogical University (Berdiansk, Ukraine). 42 lecturers participated in the survey.

The results of the survey of information technology lecturers revealed that they use the most relevant teaching methods and technologies in the educational process, including project method, startup projects, flipped learning, artificial intelligence technologies, simulation technologies, gamification technologies, STEAM technologies, problem-based learning, collaborative learning, cooperative learning, blended learning technology, discussion technologies, interactive methods, case methods, and others. Among the forms of teaching, lecturers highlighted distance learning. In their teaching practice, respondents widely use online platforms and courses, learning platforms (Moodle, Collaborator, and Google Classroom), simulation platform, interactive e-books and resources, video conferences (using Zoom, Google Meet, and Tims), mobile applications for learning, digital educational games, artificial intelligence platforms, and others.

The analysis of the lecturers' answers to the questions "What do you understand by cooperative education?" and "What do you understand by collaborative learning?" was conducted to find out the contextuality of the concepts of cooperative and collaborative learning, which concepts are key for the respondents in defining cooperative and collaborative learning.

The frequency analysis of keywords in the respondents' description of the concepts of cooperative and collaborative learning was based on Natural Language Processing (NLP) technologies. The analysis was conducted using the Python programming language on the Google Colaboratory platform. We performed preprocessing of the data (tokenization, text cleaning, part-of-speech tagging (POS tagging), removing stop words, lemmatization), calculated statistics of word frequency distributions, and built a digital graphical model. Based on the results of processing the respondents' answers using NLP technologies, the following results were obtained.

As a result of the analysis of teachers' answers to the question "What do you understand by cooperative learning?" based on the frequency distribution of keywords (figure 3, figure 5 (a)), it was found that the key characteristics of the content of the concept of cooperative education for respondents are 'teaching' 'based' on 'cooperative' 'work' in a 'small' 'group' (learning based on cooperative work in a small group), 'learning' 'together' to 'achieve' a 'common' 'goal'.

The frequency analysis of lecturers' answers to the question "What do you understand by collaborative learning?" based on the distribution of keywords (figure 4, figure 5(b)) showed that the key characteristics of the content of the concept of collaborative learning for respondents are 'learning' 'work' of students in a 'small' 'group' 'based' on 'collaborative', who have different 'abilities' and cooperate 'together' to 'solve' problems or 'complete' 'project' 'task'.

So, the common key characteristics of cooperative and collaborative learning are 'teaching' or 'learning' 'work' of students in a 'small' 'group', 'learning' 'together'. The difference in the respondents' answers is that cooperative learning is supposed to 'achieve' a 'common' 'goal', while in the characterization of collaborative learning the goal is specified and indicates 'solve' problems or 'complete' a

