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Applying collaborative activities in high school physics course during a hybrid model of learning

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Many large educational institutions and international studies point out that collaborative problem solving is a key competence for the successful integration of students into society and the workforce. Therefore, teachers need to apply methods and activities that develop students' teamwork skills. But for two school years now, we have been facing the challenges of distance learning because of the coronavirus crisis. Lacking the possibility of full attendance of students in the classroom, there is a need for an innovative and flexible approach to be applied by teachers to be able to cope with this emergency. This report examines the possibilities for implementing collaborative activities in the high school physics course during the hybrid model of learning. Surveys were conducted among students from ninth to eleventh grade to investigate whether there is an increase in interest in physics and STEM disciplines if collaborative activities are implemented in high school physics courses during the hybrid model of learning.

Keywords: collaborative activities, hybrid learning, collaborative problem solving, physics education

INTRODUCTION

There is no doubt that education systems around the world face enormous challenges. The coronavirus has caused huge changes around the world. Education is one of the most affected systems.

But even before the coronavirus, educational systems had to meet new challenges and change so that students could successfully integrate into the future world of innovation and technological change. Leading world organizations such as UNESCO at the UN, the European Parliament, the Council of Europe, the PISA program at the OECD, and others recommend focusing teaching efforts on developing the skills and competencies needed by today's students to live in the challenges of the 21st century [1, 2]. To achieve this goal, education systems are expected to provide high-quality education, training, and lifelong learning for all, as well as to assist teachers in implementing competency-based learning approaches [3].

The main competencies that students need for their successful integration into society and for their successful professional realization are critical thinking, creativity, collaboration, and communication [4].

Collaborative problem solving was chosen by the Organization for Economic Co-operation and Development (OECD) as a new competence, which was explored in the PISA international study in 2015. There are many reasons for collaborative problem solving to be in focus. International studies indicate that collaborative problem solving is a key competence for the successful integration of adolescents into society and the workforce. It is also believed that much of the planning, and problem-solving decision-making will be done by teams and teamwork [5].

The implementation and application of the new competencies are important for the Bulgarian educational system. In the PISA assessment from 2012 of the module problem solving of 43 participants, Bulgarian students were in 42nd place, and in 2015 in the PISA assessment of the module collaborative problem solving of 51 participants, Bulgarian students were in 40th place [6]. These examples show that serious changes are needed in the Bulgarian learning environment to lead to a qualitative improvement of skills and competencies of the 21st century.

BENEFITS

Teamwork is a key competence that students must possess to be successful in the 21st century. Therefore, it is important to have sufficient quantity and quality practices in the learning process for students to work in a team. In this way, we can guarantee with a high probability that students will develop their teamwork skills through appropriately selected team activities. Collaborative learning does not only develop students' teamwork skills. Many studies show different benefits of collaborative learning [7-12].

According to research, students show a higher level of knowledge if they have participated in team activities.

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Research usually compares a group of students who have participated in collaborative learning and an active form of learning with a group of students who have only listened to a lecture. The differences in the achieved results vary, but there is a significant difference in the results. The explanation is that students should be an active part in discussing the problem when working together. This stimulates them more and makes them think more about the problem. Whereas if they only listen to a lecture, they are in a passive role. This passive role does not allow them to delve into the problem and therefore it is difficult to acquire quality and long-lasting knowledge.

CHALLENGES

Collaborative learning has many challenges and is not easy to implement in the curriculum. To successfully implement collaborative learning, it is necessary to have a proficient teacher. Many teachers do not feel confident enough to leave their comfort zone and try new teaching methods and techniques.

Unfortunately, many students have "group hate" [13]. Some students do not want to work in groups. This can be due to various factors. Some students are introverted. These students don't feel comfortable talking to other people. They usually remain silent and do not take part in discussing the problem. The other team members begin to ignore them and thus the opposite effect occurs. These students are increasingly starting to dislike teamwork [14]. In order not to get into such situations, the teacher must know the students and be able to make the groups feel comfortable. That's not easy. A teacher is required to know the students and to have some experience in managing teamwork.

Another challenge is loafing. There are usually students who don't take responsibility for their role, even if it is the smallest role in the group [15]. This leads to conflicts within the group. Students expect everyone to do their job conscientiously. In order not to get into such situations, the teacher should carefully monitor the progress of the groups and, if necessary, intervene.

An important issue in collaborative learning and common projects is evaluation. To avoid conflicts, the teacher from the very beginning must be sure that the work is fairly divided between the individual participants. Individual team members must have agreed from the outset on how the work will be divided. In the process of performing the tasks, the teacher must ensure that each member of the team performs his/her duties. The assessment should be formed based on the individual performance of the tasks by the student and the demonstrated skills for teamwork. Students need to know the criteria and agree to the procedure from the outset.

