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THE JIGSAW TECHNIQUE IN LOWER SECONDARY PHYSICS EDUCATION: STUDENTS' ACHIEVEMENT, METACOGNITION AND MOTIVATION

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Abstract. *Physics teaching should facilitate students to acquire knowledge, increase metacognitive awareness and motivation for learning physics. The implementation of cooperative learning could be useful for improving teaching. The aim of this research was to examine the effect of cooperative learning (specifically the jigsaw technique) on students' achievement in physics, metacognitive awareness, and motivation. An experiment with parallel groups (experimental and control) was carried out with 92 seventh-grade students (in lower secondary education). Jigsaw technique was implemented in the experimental group, while the control group was taught using teacher-directed teaching method. Students' physics achievement, metacognitive awareness and motivation were measured using knowledge tests and questionnaires (before and after the experiment). Statistical analysis included calculations of Cronbach's Alpha coefficient, performance of the Shapiro-Wilk test, Mann-Whitney U test and the Wilcoxon Signed Ranks Test. The research results showed that the implementation of jigsaw technique in physics classes significantly improved students' physics achievement, metacognitive awareness, and motivation. Therefore, it can be suggested that this technique is beneficial in lower secondary physics education, and it can be recommended to implement the jigsaw technique in everyday school practice.*

Keywords: *cooperative learning, metacognitive awareness, parallel group design, physics education*

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Introduction

A number of students think that physics content in lower secondary education is difficult, and they cannot master it successfully. To improve physics teaching, it is important to supervise students' achievement, characteristics, and feelings. Successful teaching results in functional knowledge, increase in students' metacognitive awareness and motivation for learning. Social interaction within the group is essential for the educational development of an individual, as it allows the exchange of ideas, views and attitudes in building and shaping knowledge necessary for bringing up common solutions (Cole & Stanton, 2003). Since the ability of working in team is important quality of employers nowadays, it is important to foster students' teamwork skills starting from their early age (Xiang & Han, 2021).

Cooperative learning is probably the oldest form of group learning. The theoretical foundations of cooperative learning stem from the research of Deutsch (1949), who has studied the effectiveness of groups that foster cooperation rather than competition with regards to the individual and group achievement. Johnson and Johnson (2002) have spent nearly four decades studying and understanding the effects and effectiveness of cooperative learning within different levels of the educational process.

Cooperative learning is a learning approach characterized by the responsibility of the individual to understand their own part of the material/task, but also the responsibility to understand/solve the material/task of the whole group (Johnson & Johnson, 2002). It is an active method of learning in which students in small groups work together on inquiry and problem solving (Slavin, 2014). They help each other in learning, developing communication techniques, strengthening self-confidence, and active participation in the learning process (Akçay & Doymuş, 2014). Johnson et al. (1998) have defined five key elements on which cooperative learning is based: positive interdependence, face-to-face interaction, individual and group responsibility, social skills development, and group evaluation.

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According to Davidson and Major (2014), the following learning strategies supporting cooperative learning have been developed: the group research technique (Sharan & Sharan, 1990), the shared learning technique (Johnson et al., 1998), the read-write-present technique or think-match-present technique (Lyman, 1992), the timed-pair-share technique (Kagan & Kagan, 2009), the three-step interview technique (Kagan & Kagan, 2009) and finally the jigsaw technique (Aronson & Patnoe, 2011).

The jigsaw is a cooperative learning technique based on the work and cooperation of students within the home and expert groups. The teacher forms the home groups of four to five students (diverse in terms of gender, ability, and other students' characteristics). Each member of the home group is assigned some material (content/tasks) which then falls under the student's responsibility. After sharing the material, the students that were assigned the same task (one from each home group) are transferred to form the expert groups, in which all the members work together to master the same task. While working on the task, the members of the expert group cooperate with each other, communicate, explain to each other, convey information, and discuss, but also devise a plan on how to transfer their part of the task to other members of the home group (Fortner, 1999). After returning to the home group, individual experts must cooperate to reach a pre-determined solution together. In this way, cooperative learning becomes meaningful to everyone in the learning process. Students exhibit different efforts in social relations and learning behavior, in the search of possible solutions, in the exchange of information, thus expanding their understanding of the subject (Karacop, 2017).