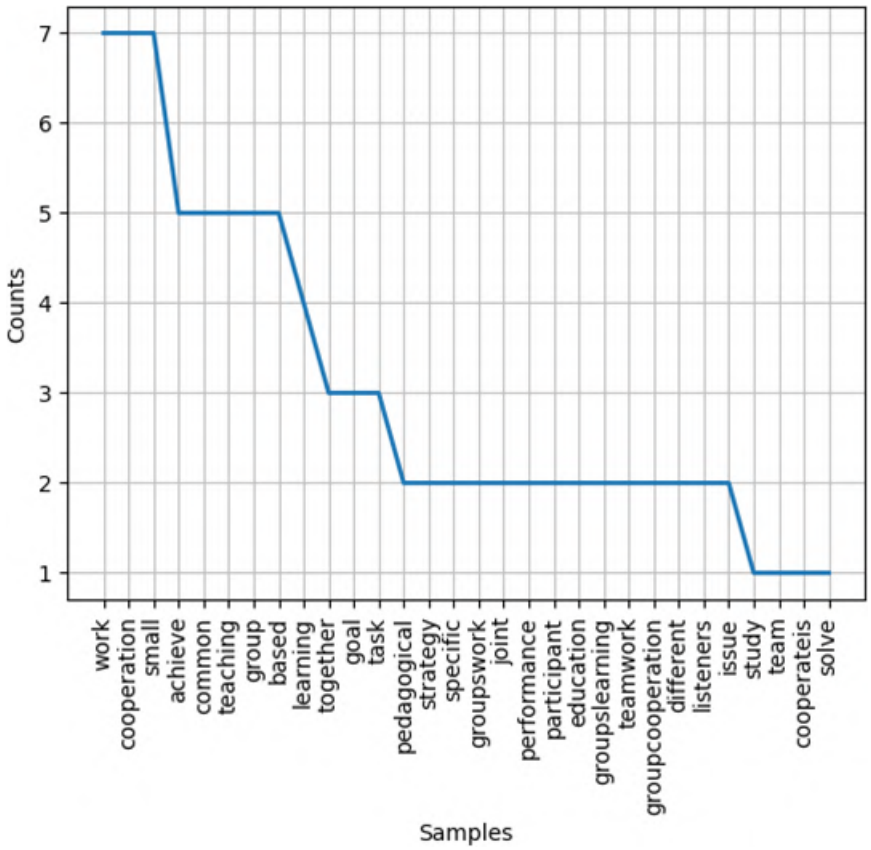

Figure 3: Frequency distribution chart of keywords characterizing the concept of cooperative learning.

'project' 'task'. The main difference in the characteristics of cooperative and collaborative learning is that cooperative learning involves cooperative work and collaborative work respectively.

Let's find out if there is a statistically significant difference in the respondents' assessment of the impact of cooperative and collaborative learning on the development of students' teamwork skills. For this purpose, we will use the Wilcoxon signed-rank test. We will form a table of the values of the respective ratings of the respondents, the difference between which is not equal to zero, and the ranks of the absolute values of the differences (table 2).

We calculate the sum of the ranks of the differences in respondents' ratings that characterize the "Atypical" shift (R_{atyp}, formula (1)):

$$R_{atyp} = \sum_{i=1}^{8} r_i = 102.$$

The critical values of R_{cr} for the Wilcoxon signed-rank test for $n = 23$ according to the table of critical values for this test are equal:

- for $a < 0.05$ the $R_{cr} = 83$,
- for $a < 0.01$ the $R_{cr} = 62$.

Since R_{atyp} = 102 is greater than $R_{cr} = 83$ ($102 > 83$) at $a < 0.05$, and even more so than $R_{cr} = 62$ at $a < 0.01$ ($102 > 62$), we accept the hypothesis $H0$. This means that the intensity of the "Typical" shifts is statistically significant at the level of significance $a < W$ does not exceed the intensity of the "Atypical" shifts, that is, the value of respondents' assessments of the impact of cooperative learning on the formation of students' teamwork skills is statistically significant at the level of significance $a < 0,05$, (especially at the level of significance $a < 0.01$) do not differ significantly from the values

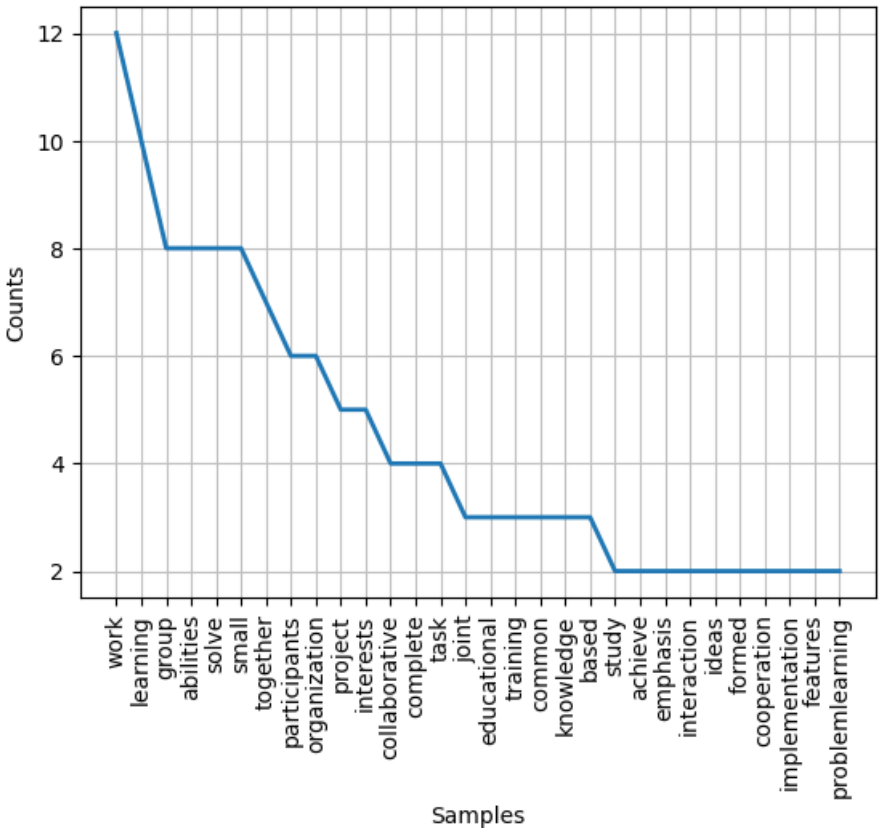

Figure 4: Frequency distribution chart of keywords characterizing the concept of collaborative learning.