Our research in the presented report is oriented to study the attitudes of students to work in a team in a hybrid form learning environment using two methods - Peer instruction and JIGSAW. The main method of research is a survey, which is conducted twice - during the first term without the use of both methods and during the second term, after training students in employing the suggested methods.

We defined the research tasks as follows:

1. Compiling and evaluating questions to survey attitude to teamwork.
2. Analyzing survey data after the first term.
3. Developing methodological cases that apply methods of teamwork for three groups of classes.
4. Evaluating the results of the survey after applying the methods of Peer instruction and JIGSAW in the same sample of students in the second term.
5. Performing comparative statistical analysis for estimating the differences in attitudes based on the results of the two surveys.

EXPERIMENT

During the 2020-2021 school year, the learning process took place in a hybrid form that is alternated periods of face-to-face education and those in an online environment. In the online environment, the lessons were conducted *via* online video meetings, using the Google G Suite platform for education. During the study, the possibilities of information and communication technologies were used to see if collaborative learning could be used effectively by teachers in an online environment. For this purpose, we focused on two methods of collaborative learning. These methods are Peer instruction and JIGSAW. Many resources describe the implementation of Peer instruction and JIGSAW in a learning environment. But these resources describe face-to-face education. Therefore, we wanted to implement these methodologies in an online environment and see where the difficulties are.

To achieve the objectives of our study, we implemented both methodologies for cooperative learning during the second term of the 2020-2021 school year. During the first term, students did not have a learning process that used the methodologies of Peer instruction or Jigsaw. The students were in a hybrid form of learning. During online learning, students had cooperative projects. These cooperative projects consisted in making joint presentations or posters on a particular topic. During the first term, students used the following software to conduct online classes: Google G Suite for Education, Google Meet, Google Slides, Google Sheets, Google Docs, and Jam Board. At the beginning of the second term, before implementing the two methodologies, we asked the students questions through the Likert scale. A five-point Likert scale was used for evaluation. The following scale was used: not at all (1), no (2), neutral (3), yes (4), and very much (5). After completing the educational process using both methodologies at the end of the second term, we asked the same questions again. The questions are:

Q1. Did you like the physics course?

Q2. Did you like the team projects during in-person learning?

Q3. Did you like the team projects during online learning?

Q4. Did you like the software tools?

Q5. Would you like to have more team activities?

Two ninth-grade classes, two tenth-grade classes, and one eleventh-grade class were included in the survey. The number of participants was 109, of which 49 were in ninth grade, 41 were in tenth grade and 19 were in eleventh grade. In ninth and tenth grade, one class majors in mathematics and physics, while the other has a humanities profile. In the eleventh grade, only the class with majors in mathematics and physics participated, because the humanities class does not study physics in a curriculum. Peer instruction is a very popular method for collaborative learning developed by Mazur [16]. The teacher prepares materials on the given topic in advance. These materials can be short text or video. The teacher then gives these materials to the students to get to know them before class. Students get acquainted with the materials and mark or comment on things that are unclear to them. Based on the comments, the teacher chooses what to specify in the short lecture. He/she then asks questions to test students' knowledge and understanding. Students have a short time to answer questions, usually one minute per question. It should be noted here that they respond individually. They then gather in groups of up to five people. In the group, students discuss the questions and discuss which answers are correct. They usually have three to five minutes to discuss. The teacher then asks the same questions again. Students again answer individually. The results are compared and depending on the number of correct answers the teacher decides whether additional explanations are needed or can move on to the next topic. This method has proven its effectiveness in the educational process. Here we will note that the method has been tested in Bulgaria and found to give good results [17].

At first, we thought it would be very difficult to implement Peer instruction in online learning. But later we were even amazed at how easy and convenient it is to implement this method in online learning. The technologies we mainly used were Google G Suite for Education, Google Docs, Kahoot, VideoAnt, and Edpuzzle. Schools in Bulgaria mainly use Google G Suite for Education or Microsoft Teams for online learning. Google G Suite for Education is being used at Boyan Penev High School. Therefore, we had to implement a Peer instruction methodology so that it could be used through Google G Suite for Education. Before the beginning of each class, we posted materials on the topic and asked questions on the topic using Google docs for text information and VideoAnt and Edpuzzle for videos. Students answered questions or remarked on what they did not understand. We noticed that even with the comments on the questions, interesting discussions arose between the students. Based on these answers and notes, we created the conceptual questions to ask during the class. The technology we used to ask questions and poll is Kahoot. This proved to be very effective during online training. Teachers are used to judging by the reactions of their students whether they understand the material and whether additional explanations or additional examples are needed. But during online learning, it is very difficult to see the reactions of students. Therefore, we find this method very useful and at the same time, it engages students in the learning process. To make the most of our time, we asked a series of questions. We then divided the students into groups through breakout rooms. Then we asked the same questions and what we noticed was that the number of correct answers increased significantly. This indicates that students were able to better understand the material by communicating with each other. For each class, we did five lessons based on Peer instruction. Jigsaw is also a very popular method for collaborative learning. There are different variations of Jigsaw but we chose to focus on Aronson's concept [18].