Literature Review

There are several research studies that support a wide range of outcomes of cooperative learning, for instance, students' academic achievement in various subjects, social relations, group behavior, social cohesion, or a person with disabilities inclusion into the group (Slavin, 2014). The cooperative learning, in contrast to competitive and individual learning, enables greater achievement on tests in several subjects for students from primary school to university (Johnson & Johnson, 1988). Slavin (1983) has indicated that cooperative learning resulted in better students' achievement than the traditional learning in more than half of the relevant research about implementation of cooperative learning; some of the research studies have found no difference and only few research have shown that the traditional learning resulted in better students' achievement than the cooperative learning. Kagan (1994) has shown that students with low achievement made the most progress when applying the cooperative method. The decades of research into the teaching of physics using the cooperative method have led to incorporating cooperative learning within the physics class reform around the world to increase the students' achievement in physics (Awoniyi & Kamanga, 2014; Eshetu et al., 2017). Howe et al. (2007) and Topping et al. (2011) have shown significant improvement in students' academic achievement and the improvement in social relations within groups.

Motivation during cooperative learning may depend on an adequate structure of the task set by the teacher, the students' desire to solve the task within the group as successfully as possible, and the achievement of a predicted reward for solving the problem (Slavin, 1995). Each member of the group can achieve personal goals and be responsible for his/her part of the task, help other members of the group in solving the task to make the group as a whole more successful, encourage other members to work and perform better. Students strengthen their interpersonal structure, but also their social relations with other members of the group through cooperation within that group. Teacher-directed teaching method in physics classes, in which teachers are active and students are passive, affects students' motivation negatively (Baş, 2010; Schaal, 2010). Students simply listen, record, and become burdened with information that they merely memorize, without the opportunity to ask questions and come to a solution by dealing with the problem itself (Cano et al., 2013). Humphreys et al. (1982) have shown that students who studied physics in cooperative groups described their learning experience much more positively than the other respondents, when compared to the competition groups and individual work.

Metacognition refers to metacognitive knowledge, metacognitive regulation, and metacognitive experiences (Efklides, 2006). Metacognitive knowledge refers to the awareness of oneself as a learner, the knowledge of learning strategies and the appropriacy of a particular strategy for implementation. Metacognitive regulation includes planning of the learning process, managing information, monitoring, evaluating, and debugging during the thinking/learning process. Metacognitive experiences include a variety of feelings and judgments related to thinking/learning (e.g., feeling of knowing, judgment of learning). Studies have shown that higher metacognition is related to a more successful cooperative learning (Bernard & Bachu, 2015; Hurme et al. 2015,

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Kramarski & Mevarech, 2003). Further, Bilgin and Geban (2006) have emphasized that the active involvement of students in the learning process during the application of cooperative learning results in the improvement of critical thinking, reasoning and problem solving, which is directly reflected in the change of the students' metacognition. On the other hand, Slavin (1995) has stated that cognitive understanding is a key to the interaction between group members, linking the success of the method to the students' metacognition and vice versa. Chang and Mao (1999) have suggested that each method of cooperative learning, if adequately used, can allow students to increase the understanding of the learning flow in all the members of the group. The increase in the academic achievement directly affects the change of metacognitive experience – the increase in self-esteem, positive attitude towards learning and school, and others (Bilgin & Geban, 2006). Alternatively, Cheong (2010) has mentioned that cognitive development during cooperative learning depends on the teachers' approach and interaction with the student groups.

Research Problem

The achievement in physics directly depends on the students' interest in studying physics in schools and universities (Smithers, 2006). Young people often believe that physics as a science is too difficult. It is unpopular since requiring skills to think, precise and correct use of language, solve algebra problems and use arguments (Demkanin, 2018). The reasons for the declining interest in studying one of the fundamental sciences could be the fact that physics has a reputation of a 'difficult and boring' science that deals with abstract concepts that the students find hard to conceive (Sillitto & MacKinnon, 2000). Moreover, students around the world find most of the physics curriculum boring, uninteresting, and irrelevant (Lavonen et al., 2007; Lyons, 2006) and accordingly, the interest in studying physics declines during the course itself.

The curriculum of physics in lower secondary education in Serbia has been reformed with the aim of facilitating learning. Moreover, various methods for teaching physics are being proposed (Cvjetićanin et al., 2015). The focus has shifted from learning tasks to learning outcomes. This includes modernizing the learning and teaching processes, such as teachers' training, and the implementation of the group and project-based learning that enable the accomplishment of learning outcomes.

Considering the above characteristics of teaching physics and the method of cooperative learning, there is a need to implement cooperative learning in the realization of physics content in lower secondary education and measure its effects. There is a lack of comprehensive research that simultaneously examined students' achievement, metacognition, and motivation (looking at their components separately) when cooperative learning is implemented. The importance of this research is reflected in providing a comprehensive insight into the possibilities of implementing cooperative learning, specifically jigsaw technique, in physics classes.

Research Aim and Research Questions

The aim of this research was to explore the effect of the jigsaw technique in lower secondary education on student's physics achievement, metacognitive awareness, and motivation. Therefore, the following research questions were defined: (1) Would the implementation of the jigsaw technique increase students' achievement in physics? (2) Would the implementation of the jigsaw technique increase students' metacognitive awareness? (3) Would the implementation of the jigsaw technique increase students' motivation for learning physics? Answers to these questions can give an important insight into the extent in which the implementation of the jigsaw technique can improve physics classes.

Research Methodology

Research Design

To answer the above-mentioned research questions, an experiment with parallel group of students (experimental and control) was applied. The experimental factor was cooperative learning (jigsaw technique). It was introduced in the experimental group of students (E group), while the control group (C group) was taught using teacher-directed teaching method. During the research, both groups were taught the same content by the same teacher. The research was carried out from the beginning of September to the end of December in 2019.

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Research Sample

The research was carried out in a school in the Republic of Serbia. A convenient research sample was selected. Four classes of seventh grade (13 years old) participated in the research, i.e., 92 students (38 boys and 54 girls). This students' age was selected because physics as separate subject is introduced in the sixth grade of lower secondary education in the Republic of Serbia, so the seventh-grade students already have experience of one year in learning this subject. In the seventh grade, the students are taught about basics of mechanics (four teaching topics) and thermal phenomena (one teaching topic) in physics. The two class groups formed the E group (a total of 44 respondents, 17 boys and 27 girls) and another two class groups formed the C group (a total of 48 respondents, 21 boys and 27 girls). The E and C groups were formed based on equality: to have approximately the same number of students, similar gender distribution, the same level of students' achievement in physics, metacognitive awareness, and motivation for learning physics (Table 2).

Prior to the implementation of the research, the school board gave the ethical approval for carrying out the research. Moreover, the topic, purpose and the procedure of the research were introduced to the students' parents and the formal parental consent on the students' participation in the research was obtained. The research was anonymous, and all the participants were voluntarily involved in the research and could leave it at any time.

Research Instruments

For the purpose of this research, knowledge pre-test (covering knowledge about acceleration and Newton's second law of motion) and post-test (covering knowledge about motion under the influence of a force) were created. Each test consisted of five items which were scored differently (the tasks requiring the higher levels of knowledge for the correct answers were scored with more points) and the maximum score that a student could gain was 100 points. The tests were further verified by an expert group. The tests were evaluated as appropriate for use. The reliability of the tests was verified by calculation of Cronbach's alpha; the value of this coefficient indicated that these tests could be considered reliable (Table 1).

Students' metacognitive awareness was estimated using the Serbian version of Metacognitive Awareness Inventory (Bogdanović et al., 2015). This is a translated and adapted version of the original questionnaire developed by Schraw and Dennison (1994). The adapted version retained 31 items with the 5-point Likert-type scale responses (from "strongly disagree"-1 to "strongly agree"-5). This adaptation of the questionnaire proved as applicable for the participants in this research; also, it covered the following metacognitive components: declarative knowledge, procedural knowledge, conditional knowledge, planning, information management, monitoring, debugging and evaluation. The Cronbach's alpha coefficient for each subscale indicated acceptable reliability (Table 1).

Students' motivation toward science learning (SMTSL) questionnaire, originally developed by Tuan et al. (2005), was also used in its' Serbian version (Olić et al., 2016). This version consists of 29 items with the 5-point Likert-type scale responses (from "strongly disagree"-1 to "strongly agree"-5). This questionnaire covers five aspects of motivation: self-efficiency, active learning strategies, physics learning value, the performance goal, and the achievement goal. For the listed subscales, the calculated values of the Cronbach's alpha coefficient suggest their reliability (Table 1).

Research Procedure

Before the research started, all the students took the pre-test in physics that served for the assessment of students' physics achievement. This testing was realized through a standard paper and pen test that lasted for 45 minutes. In another class, students filled out questionnaires on their motivation for learning physics and metacognitive awareness. The completion of the questionnaires was also realized through standard testing (paper and pen) for which students had 30 minutes. Based on the pre-test results and several aligned criteria already mentioned, two classes were selected for the E group and other two classes for the C group. During the research, the following teaching units were covered in the topic Motion under the influence of a force: Acceleration, Non-uniform motion, Graph of non-uniform motion, Motion under the influence of gravity, Acceleration due to gravity, Free fall, Tossed objects upward, and Tossed objects downward.

In the E group, teacher explained the basics of cooperative learning and jigsaw technique to the students using video examples. After that, the E group was divided into five home groups (each home group had five members)

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based on the students' achievement, motivation, and social skills (based on the teacher's judgment). The groups were heterogeneous according to all the criteria, so that the students with low achievement could improve their knowledge, the demotivated ones could develop motivation for learning physics, and the marginalized ones could be included in social life of the class.

For the realization of the jigsaw method, for each topic, the teacher prepared worksheets with five tasks for the home groups (the example for teaching unit Free fall is given in Appendix 1). The home groups were diverse in terms of gender, ability, and other students' characteristics. The tasks set by the teacher on the worksheets were aligned with the learning outcomes. Within each home group, the students themselves discussed the topic and they could freely choose one of the suggested tasks, after which they were separated into the expert groups (from each home group a student that selected a particular task was transferred to the expert group dealing with that task) (Appendix 2). Although cooperative learning stemmed from the home group, all the steps and elements of cooperative learning are visibly realized in the expert group. The work within the expert group was based on the problem identification, the consideration of possible approaches to the problem research, problem research plan creation, communication with each other with the purpose of explaining the smallest details of the problem by raising as many questions as possible. During the research realization, the students practiced communication, encouraged each other, helped each other, and praised each other after achieving the goal. After working in the expert groups, where they developed the sense of individual responsibility, positive interdependence, and social skills in addition to the academic skills in physics, the students returned to the home groups. Each student had to explain the process by which he/she realized his/her task to the rest of the home group and pass on conclusions and new knowledge to them. While one student explained his/her part of the work, the other students filled in their worksheets. The home group had one large piece of paper where each student in the group filled in the part to complete the group task. During the process of transferring the acquired knowledge among the students, the students themselves evaluated their work, improved social skills, and positive interdependence. At the very end, each home group presented their work to the teacher or the whole class, and the evaluation of the group's work was carried out (Appendix 2).

During the treatment of the topic Motion under the influence of a force, within the C group, the teacher applied the teacher-directed teaching method with the predominant 'ex cathedra' lecturing, accompanied by some occasional group and individual students' work. The presentations and video materials were used while processing the new content, and the students were solving tasks on the blackboard; the quizzes were used for the recap of the material, either in the introductory or the final parts of the lesson.

The post-test was realized after the end of the research in the form of a standard physics test (covering the content realized during the research) lasting for 45 minutes. At the end of the research, the students had 30 minutes for filling questionnaires of motivation and metacognition (pen and paper).

Data Analysis

In the data analysis, students' achievement was expressed in scores on physics knowledge tests. Metacognitive awareness was expressed in scores on subscales on MAI (declarative knowledge, procedural knowledge, conditional knowledge, planning, information management, monitoring, debugging, evaluation) and motivation for learning physics was expressed in scores on subscales on SMTSL (self- efficacy, active learning strategies, physics learning value, performance goal and achievement goal). The Cronbach's Alpha coefficient was calculated for each subscale to estimate the reliability of instruments used for data collection. The Shapiro-Wilk test was performed to check normality of data and since the data were not normally distributed within groups, for further analysis nonparametric tests were used. All variables were analyzed using Mann-Whitney *U* test to explore possible differences between C group students and E group students, on both pre-test and post-test. Besides, for all variables was performed the Wilcoxon Signed Ranks Test to compare post-test and pre-test scores within Group C, as well as Group E.

Research Results

To reflect the effects of the jigsaw technique on the students' physics achievement, their metacognitive awareness and their motivation in detail, the subscales measuring different components of students' metacognitive awareness and motivation were analyzed separately. Accordingly, Cronbach's alpha coefficient was calculated for these subscales (Table 1).

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Table 1
The Cronbach's Alpha Coefficient for the Subscales of the Research Instruments

		Cronbach's Alpha	
		Pre-test	Post-test
Physics achievement		.70	.65
Metacognitive awareness	Declarative knowledge	.53	.77
	Procedural knowledge	.78	.65
	Conditional knowledge	.74	.81
	Planning	.93	.92
	Information management	.82	.90
	Monitoring	.86	.90
	Debugging	.61	.77
	Evaluation	.89	.92
Motivation	Self- efficacy	.90	.96
	Active learning strategies	.91	.96
	Physics Learning Value	.82	.91
	Performance Goal	.70	.52
	Achievement Goal	.78	.83

Since the *p* values of Mann-Whitney *U* test were below .05 for most variables (except for planning, evaluation, and self- efficacy in the C group, monitoring, and performance goal in both groups), normal distribution could not be assumed.

After equalizing the C and the E group, students in both groups showed similar physics achievement, metacognitive awareness, and motivation in the pre-test (Table 2).

Table 2
Mann-Whitney U Test and Median Values for the Pre-Test and Post-Test Scores

Variable		Pre-test					Post-test			
		Group	*Md*	*U*	*z*	*p*	*Md*	*U*	*z*	*p*
Physics achievement		C	67.5	872	-1.60	.11	62.5	575	-3.90	<.0001
		E	80.0				85.0			
Metacognitive awareness	Declarative knowledge	C	4.33	675	-3.15	.002	4.33	853	-1.77	.076
		E	3.67				4.33			
	Procedural knowledge	C	4.00	968	-0.87	.38	3.67	428	-5.07	<.0001
		E	4.00				4.33			
	Conditional knowledge	C	4.00	957	-0.96	.34	3.67	688	-3.05	.002
		E	4.33				4.67			
	Planning	C	3.40	831	-1.92	.054	3.30	399	-5.25	<.0001
		E	4.00				4.40			
	Information management	C	4.00	948	-1.02	.30	4.10	629	-3.51	<.0001
		E	4.20				4.80			
	Monitoring	C	3.60	834	-1.90	.057	3.60	471	-4.70	<.0001
		E	4.00				4.60			
	Debugging	C	4.33	1023	-0.45	.66	4.33	654	-3.36	.001
		E	4.33				4.67			
	Evaluation	C	3.38	892	-1.45	.15	3.75	570	-3.95	<.0001
		E	4.00				4.50			

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Variable		Pre-test					Post-test			
		Group	*Md*	*U*	*z*	*p*	*Md*	*U*	*z*	*p*
Motivation	Self- efficacy	C	3.71	897	-1.41	.16	3.57	528	-4.28	<.0001
		E	4.14				4.71			
	Active learning strategies	C	4.00	753	-2.53	.012	4.00	513	-4.38	<.0001
		E	4.50				4.75			
	Physics Learning Value	C	3.80	887	-1.49	.14	4.00	440	-4.95	<.0001
		E	4.00				4.60			
	Performance Goal	C	3.00	795	-2.21	.027	2.80	959	-0.94	.345
		E	2.80				2.60			
	Achievement Goal	C	4.25	858	-1.73	.083	4.50	877	-1.60	.110
		E	4.75				4.75			

Regarding the students' metacognitive awareness, it was shown that there was a significant difference in the declarative knowledge of the C group students and the E group students, in favor of the C group students. Within the students' motivation for learning physics, the difference was shown to be significant in active learning strategies (in favor of the E group students) and the performance goal (in favor of the C group students).

In the post-test scores, the results of Mann-Whitney *U* test showed that the statistically significant difference existed between the groups C and E in all the variables measured, except for the following three: declarative knowledge within metacognitive awareness, the performance goal, and the achievement goal within motivation (Table 2). All the discovered differences were in favor of the E group students.

For the C group students, the Wilcoxon Signed Ranks Test showed that only four variables were significantly different on the post-test with regards to the pre-test. These four variables showed an unexpected decrease from the pre-test to the post-test (Table 3).

Table 3

The Statistics of Wilcoxon Signed Ranks Test Exploring the Differences between the Pre-Test and the Post-Test Scores in the Group C and Group E

		Group C				Group E			
		M		*Z*	*p*	*M*		*Z*	*p*
Variable		Pre-test	Post-test			Pre-test	Post-test		
Physics achievement		64.5	60.8	-1.17[a]	.24	74.7	82.0	-2.41[a]	.016
Metacognitive awareness	Declarative knowledge	4.04	3.97	-0.99[a]	.32	3.62	4.34	-5.05[a]	<.0001
	Procedural knowledge	3.76	3.44	-3.66[a]	.000	3.96	4.31	-3.29[a]	.001
	Conditional knowledge	3.85	3.63	-2.39[a]	.017	4.03	4.30	-2.89[a]	.004
	Planning	3.28	3.16	-1.40[a]	.16	3.71	4.23	-5.02[a]	<.0001
	Information management	3.86	3.90	-0.23[b]	.82	4.11	4.55	-5.02[a]	<.0001
	Monitoring	3.46	3.46	-0.22[b]	.82	3.85	4.32	-4.97[a]	<.0001
	Debugging	4.10	4.08	-0.27[a]	.79	4.20	4.60	-4.43[a]	<.0001
	Evaluation	3.40	3.48	-0.57[b]	.57	3.72	4.26	-4.65[a]	<.0001
Motivation	Self- efficacy	3.66	3.41	-2.73[a]	.006	3.83	4.37	-5.27[a]	<.0001
	Active learning strategies	3.86	3.77	-1.32[a]	.19	4.27	4.52	-3.74[a]	<.0001
	Physics Learning Value	3.75	3.72	-0.01[b]	.99	3.98	4.44	-5.47[a]	<.0001
	Performance Goal	3.28	2.80	-4.69[a]	.000	2.84	2.71	-2.07[b]	.038
	Achievement Goal	4.23	4.32	-1.81[b]	.071	4.50	4.59	-2.07[a]	.038

[a]. Based on positive ranks.
[b]. Based on negative ranks.

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For the E group students, the Wilcoxon Signed Ranks Test showed that all the variables were significantly different between the post-test and the pre-test. All the variables showed an increase from the pre-test to the post-test, except for the performance goal where the decrease was shown (Table 3).

Discussion

The results of this research showed that the changes in the physics teaching, particularly the implementation of the jigsaw technique in physics classes, can lead to significant changes in the students' achievement in physics, increase motivation for learning physics and metacognitive awareness.

The analysis of the students' achievement in the pre-test showed that there were no differences between the pre-test scores of four classes of the sample (Table 2). These results indicate that before the research, the teaching process in physics has been carried out in the same way in all the classes, and that the researchers adequately divided the classes into C and E groups at the beginning of the research. After the implementation of the jigsaw technique in the E group and the teacher-directed teaching method in the C group, a post-test of acquired physics knowledge was administered to students. The students from the E group had significantly higher achievement compared to the pre-test, while in the C group there was no significant difference between pre-test and post-test. A significant difference was shown between the students' post-test achievement in E and C group, in favor of the students' achievement in the E group. These results, indicating that the cooperative learning has a positive effect on students' achievement in physics, are in line with the results of the research carried out by Topping (2011) et al. Ho and Boo (2007).

According to the previous research, students' metacognitive abilities may (Bilgin & Geban, 2006, Chang & Mao, 1999) or may not (Slavin, 1995) develop during the application of the cooperative learning, depending on the adequacy of the method and the approach, as well as the interaction of the teachers with groups of students (Cheong, 2010). In this research, the students' metacognitive awareness was measured using questionnaire before and after the pedagogical experiment. A significant difference was only shown between the declarative knowledge in pre-test of students in the E and C group, in favor of the students in the C group. This result is in accordance with E and C group being equalized. The post-test results showed that there was no significant difference between the declarative knowledge of students in C and E group, that is, the E group students caught up with the C group students. The progress of the E group during the research is in line with the previous research, confirming that students' metacognition develops by applying cooperative learning (Bernard & Bachu, 2015; Hurme et al., 2015; Kramarski & Mevarech, 2003). In the post-test, the values of all other metacognitive components (procedural knowledge, conditional knowledge, planning, information management, monitoring, debugging and evaluation) were significantly higher in the E group than in the C group. The obtained results are in accordance with the already cited literature (Bernard & Bachu, 2015; Hurme et al., 2015; Kramarski & Mevarech, 2003) in which it was shown that the cooperative learning develops students' metacognition. Bilgin and Geban (2006) showed that active student participation in the cooperative learning leads to the development of critical thinking, reasoning and problem solving, which directly affects the development of students' metacognition. If each step that students apply and each element of cooperative learning are observed in detail, including the division of tasks, planning their realization, carrying out research and the knowledge acquisition, individual responsibilities for the task, development of cooperation, social skills, self-evaluation, and the group evaluation, it can be suggested that students develop their metacognitive abilities. On the other hand, the obtained results of the increase in metacognitive awareness can be directly related to the increase in the students' achievement in physics, which aligns with the results of research carried out by Bogdanović et al. (2015). Finally, through the application of the cooperative learning, students develop their independence in work and the increase in all the metacognitive components is expected. Besides, research results showed that the C group students showed the decrease in the procedural and conditional knowledge, which indicated that the students are passive, and the metacognition is not nurtured in the teacher-directed teaching method. For the E group students, all the metacognitive components had significantly higher values on the post-test than on the pre-test. Accordingly, it can be indicated that the implementation of the jigsaw technique had a positive effect on the development of students' metacognitive awareness.

In the pre-test there was no significant difference between C and E group regarding motivational aspects, except for the aspect of active learning strategy which was in favor of the E group students while the aspect of the performance goal was in favor of the C group students. According to the data obtained on the post-test, the variables of self-efficiency, active learning strategies and the physics learning value were significantly higher for

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the E group students than for the C group students. These results are in line with the results of the research on the effect of cooperative learning on students' motivation carried out by Slavin (1995). The difference in the first two variables can be interpreted through the E group students' desire to successfully solve the set task within the expert group while the jigsaw technique was implemented, and to transfer their knowledge to the students within the home group with the aim of attaining awards for being successful. Besides, the increase in self-efficiency can be achieved through accomplishing personal goals and the development of individual responsibility for the task. The significantly higher level of physics learning value of E group students than C group students confirmed that the implementation of cooperative learning in physics classes can lead to the change in status of physics as a school subject. No significant difference was obtained within the performance goal and achievement goal between the E and C group students. By comparing the data on the student motivation in the pre-test and post-test, a decrease in the students' self-efficiency has been shown in the group C, which might be expected for long-term application of teacher-directed teaching method. This result points to the need for a change in the way the teachers deal with students. The same has been shown for the performance goal, where the cause of the decrease in value could be the fact that students work hardest at the beginning of the school year. As the semesters go by, students count on the good impression they left, or they simply lose enthusiasm to do better because they already have grades that they have accepted as "theirs". For the E group students, there is an increase in the self-efficacy, active learning strategies, the physics learning value, and the achievement goal. The performance goal, like within the group C, has slightly declined compared to the pre-test, which could be explained by the students' satisfaction with their own performance, and their focus on the realization of the cooperative learning, and not on the grading.

In this research, it was shown that the implementation of the jigsaw technique in the seventh grade of lower secondary education increased students' achievement in physics, metacognitive awareness, and motivation for learning physics. However, there are some research limitations. The main limitation of the research lies in the sampling procedure. The researchers used pre-formed classes instead of randomly selecting students to form C and E groups. Also, only the seventh-grade students participated in the research. The students of different age might give different outcomes with regards to motivation and metacognition, which might change the overall outcome of this research. Besides, there was a limitation in the form of the width of the treated physics content since the research was limited to a certain period. Finally, the self-assessment scales were used, which are quite demanding for younger students and there is also a possibility that students wanted to show themselves in a 'better' light so they gave answers they recognized as preferable.

Conclusions and Implications

The purpose of this research was to explore the effect of jigsaw technique in the seventh grade of lower secondary education on students' achievement in physics, metacognitive awareness, and motivation. Students' metacognition and motivation were recognized by educators worldwide as important students' qualities that should be nurtured through education. These variables, along with students' achievement, were measured and explored in many studies. However, there is a further need for validating various techniques that would improve students' physics achievement, metacognition, and motivation for learning physics since the difficulties are often most pronounced in complex school subjects, such as physics. The jigsaw technique is proposed by a number of researchers as useful for improving teaching process and although it has been already explored in relation to various school subjects and different levels of education, its effects on physics achievement of 13-year-old students, metacognition and motivation for learning physics were not previously explored. The uniqueness of this research also lies in the fact that all components of students' metacognition and different aspects of students' motivation for learning physics when cooperative learning, specifically jigsaw technique, is implemented were examined separately.

Despite the above-mentioned research limitations, all the three research questions were successfully answered. It was shown that the implementation of the jigsaw technique increased the seventh-grade students' achievement in physics, metacognitive awareness, and motivation for learning physics. In addition, this research highlights that all the metacognitive components and all the motivational aspects were positively affected by the implementation of the jigsaw technique. Moreover, the significance of this research reflects in the fact that, so far, there has been no research that deals with the effect of jigsaw technique in physics classes on these three variables simultaneously. Providing a comprehensive insight into the possibilities of implementing jigsaw technique in lower secondary education physics classes can be of great value to science teachers worldwide because physics content is often least popular within school subject Science. Further, this research provides new insight

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into the potential to encourage students' metacognition and motivation with appropriate teaching techniques. The results of this study indicate that the training of teachers and students about the implementation of the jigsaw technique is advisable. Also, the findings obtained in this research may be the starting point in the future research on the application of cooperative learning. On the same note, the verification of these results can be realized by increasing the sample and expanding the age range of students, increasing the time interval, and increasing the volume of processed material, introducing other instruments for assessing motivation and metacognition, and including other variables in the research.

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Appendix 1. Worksheets with tasks for teaching unit Free fall in E group

Task Number 1 – Motion of the freely falling object

Demonstrate (using a ball) and describe the free fall:

- Describe the motion of the freely falling objects?
- Determine what type of motion the free fall represents, whether the free fall has an initial velocity.
- Which force affects the freely falling objects?
- What kind of acceleration freely falling objects have?
- How does the velocity change during the free fall?
- When is the velocity of the freely falling object greatest?
- Sketch the freely falling ball pattern and try to define free fall.

Watch a video about Felix Baumgartner's jump.

Task Number 2 – Velocity of the freely falling object

Demonstrate free fall (using a ball) and describe the change in the velocity during the free fall:

- How does the velocity change during the free fall?
- Express a formula for the velocity of the freely falling object based on the formula for the velocity of the uniformly accelerated motion.

Check your conclusion using the PhET simulation that shows the dependence between the velocity and the time of the falling object.

<u>Solve the computational problem:</u> The body falls freely for 10 s and hits the ground. Determine the velocity of the body after 2 s in motion, after 5 s and when hitting the ground.

Task Number 3 – Distance the object falls

Demonstrate free fall (using a ball) and describe the change in the distance an object falls during the free fall:

- Describe the correlation between the distance an object falls, and the time spent freely falling.
- Express a formula for the distance an object falls based on the formula for the distance of the uniformly accelerated motion.

<u>Solve the computational problem:</u> The freely falling object hits the ground after 5 s. Determine the distance after 3 s of falling and distance to the ground.

Task Number 4 – Correlation between the velocity and the distance

Demonstrate free fall (using a ball) and describe correlation between the velocity and the distance:

- Find the correlation between the velocity and the distance an object falls while freely falling and express a formula for free fall based on the formula for the uniformly accelerated motion.

<u>Solve a computational problem:</u> The body falls freely from a height of 20m. Determine the velocity at which it hits the ground.

Task Number 5 – Weightlessness

Use the video materials related to the concept weightlessness (paratroopers jumping from planes, astronauts on the International Space Station) to comprehend, describe and define the concept.

<u>Solve a computational problem:</u> The parachutist has a mass of 76 kg. Determine his weight before opening the parachute – during free fall.

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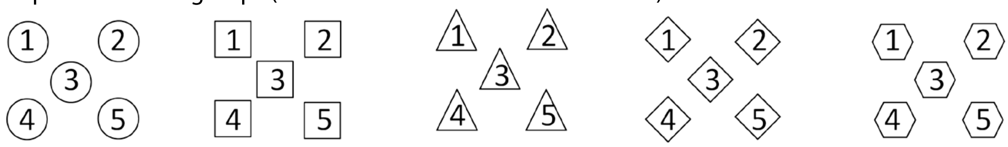
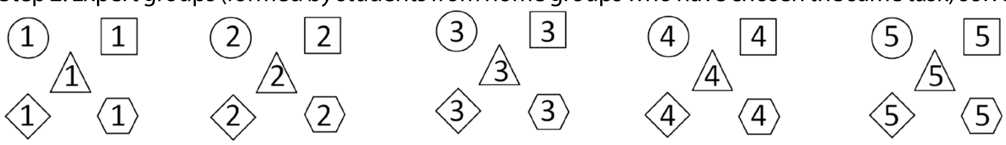
Appendix 2. Scheme of Jigsaw steps

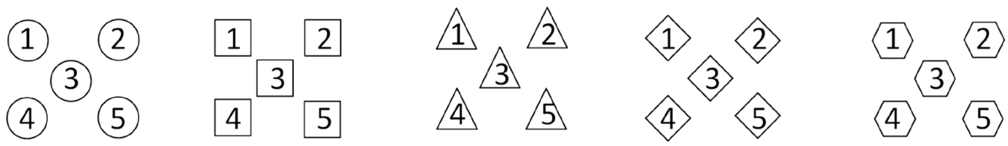
Step 1. Five home groups (each student chose one of five tasks)



Step 2. Expert groups (formed by students from home groups who have chosen the same task) solve their tasks.



Step 3. Students from expert groups back to their home group and share the knowledge about the task



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