(a) (b)

Figure 5: Word cloud of keywords characterizing the concept of cooperative learning (a) and collaborative learning (b).

of respondents' assessments of the impact of collaborative learning on the development of students' teamwork skills.

There are no significant differences between the respondents' assessments of the impact of cooperative and collaborative learning on the development of students' teamwork skills. Compare the mean values (σ) and standard deviations (σ) of the estimates of the impact of cooperative and collaborative learning on the development of students' teamwork skills (table 3).

As can be seen from table 3, the mean values of the impact assessments of cooperative and collaborative learning do not differ significantly. However, based on the values of standard deviations, we can say that the scores of collaborative learning on average fluctuate less relative to the mean than the scores of cooperative learning. That is, they are more homogeneous.

The slight differences between the respondents' assessments of the impact of collaborative and cooperative learning on the development of students' teamwork skills can be explained by the fact that they have much in common. Both collaborative and cooperative learning are implemented by organizing

Table 2
The value of respondents' evaluations of the impact of cooperative and collaborative learning on the formation of teamwork skills among students, the difference between which is not equal to zero, and the ranks of the absolute values of the differences.

Order numbers of the shifts, m	Evaluations of the impact of cooperative learning, a_i	Evaluations of the impact of collaborative learning, b_i	Difference, $b_i - a_i$	The absolute value of the difference, $\|b_i - a_i\|$	Ranks of absolute values of differences, r_i
1	1	7	6	6	23
2	9	10	1	1	4.5
3	9	6	-3	3	19
4	8	10	2	2	12
5	8	9	1	1	4.5
6	5	8	3	3	19
7	5	7	2	2	12
8	7	5	-2	2	12
9	8	9	1	1	4.5
10	9	7	-2	2	12
11	2	5	3	3	19
12	7	8	1	1	4.5
13	8	5	-3	3	19
14	10	9	-1	1	4.5
15	10	7	-3	3	19
16	7	5	-2	2	12
17	7	9	2	2	12
18	7	8	1	1	4,5
19	8	9	1	1	4,5
20	5	8	3	3	19
21	4	6	2	2	12
22	7	6	-1	-1	4.5
23	7	10	3	3	19

Table 3
Arithmetic means ($\bar{X}$) and standard deviations (σ) of the estimates of the impact of cooperative and collaborative learning on the development of students' teamwork skills.

Teaching method	Expected value (arithmetic mean), $\bar{X}$	standard deviation, σ
cooperative	7.21	1.95
collaborative	7.57	1.55

a small group that has its own typical patterns of existence and development – group dynamics.

Regarding the use of cooperative and collaborative teaching methods by respondents in educational practice, the following data were found (figure 6).

The distribution shown in this graph indicates the dominance of cooperative learning compared to collaborative learning. We explain this distribution by the fact that cooperative learning is more traditional and established, and therefore is used more often. Collaborative learning is relatively new, innovative and aimed at unlocking the potential of the individual in the process of joint activities.

The results of respondents' answers for the question "Have you involved students in team project work?" are shown on figure 7. The distribution shown in this graph indicates the dominance of auditory classes in lecturers' educational practices. Auditory classes are almost 4 times more prevalent than the optional work. We believe that this distribution is a manifestation of an established tradition in which collective learning dominates both in actual and contextual formats. Collective learning needs more external control and management by the lecturer, in which external motivation is significant,

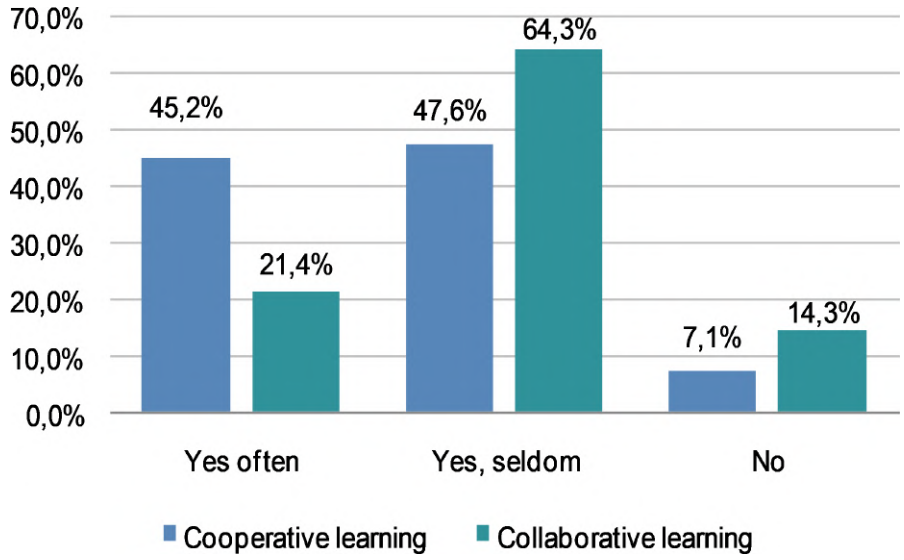

Figure 6: Bar chart visualizing the answers of respondents to the questions "Do you use cooperative learning methods in your teaching practice?" (a) and "Do you use collaborative learning methods in your teaching practice?" (b) (Answer options: Yes often; Yes, seldom; No).

which determines the structure of the group and largely lays the socio-psychological foundations of group dynamics. In collective learning, self-organization is not the dominant aspect, which is primarily manifested in the possibility of free choice of tasks and ways to solve them. Collective learning forms a fairly effective grid structure in a small group format, which is at the same time one-dimensional, rather rigidly determined and largely predictable. We consider this structure to be "social-intellectual", which determines the dominance of the social over the personal and intellectual and, accordingly, can be designed for the effective implementation of a certain not very high class and level of tasks. Hence, collective learning is a system that is quite efficiently and rigidly formed and maintained.

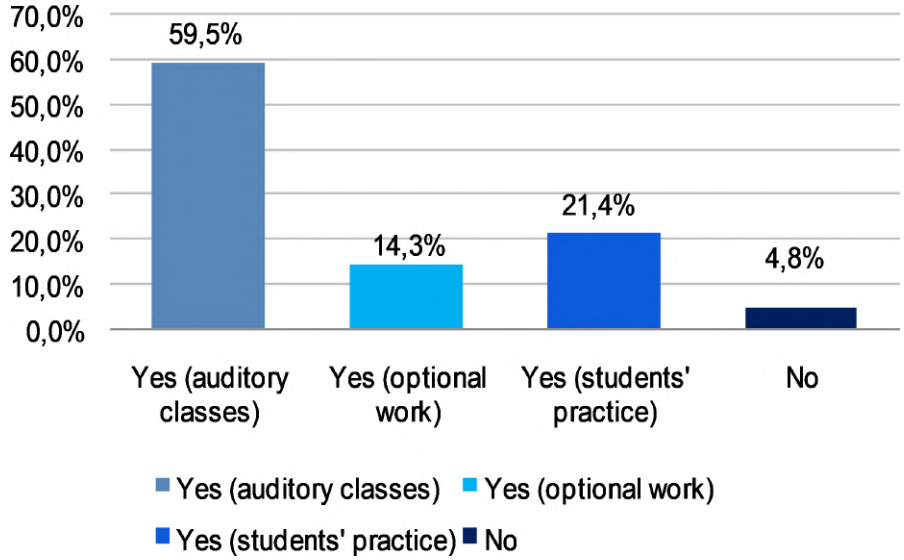

Figure 7: Bar chart visualizing the answers of respondents to the questions "Have you involved students in team project work? If yes, in what form was the project work carried out?" (Answer options: Yes (auditory classes); yes (optional work); Yes (students' practice); No.

In our opinion, self-organization and autopoiesis are important in collaborative learning, which contribute to the actualization of intrinsic motivation. This, in turn, forms the system as a multidimensional "socio-psychological-intellectual" grid, which determines the dominance of personal and intellectual

over social and, accordingly, can be designed for the effective implementation of different levels of tasks (including high). This structure is dissipative in its conceptual essence (it supports itself), having received the initial organizational and management "impulse".

Collective learning, in which the social aspect is distinct, can be seen as the first stage in the application of collaborative learning, which in its essence (despite being implemented in the format of group work) is personalized, intellectualized and socio-psychological.

During the research, it was found that only every 7th lecturer has the experience of training student teams to participate in team programming. Since the answers to the question "Do you prepare student teams for participation in team programming?" were distributed as follows: Yes (14.3%); No (85.7%). If we compare this with the fact that team programming is a specific and highly intellectual activity that requires both effective team and personal intellectual activity, we can suggest that collaborative learning is one of the most effective and congruent (in the sense of relevant) ways to prepare for team programming. Accordingly, if lecturers have little experience in preparing student teams to participate in team programming, they cannot fully appreciate the effectiveness and "socio-personal-intellectual" orientation of collaborative learning. This phenomenon is also indicated by the two graphs above. Among the methods used by university teachers in the process of preparing students for team programming, teachers named cooperative learning and collaborative learning.

The results of the study shown in the figure 8 (a) indicate a rather significant effectiveness of collaborative learning in solving relatively simple tasks, which is typical when using group work methods. It is well known that in a group, simple tasks are performed more efficiently than in an individual. This feature is also inherent in collective learning. In these cases systematic activity, synergistic effects, collective intelligence, goal setting, and external motivation are actualized.

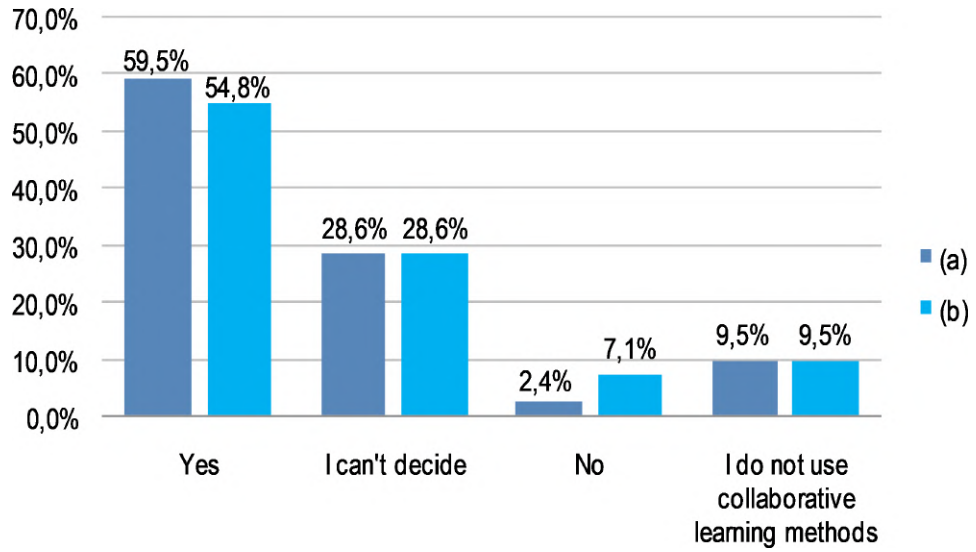

Figure 8: Bar chart visualizing the answers of respondents to the questions: (a) "When you used collaborative learning, did you observe an increase in the effectiveness of learning activities, which was manifested in solving relatively simple tasks?"; (b) "When you used collaborative learning, did you observe an increase in the effectiveness of learning activities, which was manifested in solving relatively complex tasks?" (Answer options: Yes; I cannot decide; No; I do not use collaborative methods in teaching).

As shown in figure 8 (b), the study's findings suggest that a fairly significant effectiveness of the use of collaborative learning in solving relatively complex tasks within team programming. Compared to the previous graph, which shows the effectiveness of solving relatively simple tasks, this graph indicates a slightly lower efficiency in the implementation of complex tasks. This reflects a well-known phenomenon, the essence of which is that working in a group does not always contribute to the effective solution of complex intellectual and creative tasks. This requires both group work and individual activity. At the same time, the rate of solving complex tasks is quite high – 54.8%, which indicates the effectiveness of collaborative learning as a group activity that simultaneously actualizes the intellectual

and creative potential of the individual. That is, both collective and individual intelligence are effectively manifested in collaborative learning.

The results presented in figure 9 imply that a significant aspect of collaborative learning is the formation of effective goal setting and understanding of the tasks that can be viewed as technology-oriented problematization.

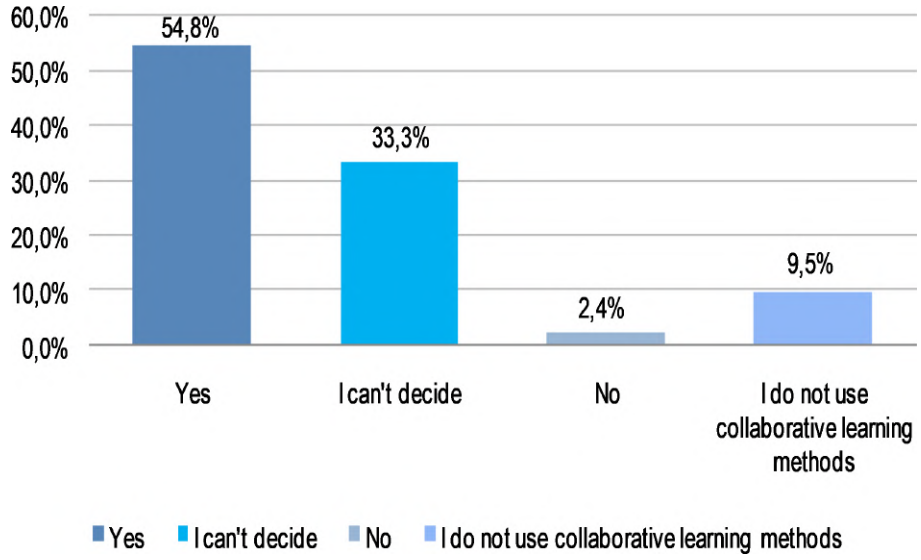

Figure 9: Bar chart visualizing the answers of respondents to the questions "Did the use of collaborative learning contribute to a better understanding of the tasks and the formation of effective goal setting?" (Answer options: Yes; I cannot decide; No; I do not use collaborative methods in teaching).

The figure 10 (a) reveals the emotional aspect of collaborative learning in the format of effective interaction in the group, which is 54.8%. Effective emotional interaction helps to consolidate the group, develop goal setting and communication, and form a collective mind.

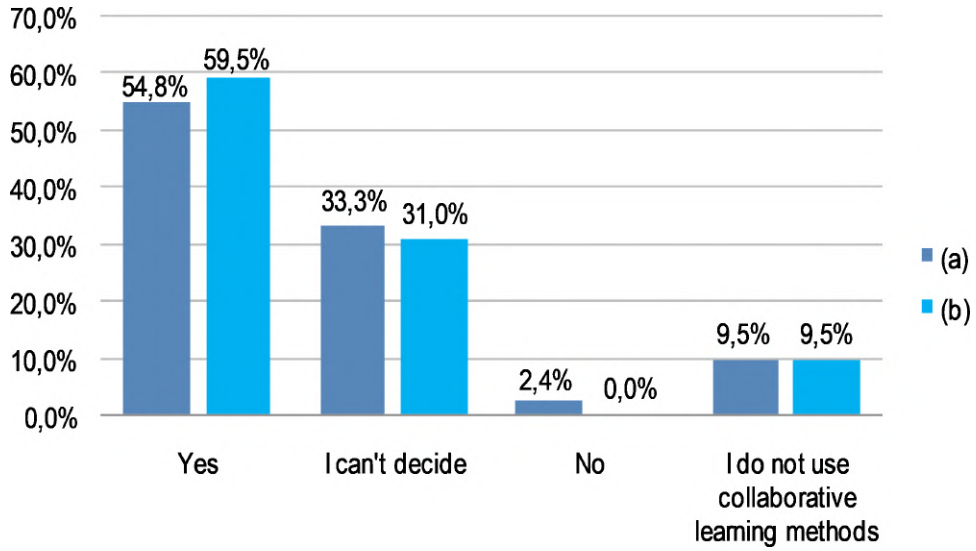

Figure 10: Bar chart visualizing the answers of respondents to the questions: (a) "Did the use of collaborative learning contribute to the formation of effective emotional interaction in the group?"; (b) "Did the use of collaborative learning contribute to the formation of effective cognitive interaction in the group?" (Answer options: Yes; I cannot decide; No; I do not use collaborative methods in teaching).

The figure 10 (b) shows the phenomenology of effective cognitive interaction in the group, which is quite high – 59.5%. This indicates that collaborative learning contributes to the disclosure of individual

intelligence, the formation of a collective mind and intellectual communication, which ultimately manifests itself in the effective solution of intellectual problems.

According to the data presented in figure 11, a fairly significant percentage (57.1%) characterizing the development of common values in the group's activities. These values are relevant because they represent an axiological basis that determines the consolidation of the group, its focus, goal setting, ethics of activity and, ultimately, the effectiveness of solving intellectual tasks assigned to the group.

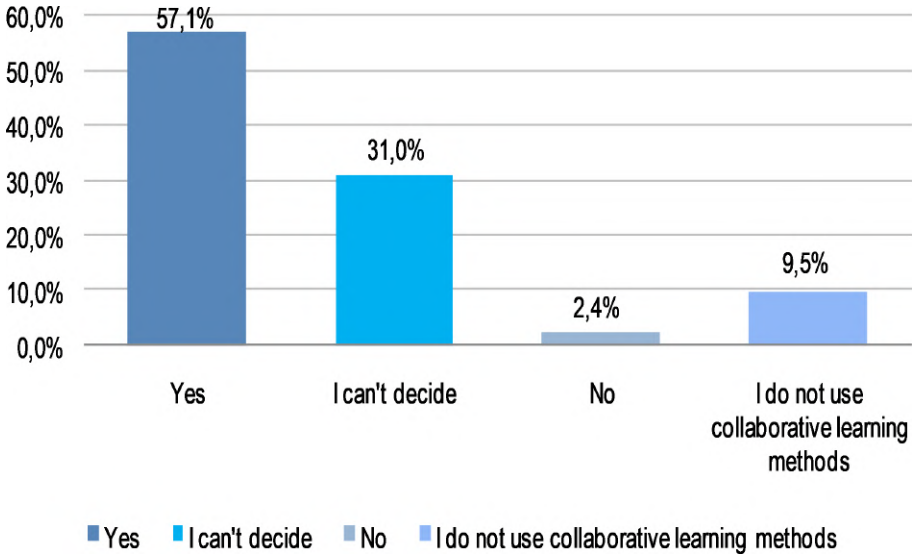

Figure 11: Bar chart visualizing the answers of respondents to the questions "Did the use of collaborative learning contribute to the formation of common values in the group?" (Answer options: Yes; I cannot decide; No; I do not use collaborative methods in teaching).

It is important to emphasize that, in summary:

- Quite often, cooperative and collaborative learning are used integratively.
- The use of cooperative learning as a basis and/or prerequisite for collaborative learning is typical.

In those cases in which collaborative learning is used, the capabilities of individual and collective intelligence, including emotional intelligence, are integratively actualized. Also, both external and internal motivation are effectively manifested, with the dominance of the latter. This helps to reveal the personal and creative potential of the participants.

Collaborative training activates the valuable dimension of a specialist as a creative and active person. Collaborative educational activity, thanks to the actualization of the personal-existential dimension of the individual, contributes to the internalization of the values of activity and personality. And also their transition into the axiological contexts of professional existence as an individual and a team. There is also a structuring and hierarchization of the specialist's values and their transformation into personal axiological systems. At the same time, the transition of values into value orientations and motivations is carried out. Accordingly, value orientations and motivations are those mental formations that contribute to the development, maintenance of direction and goal-setting of the individual. They are aimed at the performance of a certain specific task, which is considered as a significant component of life creativity and professional realization and self-actualization. There is also a concretization and practically oriented transformation of values and their inclusion in the scheme of activity, which can be simplified as "subject – action – object". That is, values under the influence of collaborative learning are transformed, concretized and, accordingly, become a prolonged regulator and stimulator of activity and a structure-forming factor in the development of professional subjectivity and an axiological-motivational prerequisite for creativity.

In cooperative learning, we believe that the above-mentioned axiological transformations are observed to a somewhat lesser extent. And values remain mainly external socio-psychological or worldview-philosophical prerequisites of activity.

A significant factor of collaborative learning is the actualization of spontaneity, freedom and responsibility as significant manifestations of the existential dimension of the individual. The specified aspects in cooperative learning are less pronounced due to the dominance of specifics and "plannedness" necessary to perform certain tasks. In cooperative learning, the dominance of the "spirit" of collectivism as such, which becomes a self-sufficient value, is also significant, rather than the focus on creativity, personality and its development and the final result, which can be achieved variably and creatively.

4. Conclusion

The concept of sustainable development as a system-organizing strategy for the development of humanity is primarily based on the concept of ecologically oriented human qualities (Aurelio Peccei). This determines the need to consider the anthropological, psychological and intellectual factors represented in the educational format as one of the determinants in the implementation of the concept of sustainable development. In this aspect, the actualization of the intellectual potential of both the individual and the group acquires special significance, an effective way of which is the use of collaborative learning.

There are many similarities between cooperative and collaborative learning, there are also significant differences. Compared to cooperative learning, collaborative learning involves a more intensive and multidimensional integration of the group, as well as a deeper and more specific and practically oriented understanding of the problem being solved by the group. Thanks to collaborative learning, a "collective mind" is formed in the group relatively quickly, which, first of all, increases the team's ability to effectively problematize, clarify, expand, and interpret a particular problem, while maintaining the integrity of its perception. Typical for cooperative learning is the distribution of certain tasks among team members, which they solve both independently and in consultation with others. In collaborative learning, although this distribution of tasks may also be present, it is mostly joint task performance that involves a certain change of performers, for example, by distributing and changing roles in the team. An important effect of collaborative learning, which is observed in comparison with cooperative learning, is the relatively equal distribution of performance indicators, which indicates the stability of the group, the effectiveness of its goal setting and focus on a particular task, the formation of a subject of collective action and, in general, effective group dynamics aimed at achieving the set tasks.

Collaborative learning is considered as one of the modern effective group learning directions, the phenomenology of which is integratively revealed: socially oriented in the format of group dynamics and intellectually and psychologically as a way of developing creativity and intelligence by revealing personal potentials. Collaborative learning as a social and intellectual-psychological technology forms a system that can be represented as a multidimensional "social-psychological-intellectual" grid. This "social-psychological-intellectual" grid can be considered as a dissipative structure capable of forming synergistic effects and capable of self-maintenance, self-organization, and transformation.

Based on the conducted theoretical and practical studies, it can be said that collaborative learning, which is implemented in the format of group work, is at the same time personalized, psychologized, intellectualized, and socio-psychological. When using collaborative learning, the processes of self-organization and autopoiesis and actualization of internal motivation are the leading systems. The innovativeness and democratization of collaborative learning makes it possible to organically and synergistically integrate the individual and collective mind and, accordingly, to obtain significant educational, creative and intellectual effects when it is applied.

In order to form general ideas about the features of the use of collaborative learning and its significance and place in the training of future specialists in information technologies, namely in the process of team programming, a study of university lecturers was conducted using a questionnaire developed by the authors. When analyzing the results of the study, it is determined: that teachers actively use collective learning, which to some extent we consider as a stage in the use of collaborative learning; when organizing collaborative learning, classroom work is often used and the issue of free choice of tasks is actualized to a somewhat lesser extent; the majority of the studied teachers have relatively little experience of training student teams to participate in team programming, which, despite the significant

interest in this educational technology, indicates insufficient understanding and practical application of it; when using collaborative learning, there is a certain (insignificant) decrease in efficiency when solving relatively complex tasks compared to simple ones, which corresponds to the researched regularity of intellectual work in group work; collaborative learning contributes to the formation of common group values, effective goal setting and understanding of assigned tasks, effective emotional interaction, and also develops group consolidation and forms goal setting, communication, effective cognitive interaction and collective mind, and reveals the potential of individual intelligence.

According to the survey, 21.4% of respondents often use collaborative learning in their educational practices. This technology is used episodically and rarely in 64.3% of cases. This quantitative distribution indicates the significant importance of collaborative learning in the professional activity of teachers as an important innovative and psychologically and personally oriented educational technology among other modern and traditional methods and technologies of education. This also speaks of the relative novelty of collaborative learning as a technology, which, in comparison with cooperative learning, requires from the teacher for its implementation appropriate professional, including psychological, training, as well as innovative thinking of personal-oriented visions.

The use of collaborative learning by teachers to solve relatively simple tasks in 59.5% of cases and to solve relatively complex tasks in 54.8% of cases indicates its ability to equally actualize the intellectual and creative potential of both groups and individuals. The indicated effectiveness of intellectual activity, which is revealed, first of all, when solving complex tasks, is related to the fact that collaborative learning in 54.8% of cases contributes to the development of effective goal setting and a better understanding of the essence of tasks by students, and is also caused by effective emotional interaction, which is determined in 69% of cases and effective cognitive interaction, which is observed in 59.5% of cases. The indicated effectiveness of intellectual activity is also due to the actualization of the value dimension of both the individual and the group. Accordingly, it is determined in 57.1% of the formation of common values.

Thus, the use of collaborative learning in the process of training future information technologies specialists provides an opportunity to: share knowledge and experience among team members, which allows for faster learning and development; improve communication skills and the ability to work in a team; increase the motivation and involvement of each participant in the learning process; to receive feedback and correct mistakes in the learning process, and therefore potentially improve the results that the team achieves.

Declaration on Generative AI: The authors have not employed any Generative AI tools.

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