The teacher introduces the strategy and the topic to be studied. She or he divides the students into groups. Typically, the groups consist of 3 to 5 students. These groups are commonly referred to as home groups or basic groups. The separation can be done at random or at the discretion of the teacher. The goal is to get equal groups. The teacher divides the topic into several topics. Each student receives a specific topic to study. Usually, the students distribute the topics in the group themselves. The teacher then creates the so-called expert groups. Each expert group is responsible for a specific topic and consists of students from the home groups who are responsible for this topic. Students work collaboratively in expert groups. They discuss the problem together. Together they come to the formulation of the problem. They are looking for the necessary information to solve the problem. Each student is encouraged to make a hypothesis on the given problem and the corresponding argumentation. Then each student accepts or rejects the given hypothesis by presenting his arguments. Typically, the students in the expert groups unite around one working solution. The students then turn to their home groups. There, each student presents his/her topic and helps his/her classmates to understand it if there are any ambiguities. The overall solution to the problem is to combine the solutions of the individual subtopics. Again, students enter a discussion in shaping the overall solution. Finally, they must reach a general solution to the problem or a final product. Each group then presents its overall solution or product.

The implementation of this method in the Bulgarian educational system is a challenge. The main problem is that the lessons are 40 minutes. The other challenge is that teachers should be able to combine several lessons into one larger topic. Then divide this topic into sub-topics of the individual students. For the implementation in the online environment, we used the same technologies as in Peer instruction. We usually use Jigsaw when we give larger research projects, for example, the colonization of Mars. We divide the class into groups of three to five students. We divide the topic into separate parts. An expert group is responsible for each part. Each expert group receives materials and is also free to find materials on its own. In the online environment, each expert group works in separate breakout rooms and makes notes in Google docs. Students then return to their home groups. If we are in an online environment again in different breakout rooms students take notes and discuss issues in Google docs. Finally, the whole class comes together. Each home group presents its solution. We ask them questions and they answer using Kahoot. For each class, we did two lessons based on Jigsaw.

RESULTS AND DISCUSSION

The descriptive statistics (mean, standard deviation, and standard error) for both surveys (pre-test and post-test) are given in Table 1. The unidimensional reliability test shows an excellent value of Cronbach's alpha (0.974) in Table 2.

The exploratory factor analysis also confirms the high reliability of the scale and its one-dimensionality (Tables 3a, 3b).

Table 1. Descriptives

	N	Mean	SD	SE
Question1 (Pre-Test)	109	2.945	1.145	0.110
Question1 (Post-Test)	109	3.422	1.030	0.099
Question2 (Pre-Test)	109	3.174	1.177	0.113
Question2 (Post-Test)	109	3.661	0.983	0.094
Question3 (Pre-Test)	109	3.101	1.178	0.113
Question3 (Post-Test)	109	3.569	1.003	0.096
Question4 (Pre-Test)	109	3.101	1.146	0.110
Question4 (Post-Test)	109	3.550	0.995	0.095
Question5 (Pre-Test)	109	3.147	1.193	0.114
Question5 (Post-Test)	109	3.651	0.975	0.093

Table 2. Frequentist Scale Reliability Statistics

Estimate	Cronbach's α
Point estimate	0.974
95% CI lower bound	0.966
95% CI upper bound	0.981

Table 3a. Factor Loadings for Pre-Test Scores

	Factor 1	Uniqueness
Question3 (Pre-Test)	0.956	0.086
Question4 (Pre-Test)	0.946	0.105
Question2 (Pre-Test)	0.941	0.114
Question5 (Pre-Test)	0.937	0.122
Question1 (Pre-Test)	0.920	0.153

Table 3b. Factor Loadings for Post-Test Scores

	Factor 1	Uniqueness
Question3 (Post-Test)	0.943	0.112
Question2 (Post-Test)	0.912	0.167
Question5 (Post-Test)	0.911	0.170
Question1 (Post-Test)	0.904	0.183
Question4 (Post-Test)	0.904	0.183

Only one variable (one factor) is observed in both pre-test and post-test factor analysis. An interesting result is that Question 3 (Did you like the team projects during online learning?) has the greatest weight in the factor in both the pre-test and the post-test factor analysis. Question 2 (Did you like the team projects during in-person learning?) almost retains its position. The same can be said for Question 1 (Did you like the physics course?), which ranks last and penultimate, respectively. Here it is necessary to make more detailed research as to why there is a big difference in the weights that the group activities and the physics course have in determining the factor. We will return to this question when we discuss the mean differences and the effect size in Table 5. For now, it is sufficient to say that the attitude towards the physics course has a little bit improved (the weight of Question 1 increased from 5^{th} to 4^{th} position comparing Tables 3a and 3b). The desire for more team activities has also increased, i.e., Question 5 (Would you like to have more team activities?) raised its weight from position 4 to position 3 in Tables 3a and 3b. The largest shift in weights is observed for Question 4 (Did you like the software tools?). Its weight dropped from the second position in Table 3a to the last position in Table 3b.

The mean differences in the results of the pre-test and the post-test scores will be analyzed for significance by the Paired Samples T-Test later according to Table 5. We do not check for homogeneity variances with Levene’s test like within the Independent T-test because we test the same group of students.

The descriptive statistics (mean, standard deviation, and standard error) for both of the surveys (pre-test and post-test) are given in Table 1.

Table 4. Test of Normality (Shapiro-Wilk)

		W	p
Question1 (Pre-Test)	Question1 (Post-Test)	0.844	< .001
Question2 (Pre-Test)	Question2 (Post-Test)	0.790	< .001
Question3 (Pre-Test)	Question3 (Post-Test)	0.824	< .001
Question4 (Pre-Test)	Question4 (Post-Test)	0.834	< .001
Question5 (Pre-Test)	Question5 (Post-Test)	0.845	< .001

Note. Significant results suggest a deviation from normality.

Table 5. Paired samples T-Test

Measure 1	Measure 2	Test	Statistic	z	df	p	Location Parameter	SE Diff.	Effect Size
Question1 (Pre-Test)	Question1 (Post-Test)	Student	67.500	-5.582	108	< .001	-1.000	0.071	
		Wilcoxon	-6.837			< .001	-0.468		-0.746
Question2 (Pre-Test)	Question2 (Post-Test)	Student	192.500	-5.227	108	< .001	-1.000	0.066	-0.706
		Wilcoxon	-6.578			< .001	-0.450		-0.898
Question3 (Pre-Test)	Question3 (Post-Test)	Student	216.000	-5.050	108	< .001	-1.000	0.068	-0.655
		Wilcoxon	-6.884			< .001	-0.505		-0.782
Question4 (Pre-Test)	Question4 (Post-Test)	Student	168.000	-5.323	108	< .001	-1.000	0.068	-0.630
		Wilcoxon				< .001	-1.000		-0.756
Question5 (Pre-Test)	Question5 (Post-Test)	Student			108	< .001	-0.468	0.073	-0.659
		Wilcoxon					-1.000		-0.804

Note. For the Student t-test, the effect size is given by Cohen's *d*. For the Wilcoxon test, the effect size is given by the matched rank biserial correlation.

Note. For the Student t-test, the location parameter is given by mean difference *d*. For the Wilcoxon test, the effect size is given by the Hodges-Lehmann estimate.

The unidimensional reliability test shows an excellent value of Cronbach's alpha (0.974) in Table 2. Therefore, the non-parametric Wilcoxon Signed Rank Test is preferred to the Student's t-test (Table 5). Again, the p-value is less than 0.05 for all five questions and we conclude that the differences in the mean values are statistically significant. The absolute value of the effect size given by the Hodges-Lehmann estimate for the Wilcoxon test shows how big the mean differences are. In descending order of the magnitude of the effect, we arrange the questions as follows: Q2, Q5, Q3, Q4, and Q1This means that the largest effects of the intervention between pre-and post-tests are the positive changes in the attitudes towards the team projects during in-person learning (Q2) and the willingness for more team activities (Q5). On the other hand, the intervention made the lowest effect on the attitude to the physics course and the software tools.

CONCLUSIONS

The article evaluates the change in students' attitudes towards teamwork in a hybrid learning environment for two terms using the Peer instruction and Jigsaw methods for teamwork during the second term.

After the statistical analysis of the results obtained through a survey of attitudes, the following conclusions can be drawn.

The questions from the survey show a great deal of consistency (Cronbach's alpha is above 0.9). All questions show a change with a different statistical difference. The use of both methods has a positive effect on attitudes towards teamwork. Students prefer face-to-face learning with a will to use more diverse methods, one of which is teamwork. The use of different software products does not affect the attitudes toward teamwork as this generation of students generally wants to work with computer technology regardless of the methods their teachers use. There is no significant change in the attitude towards physics as a subject. The attitude towards teamwork during the online training is the most significant change and a positive one that we can notice.

The use of surveys as a tool for establishing attitudes towards certain teaching methods and activities such as teamwork is a reliable method for research in education. These give better valid results with the statistical method of dependent samples. It can serve as a diagnosis of the effectiveness of the learning process and a basis for decision-making related to learning objectives.

These results give us a reason to conclude that the proposed methods can be used by teachers to increase students' interest and motivation for the acquisition of long-lasting skills and competencies in the 21st century in a different educational environment.

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