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Case Study of Using Peer Instruction at Upper Secondary School

Jana Šestáková

Abstract

The article describes the results of the case study "Implementation of the Peer Instruction method into education in the Czech Republic", trying to answer one main question: "How is the Peer Instruction method implemented into physics teaching at upper secondary Czech school?".

The data was collected through interviews with the teacher, lesson observation and questionnaires for the teacher and students. The teacher involved in the study had been interested in the method since 2009. The research findings resulting from lesson observation and students' opinions are from the 2014/2015 school year, when the method was implemented with students aged 17–18 years in three physics classes taught at an upper secondary school, with the respective numbers of students being 28, 16 and 13. The research generated the following conclusions, among other things: (1) the method should ideally be used immediately after a presentation of a new topic, therefore e.g. once a month, (2) a maximum of two ConcepTest questions should be used within one 45-minute lesson, and (3) students' responses should be collected by means of flashcards rather than by an electronic voting system. The teacher starting with the method expected that ConcepTest questions would be simple for students and the work pace would be faster. She tried to hasten the work and therefore sometimes did not give students enough time to think about their responses, occasionally even failing to provide the option of a second answer. Nevertheless, the participating students gave positive feedback on this method, strongly indicating that that they had learned more while using this method. They admitted that using flashcards during the first answering was a strong incentive that boosted their motivation towards thinking about the answers. This article is intended for people interested in the Peer Instruction method, teachers and researchers in active learning.

Key words: Peer Instruction, case study, teaching physics, upper secondary school.

Případová studie použití metody Peer Instruction na gymnáziu

Abstrakt

V článku jsou popsány výsledky případové studie „Zavádění metody Peer Instruction do výuky v České republice“ s hlavní výzkumnou otázkou: „Jak je metoda Peer Instruction zaváděna do výuky fyziky na gymnáziu?“.

Sběr dat probíhal pomocí rozhovorů s vyučující, pozorování výuky a dotazníků pro vyučující i studenty. Vyučující zapojená do studie se o metodu zajímá od roku 2009. Závěry výzkumu plynoucí z pozorování výuky a z vyjádření studentů jsou ze školního roku 2014/2015, kdy výuka fyziky probíhala na gymnáziu se studenty ve věku 17 až 18 let ve třech třídách s 28, 16 a 13 studenty.

Z výzkumu plynou mimo jiné následující závěry: (1) metoda by měla být ve třídě použita ihned po výkladu nové látky, tedy přibližně jednou za měsíc, (2) v jedné 45minutové vyučovací hodině by měly být použity maximálně dvě konceptuální otázky a (3) studentské odpovědi by měly být sbírány spíše pomocí hlasovacích karet než elektronickými zařízeními. Vyučující začínající s metodou očekávala, že konceptuální otázky budou pro studenty jednoduché, práce bude probíhat rychleji. Snažila se práci uspíšit, proto někdy nedávala studentům dostatek času na rozmyšlení odpovědí a někdy dokonce neposkytla studentům prostor pro druhé odpovídání. Nicméně studenti, kteří se zúčastnili studie, se o metodě vyjadřovali pozitivně a zároveň dali najevo, že se tímto způsobem více naučí. Připouštěli, že použití hlasovací karty v prvním odpovídání bylo pro ně silným podnětem, který je motivoval k rozmyšlení odpovědi. Článek je určen zájemcům o metodu Peer Instruction, učitelům a výzkumníkům v oblasti aktivní výuky.

Klíčová slova: Peer Instruction, případová studie, výuka fyziky, gymnázium.

1 Introduction

Peer Instruction is a method that engages students in learning, usually at universities in the world, and helps them to understand learning material (Crouch & Mazur, 2001). The method was originally created by professor Eric Mazur (Mazur, 2014) for his introductory physics courses. It spreads to other subjects, for example to economics (Ghosh & Renn, 2006) or medicine (Rao & DiCarlo, 2000) and lower levels of education. William R. Penuel (Penuel et al., 2007) mentions in his study the use of voting systems in elementary and secondary schools to encourage group discussion, which is one of the elements used in the Peer Instruction method. Antti Savinainen (Savinainen, 2002) in his study examines the effectiveness of interactive methods, such as Peer Instruction, using the Force Concept Inventory test. The Peer Instruction method provides active learning for students during lessons. It gives students space and time to think about content, to speak in class with their classmates and mutually explain solutions of problems. The students' work has precise rules.

Students learning this way understand the content better than during lectures when they only listen passively (Crouch & Mazur, 2001).

The Peer Instruction method still has an important role in Mazur's courses. It is used in Learning Catalytics, which is part of AP50 course (Harvard.edu, 2016), and is named after an interactive tool for collecting students' responses (Pearson, 2016).

This research aims to map out a way to convey the benefits of Peer Instruction to Czech teachers while at the same time changing the existing lessons as little as possible. On the case of using the method at upper secondary school it is showed which barriers teacher must overcome or what the teacher considers to be easy, as well as the advantages and disadvantages connected to the use of this method from the teacher's point of view.

Research includes the investigation of what instruments the teacher prefers to collect students' responses, how to create groups for discussion or how many ConcepTest questions the teacher plans to include in one lesson, etc.

The goal of the research is not an evaluation of the method's effectiveness or the development of student knowledge in the field of physics. Research objectives require detailed examination of lessons, analysis of interviews with the teacher, etc., so a qualitative research, particularly a case study, was chosen.

The second section describes the following: basic principles of the Peer Instruction method, research questions, research design, researcher, teacher and classes used in the study, means of collecting data, source of ConcepTest questions suitable for the method and the way of collecting student responses. The third section provides a summary of results and the fourth section their discussion.

2 Experimental

2.1 Description of the Peer Instruction method

Peer Instruction is a learning method which activates students. The method gives students space to think during classes, students can discuss their solutions with other classmates and connect this way just acquired knowledge with already known facts. The method has a specific structure. At the beginning the students answer a ConcepTest question (or ConcepTest-short conceptual question). They answer individually, for example using an electronic voting system or flashcards. Second step is a discussion in groups of three to five students. The discussion is effective when during the individual round 30 % to 70 % students' answers were correct. The task of the students in a discussion is to argue why they chose their answer and ideally find the correct solution together. The method got the name Peer Instruction after this part because students teach each other in the groups. The discussion is followed by a second answering of the same question. This step is also important for students because they have to realize whether they changed their mind during the discussion or not. The last step is explanation of the correct answer (Mazur, 2014). You can find more information about the method online at (Schell, 2016) or in Czech at (Šestáková, 2016).

The Peer Instruction method is used worldwide as a substitution to lectures in university courses. Students in these classes are supposed to read particular chapter of a textbook before going to the class, in class they work with received information.

2.2 Research questions

The main research question of the study was: How is the Peer Instruction method implemented into physics teaching at upper secondary Czech school?

Particular research questions were focused on

- organization of lessons
  - appropriate number of questions for a lesson
  - creating groups of students for discussion
  - choosing a voting system
  - following steps of the method
  - organization of seats

- emotions and students' opinions on the method
- teacher's opinions
  - advantages and disadvantages connected to the method
  - what obstacles must be overcome by the teacher and what the teacher considers easy

2.3 Research design

Research objectives require detailed examination of lessons, analysis of interviews with the teacher, etc., so a qualitative research and a case study as a research plan was chosen. The case is the teacher and her implementation the Peer Instruction method to her classes (Švaříček & Šeďová, 2007).

2.4 Researcher

The researcher of this study is also the author of this paper. She graduated from the teaching of mathematics and physics. She has been studying Peer Instruction intensely since 2009, this method is the main topic of her doctoral studies. She uses this method and also elements of inquiry-based learning, for example from Project Heureka (Dvořáková, 2014) in physics at a lower secondary school. She is an active participant of Czech and international conferences on physics education; she leads workshops for teachers about Peer Instruction. She spent four months in Mazur Group at Harvard University working with the author of Peer Instruction professor Eric Mazur.

2.5 Teacher and classes

The teacher in this study had to meet two criteria, interest in integrating the method into teaching and interest in involvement in the research. There were more teachers who met these two criteria. Moreover, chosen teacher actively participated on seminars for developing her knowledge and experience with the method from her own initiative repeatedly. Her attitude to the research was open, which helped to get important data.

She also managed to overcome initial problems and despite the successful integration of the method she maintained perspective and in addition to the benefits she could articulate disadvantages and barriers associated with the method. Therefore she was chosen as a suitable case of successful integration of the method.

The teacher in this study is a 43-year-old woman, an active participant of conferences for physics teachers. She graduated from the teaching of mathematics and physics and she has been teaching physics and mathematics at the same upper secondary school since 2006. She was informed about the method for the first time at the seminar "How I teach physics" in October 2009. Then she spontaneously created flashcards and tried to use the method in her classes. She heard about the method again at the "Physics Teachers' Invention Fair" conference in 2011 and 2012 where she expressed an interest to participate in this study. She learnt more about the method during "The Heureka Workshops" conference in 2012 and 2014 during 90 minutes workshops, where she had, for example, an opportunity to try the role of a student in this method. Other source of her learning about the method was reading websites (Šestáková, 2016) and discussion with the researcher. She has also

been using elements of inquiry-based learning, for example from Project Heureka (Dvořáková, 2014).

The research results based on observations and students' opinions come from the school year 2014/2015. The teacher included the Peer Instruction method during the topic of thermodynamics using electronic voting system in the school year 2013/2014. In the school year 2014/2015, when the research ran, she used the method in the topic of electricity and magnetism with paper flashcards in two classes on upper secondary school. The first one was the third year of four-year study program and she taught a whole class (28 students). The second class was the seventh year of eight-year study program and she taught so-called "cut class" (one class divided into two groups, 13 and 16 students). Students in both classes were 17 to 18 years old. Participating classes were of the field of general studies. The teacher used the method during four months in six lessons, all observed by the researcher.

The goal of using the method in this study was to find the way how to convey the benefits of Peer Instruction while changing the existing lessons as little as possible. Therefore, during the study students did not read any material before class and the method was not used in the long term as the only way of teaching.

2.6 Collecting data

Before using the method in class the teacher fulfilled a questionnaire which identified how she and her students worked during physics lessons, what the teacher knew about Peer Instruction and what expectations she had of the lessons. Before every lesson there was an email communication between the teacher and the researcher regarding the preparations of lessons to map how the teacher planned to put the method into practice. A lesson observation was implemented to describe an authentic atmosphere of the teaching process. It was conducted in such a way to cause minimum disturbance of learning. Lessons or discussions in groups of the students were not recorded. Only some arguments of students in groups sitting closer to the researcher were registered and noted.

The observation during the particular lessons was focused on various goals of the study, e.g. following the steps of the method, organization of learning by teacher, students' reactions, planning lessons and comparison with real realization, etc.

Lessons were followed by an interview with the teacher to give her an immediate feedback which helped her improve the implementation of Peer Instruction and by an email communication.

At the end of the research students' opinions on learning in this way were collected by a questionnaire (Appendix). The questionnaire with three questions was given to all students during the last lesson. Students could choose and write one answer to each question and they could add any comments. Collecting of data was anonymous, all 50 present students handed in their responses (7 students were absent, 2 of 50 students did not answer to Question no. 2).

2.7 Resources of ConcepTest questions and collecting responses

ConcepTest questions used in classes were chosen with respect to the studied topics from the database designed for Peer Instruction (Šestáková, 2016), for example see Figure 1, or from commonly used collections of problems in upper-secondary-

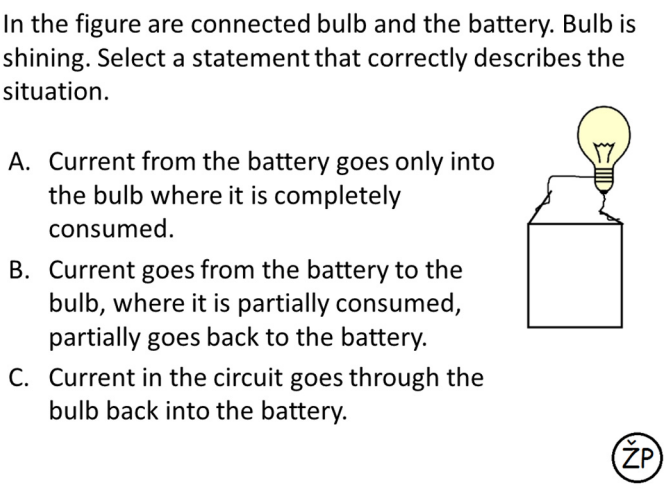

Figure 1: Example of ConcepTest questions used in the study (Šestáková, 2016)

school physics with closed multiple choice questions. The questions which were not specifically designed for the method were carefully selected.

Electronic voting system available during the study to collect students' responses was composed of simple devices allowing to send A–F replies. Students could change their answers within the time limit, devices did not allow to send multiple responses. Paper flashcards used in study were created by the teacher. Black letters were printed on colored paper and laminated. Size of each card was A6.

3 Results

Here is a summary of the research results.

(teacher) in the following text means teacher's opinion, (student) is an expression of one of the students. