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# Planning and Delivering a Cooperative Maths Lesson

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**Abstract:** School education should not only provide students with content knowledge but also with effective skills that will be appropriate in their adult lives, such as the competence in solving problems individually or being able to work as a member of a team. Students should be active participants instead of passive listeners in their lessons. There is a wide variety of teaching methods that practicing teachers can choose from to make their lessons varied. The present article explains the outline of an experiment that was based on Spencer Kagan's cooperative learning focusing on one particular lesson. The mathematics lesson was planned using cooperative teaching techniques and was taught in secondary mathematics education. We analyse how well cooperative learning can be used for improving participation and effective problem-solving in the classroom.

**Keywords:** *Cooperation in maths, cooperative teaching techniques, teaching problem-solving.*

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## Introduction

In a nowadays fast-changing world, the way we educate our children should equip them with knowledge and skills that will be relevant in their adult life as well (Ambrus, 2004). As the content of education is declared teachers do not have the freedom to change WHAT they teach but they do have the opportunity to alter the methods they use, in other words, the HOW can be changed (Kagan, 2004).

Based on personal experience and endless discussions with colleagues who also teach mathematics or science subjects we can state that it is becoming more and more difficult to facilitate students' active participation in class. Students find individual problem solving, checking, and reflecting on a solution method demanding (Pólya, 2014), many students are just passive listeners when it comes to discussions of problems. Furthermore, due to the pandemic situation in the previous years, many lessons had to be presented online which made it even more difficult to check how active our students were. These lessons also drew attention to the fact that cooperation and active participation is not always straightforward for the students. Taking the aforementioned into consideration we think that the aims of our mathematics education should also include teaching students to cooperate to solve problems that might be difficult for the individual and teaching them to participate actively in class discussions and problem-solving (Kagan, 2000b).

An experiment (Barczi-Veres, 2017a) was carried out to examine how effectively cooperative teaching techniques could be used to develop students' problem-solving skills in mathematics and to further active participation and cooperation among students. Cooperative teaching and learning as a method is well known and more and more widespread in our country, however, only a few experiments have been designed to examine the method's effectiveness in secondary education. In this article, through presenting the plan of a cooperative mathematics lesson, we would like to emphasize how productively this method can be used in secondary maths education.

## Literature review

Inevitably, one of the primary aims of teaching mathematics is teaching problem-solving to our students (Pólya, 2014). When teaching problem solving the following aspects need to be taken into consideration. First, most classes are heterogeneous containing students with mixed abilities. It is the teacher's task to develop the problem-solving skills of

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not only those who are talented (Miller, 1990) but also the average ability students which is usually a more challenging task. Furthermore, problem-solving plays an important role in every area of life that is why necessary skills should be taught not only for the sake of passing an exam (Mayer & Hegarty, 1996). To become successful problem solvers in their future lives students need to acquire ways of thinking and need to develop a "thinking tool kit" which contains problem-solving strategies. Solving countless practice problems without reflecting on the problem-solving process is not enough (Barczi-Veres, 2017a).

Mathematical thinking (Schoenfeld, 1992) and learning to think mathematically (Tanner & Jones, 1997) are vital in the problem-solving process and the development of mathematical competencies also plays an important role (Niss, 2002). Furthermore, when teaching problem solving the role and capacity of the working memory (Baddeley et al., 2009) should be taken into consideration, as well, since the capacity of the working memory of the group members "is added together" in a cooperative problem-solving scenario (Ambrus & Barczi-Veres, 2014).

*Cooperative principles and structures*

Cooperative learning is similar to group work because students are arranged in groups to solve problems or discuss ideas together. However, cooperative learning is designed in a way that group members have to trust each other, appreciate each other's contribution to the work, and help each other overcome possible difficulties. The success of the group relies on the ability of the members to work together (Kagan, 2004). In Hungary cooperative learning and teaching is becoming more and more widespread. The reason for introducing this method to our education was that it was believed to support the integration of students and develop their achievement (Józsa & Székely, 2004).

Although students work in teams, cooperative teaching and learning is not simply arranging students into groups and asking them to tackle problems (Kagan, 2009). Experienced teachers know very well that in simple group work students do not necessarily share the work and the related responsibilities. In fact, this working arrangement often results in a few or only one student carrying out the task while the others just copy the solution, often without understanding the problem-solving method. However, in a lesson planned with cooperative teaching techniques the following four principles must always be present:

1) *Positive Interdependence* (Johnson & Johnson, 2009): This element exists in a learning situation when students realize that they cannot succeed without the help of their group mates and also the success of their group mates depends on their contribution to the set task.

1) *Individual Accountability* (Johnson & Johnson, 2009): Each student needs to put effort into achieving the common goal of his/her group because the purpose of cooperative learning is also to develop the individuals and help them to get stronger through group work.

2) *Equal Participation* (Kagan, 2004): To avoid some students doing all the talking and to involve every member of a class in cooperative learning the teacher needs to ensure the following: 1) giving different roles to different students; 2) dividing the workload.

3) *Simultaneous Interactions* (Kagan, 2004): Cooperative learning allows more interactions to happen at the same time, for example, some structures require pair discussions, which means that half of a class is talking thus participating actively at the same time. Moreover, the other half is listening actively since they are also responsible for the success of their team.

These four principles establish the active participation of each team member and make sure that responsibility is equally divided among the participants (Johnson and Johnson, 2009). When planning a cooperative mathematics lesson, the teacher should make sure that the abovementioned four principles are always present. To ensure the presence of these principles in class cooperative structures were designed that were given easy-to-remember names. This helps students to remember to outline of each structure (Kagan, 2003). The following list contains some structures which can be used effectively in a problem-solving lesson. Kagan structures are free of content which means that the same structures can be applied when covering different topics (Kagan, 2000a). A detailed description of these structures can be found in Kagan, S. Cooperative Learning (2004).

*Expert jigsaw:* this structure enables students to become experts on a certain topic or of the solution of a given problem in their original groups then present this knowledge to members of newly formed groups.

*Table 1. Original groups in Expert Jigsaw*

| Topic/problem 1 | Topic/problem 2 | Topic/problem 3 |
|---|---|---|
| Pupil A | Pupil A | Pupil A |
| Pupil B | Pupil B | Pupil B |
| Pupil C | Pupil C | Pupil C |
| Pupil D | Pupil D | Pupil D |

*Table 2. New groups in Expert Jigsaw*

| 1. group | 2. group | 3. group | 4. group |
|---|---|---|---|
| Pupil A | Pupil B | Pupil C | Pupil D |
| Pupil A | Pupil B | Pupil C | Pupil D |
| Pupil A | Pupil B | Pupil C | Pupil D |

*Think-pair-share:* In groups of four students are paired up. Problems or tasks are presented to the pairs. First, every student is given some time to gather ideas then they discuss possible solutions in pairs. The following step can be a group or a class discussion.

*Gallery walk:* Students prepare a poster presenting information related to a given topic or solution to a problem. Posters are displayed in the classroom and the groups walk around to study the posters of the other groups.

*Round Robin:* Students have to answer a question or reflect on a topic/solution of a problem in a set time.

The structures might slightly be altered so that they fit the needs of secondary school students and so that they are meaningfully applicable in secondary mathematics education.

*Forming groups in a cooperative lesson*

Forming groups in a cooperative lesson depends on many aspects. The teacher's personality, the students' personality, ability and attitude, the type of the lesson, and the teacher's relationship to the class should all be taken into consideration. Groups might be heterogeneous or homogenous regarding the students' mathematical ability. Overall, the teacher should try to arrange their students into groups of four if possible, as in a group of four pairs can be easily formed. This way nobody feels neglected or left out (Burns, 1990).

*The role of the teacher*

Among many other elements, the role of the teacher also changes in a cooperative classroom. While in a frontal classroom the teacher is more of a leader who has control over the teaching and learning situation, in a cooperative environment the teacher becomes a mentor. The main tasks of the teacher include guiding students through the learning or problem-solving process, giving advice to the groups or students who fall behind, and giving feedback on the current task (Crabill, 1990). Moreover, the teacher has to maintain a peaceful learning environment. Cooperative work is definitely noisy but the classroom should not turn into a chaotic place where everybody can do what they wish (Dees, 1990).

*Cooperation in mathematics*

Cooperative teaching techniques could be useful tools in mathematics education. As there is no competition neither within nor among the groups every student has the opportunity to experience success in learning. Furthermore, working in small groups gives the opportunity to the members to discuss mathematical problems logically and teammates can help each other to learn the basic concepts and numerical methods (Davidson, 1990).

## Methodology

*Research Design*

The classroom experiment presented in this study was part of an action research (Koshy, 2005), where the teacher of the participating group was also the researcher. The duration of the whole research was one academic year. The research consisted of two main parts. The first part was a two-week period when students attended maths lessons planned only with cooperative teaching techniques. The second part was the rest of the school year when lessons were taught mainly with frontal work, applying cooperative teaching and learning when the topic or the type of the lesson made it appropriate. Qualitative data were analysed at the end of each lesson taught by using cooperative methods. The following lessons were planned taking these findings into consideration. In this study we focus on the findings related to one particular lesson which belongs to the second phase of the research.

*Research questions*

The whole research contained numerous mathematics lessons that were planned and taught using cooperative teaching techniques. We were interested in how students respond to problem-solving when they can rely on each other's explanations and guidance, so we analysed one particular lesson to have a better insight into individual reactions. Based on the behaviour and attitude of the students in this lesson we wanted to answer the following questions:

1) How does cooperative work influence the effectiveness of problem-solving?
2) How do students respond to having to rely on each other's knowledge rather than on the teacher's explanations?
3) What are the possible drawbacks of applying cooperative methods in a mathematics lesson?

*Sample and Data Collection*

The experiment took place in a mixed comprehensive secondary school. The participating students were 16 - 17 years old, most of them were interested in mathematics, science subjects and computer science. The 16 students attended a class whose main focus is providing students with knowledge well – applicable in tertiary education in technology. Altogether these students had five years to finish their secondary school studies. The academic year of the experiment was their third year in the school. In their initial year they had three maths lessons a week which increased to four in the following two years. As the number of maths lessons in this class was higher than in other classes we often had enough time to discuss a topic in more detail or to solve problems from maths competitions. The students did not necessarily have outstanding abilities in mathematics but they definitely showed a positive attitude towards the subject. Motivation and active participation were characteristics of the majority of the class.

The students participating in the experiment filled in different tests measuring their attitude toward learning mathematics (Ambrus, 2004), towards cooperative learning (Mécs, 2009) and a mathematical pre-test, post-test and delayed test. Furthermore, half of the lessons were video recorded, group discussions were recorded with a voice recorder as well, and the teacher made notes about the groups' work and the reaction of the individual students. Students had their own exercise books, or "reflection books" into which they wrote not only the solution strategies belonging to problems but also reflections on the working format and the problems.

*The lesson*

In this section, we present a lesson that was taught in the second phase of the abovementioned experiment. The topic of the lesson was describing quadratic functions. It was a practice lesson, the students were already familiar with the graph of the quadratic function and with the properties of functions. These ideas were used to help students understand transformations on graphs of functions and help them to be able to recognise properties of functions such as range, domain, monotonicity … etc.

*Lesson plan:*

1. Forming groups – Every student chooses one card that contains a graph of a quadratic function then they have to find their group mates, students who have a card with the same graph. Graphs of functions:

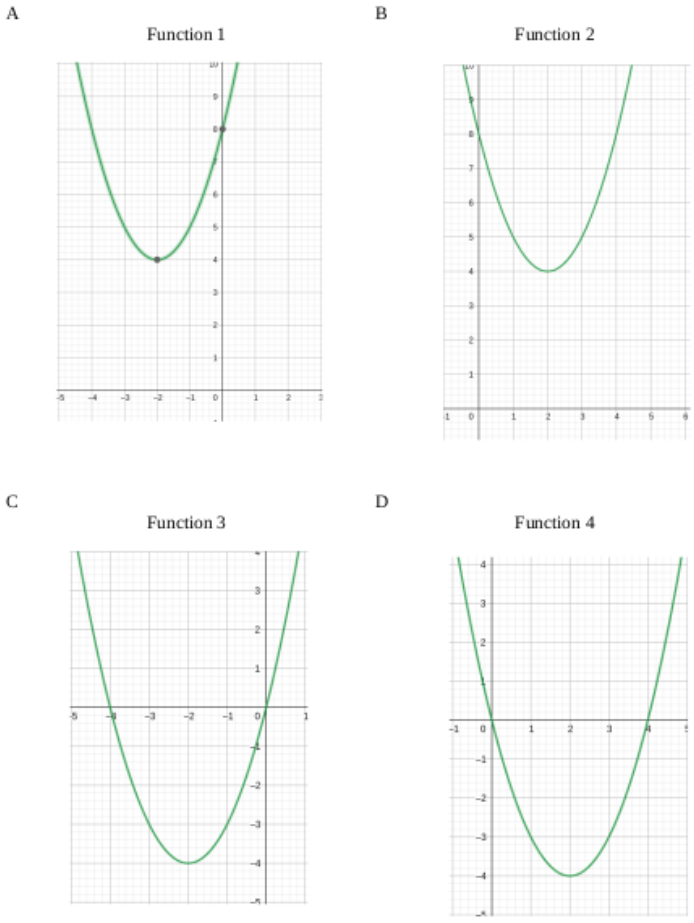


*Figure 1. Graphs of quadratic functions*

2. Describing graphs – Each group has a graph of a quadratic function and a worksheet containing different properties of functions.

*Properties - Worksheet*

1. *Assignment rule 1*

$f(x) = (x-2)^2 + 4; f(x) = (x+2)^2 + 4; f(x) = (x-4)^2 - 2; f(x) = (x-4)^2 + 2;\ f(x) = (x-2)^2 - 4;\ f(x) = (x+4)^2 - 2; f(x) = (x+2)^2 - 4; f(x) = (x+4)^2 + 2$

2. *Assignment rule 2*

$f(x) = x^2 - 4x + 8;\ f(x) = x^2 - 8x + 18;\ f(x) = x^2 + 4x;\ f(x) = x^2 + 4x + 8;\ f(x) = x^2 - 4x;\ f(x) = x^2 + 8x + 18;$
$f(x) = x^2 - 8x + 14; f(x) = x^2 + 8x + 14$

3. *Domain*

]-∞;∞[ or [2;∞[ or [4;∞[ or [-4;∞[ or [-2;∞[ or the set of real numbers ($\mathbb{R}$)

4. *Range*

]-∞;∞[ or [2;∞[ or [4;∞[ or [-4;∞[ or [-2;∞[ or the set of real numbers ($\mathbb{R}$)

5. *Zero points*

$x_1 = -4; x_2 = 0;\ x_1 = 0; x_2 = 8;$ *No zero points;*

$x_1 = 8; x_2 = 4;\ x_1 = 0; x_2 = 4;\ x_1 = -4; x_2 = 4$

6. *Points of intersection with the y-axis*

$y = 2;\ y = 8;\ y = 4;\ y = -4;\ y = 0;\ y = -2$

7. *Extreme points: Decide whether the function has a MINIMUM or a MAXIMUM point!*

*Now choose the coordinates of the extreme point:*

$(2; 4);\ (4; -2);\ (-2; -4);\ (2; -4);$

$(-4; -2);\ (4; 2);\ (-4; 2);\ (-2; 4)$

8. *Monotonicity*

*Strictly mon. decreasing on:* ]-∞;-2] *and Strictly mon. increasing on:* ]-2;∞]

*Strictly mon. decreasing on:* ]-∞;2] *and Strictly mon. increasing on:* ]2;∞]

*Strictly mon. decreasing on:* ]-∞;-4] *and Strictly mon. increasing on:* ]-4;∞]

*Strictly mon. decreasing on:* ]-∞;4] *and Strictly mon. increasing on:* ]4;∞]

The worksheets are the same for every student. The groups have to find the properties that belong to their function. Every student has to stick the graph of the function in their exercise books and list its properties below. (This is the first phase of the structure *Expert jigsaw* applied for teaching problem-solving.)

3. Checking descriptions – New groups are formed using the letters that can be found on the original cards (second phase of *Expert jigsaw*). Students with the same letter belong to one group. In the new groups each student has a different graph. Using the structure *Round Robin* members of the new groups take turns to present the graph of their functions to the other group members and share the descriptions. Group mates have to check the work of each other. They can make corrections, suggestions or ask questions.

4. Frontal discussions – As the functions described during the lesson are similar there should be no need for checking the work together. During the final discussion students can ask questions or pose problems that they could not agree on in their groups. This phase also contains a reflection on the cooperative working format.

When planning a cooperative lesson, it has to be taken into consideration that some groups might finish faster, that is why the teacher should always have a so-called *time filler* activity ready. For this topic, time filler activities might be:

a) The graph of a new function. Students have to describe this function without any helping information.

b) The assignment rule of some functions that students have to plot.

## Discussion

One of the main aims of action research is to contribute to the teacher-researcher's professional development that is why this research mainly focused on qualitative rather than quantitative data. The teacher's observations and reflections, moreover the students' comments play a vital role in understanding how cooperative teaching techniques might improve teaching problem-solving in the classroom and contribute to the active participation of the students (Wangda et al., 2020).

In this study, we used the reflections of the teacher and comments written by the participants to find possible strengths and weaknesses of applying cooperative teaching techniques in the classroom. Previous studies show that the application of Kagan structures makes learning more interesting for students, who become more willing to participate in classroom activities (Rabgay, 2018). Furthermore, the structures facilitate communication among students and raise their confidence (Winters & Galindo, n.d.). The findings of our study are in line with the aforementioned. The groups were able to proceed on their own or rarely asked for help. Furthermore, the less abled students could also contribute to the problem-solving process since their group mates assisted them with their work. Students' confidence was boosted also, since students dared to make mistakes in their groups and were more willing to ask questions in front of a smaller audience. Regarding the active engagement of the students our findings are in agreement with the statement that implementing Kagan's structure highly affects the engagement of the students (Hinson, 2015). Due to the nature of cooperative work more interactions took place and participants were more communicative than in an average lesson. However, sometimes they used their own words instead of mathematical concepts to describe their ideas. In addition, Kagan structures are good tools for supporting mathematical problem solving (Farmer, 2017), which we also experienced. Solving the set task was more successful than in an average frontal lesson. Comments written by the students related to cooperative working format support this: "I learned a lot from my group mates." or "It was easier to work together than alone, because we had people thinking differently and this helped a lot."

However, maintaining a productive atmosphere and making sure that cooperation happens in the groups is not always easy (Gradone, 2015). Our findings are consistent with this statement as in the observed lesson there was one group that consisted of students who were less abled in mathematics, therefore requiring more assistance from the teacher. This group had to be reminded more than once to focus on the task at hand. Students also mentioned that "It was helpful when X had some ideas and I could carry on from his, but the behaviour of Y was often annoying." or "The most difficult thing was to work in a noisy classroom."

## Conclusion

In this section, we provide answers to the research questions related to the observed lesson.

*How does cooperative work influence the effectiveness of problem-solving?*

Based on the lesson observation that is supported by the results of the whole experiment (Barczi-Veres, 2017a), we can state that the use of cooperative structures in mathematics education help improve problem-solving in the classroom. Students were able to tackle the problems together, putting their knowledge together, thus expanding their working memory. When working in small groups individual students were not afraid of making a mistake or asking inadequate questions as there were only 2 or 3 other students who heard them. Moreover, the teacher had a better opportunity to help students individually and had a better insight into the students' way of thinking and methods of problem-solving.

*How do students respond to having to rely on each other's knowledge rather than on the teacher's explanations?*

Cooperative teaching and learning allows students to work at their own pace, slower students have time to understand the tasks better while faster ones can help them figure out a solution method. Moreover, working in groups facilitates communication among students and encourages them to use mathematical language when explaining ideas to each other which also promotes more successful problem-solving. Furthermore, cooperation inspires even the less able students to participate more actively in the problem-solving process.

*What are the possible drawbacks of applying cooperative methods in a mathematics lesson?*

Even if we have a carefully designed plan for our cooperative lesson some factors might hinder the successful delivery of the lesson. First, there are many on-the-spot decisions a teacher has to make. For instance, the number of students present might differ from the number of students on the register and as a result, the group arrangements have to be altered. Furthermore, the tasks set for the groups might be too difficult for the majority of the class in which case the teacher might decide to continue in a frontal arrangement. Moreover, the noise level might turn disruptive for some students when the teacher has to act immediately. Cooperative techniques are time-consuming considering both planning and implementation and require creativity on the teacher's side.

All in all, we can say that enriching our everyday teaching by using different teaching methods has a positive impact on our daily work, on the students' achievement and on the students' attitude as well. However, when planning a cooperative

lesson many aspects have to be taken into consideration. It is advisable to apply this method in a group whose members are well known for the teacher. Due to the nature of cooperative techniques it is more difficult to provide a productive atmosphere with students whose attitudes and behaviour are unknown to us. Moreover, the topic of the lesson has to be carefully chosen. There are certain topics in mathematics that are better taught in frontal work. Planning a cooperative lesson requires innovative thinking and is definitely time-consuming.

## Recommendations

Practicing teachers who seek opportunities for professional development can often apply for training where alternative teaching methods are introduced in general, presenting mainly the theoretical background. However, teachers might find it difficult to implement new ideas in their own practice without seeing some illustrations of how certain teaching techniques are used for example in a mathematics classroom. Some lesson plans where cooperative teaching techniques were applied can be found in: *Solving problems – Together* (Barczi-Veres, 2017b). Furthermore, lessons planned similarly to the above lesson can be taught when discussing the absolute value function, the square root function or even trigonometric functions or composite functions.

For future researchers who are interested in examining the effects of cooperative teaching techniques on their students' attitude, achievement or problem-solving ability in mathematics lessons it is recommended to focus on qualitative data rather than measuring different results. A possible approach might be observing the lessons of other teachers who use this method or reflecting on the researcher's own practice. Interviewing students' or observing the work of individual groups also provide numerous useful pieces of information.

## Limitations

The relevance of research related to applying cooperative teaching techniques in secondary mathematics education is inevitable, however, there are some limitations of the present study that should be taken into consideration when planning future research. First, the sample size of the present study was limited, since only 16 students took part in the lessons that were observed and analysed. Conclusions were drawn based on their attitude, behaviour, comments and test results. Second, the selection of the participants was not random. The schedule of this particular class made it possible to carry out the research which is why this group of students was selected. Third, although test results were analysed, due to the small sample size, the quantitative data is not sufficient for drawing general conclusions. Therefore, the research focused on qualitative data obtaining valuable reflections from the students related to using alternative teaching methods. Fourth, as the number of previous studies related to teaching secondary mathematics applying cooperative teaching techniques is rather limited, designing the research was not always straightforward. The present study could serve as a base for further action research where more students might be involved.

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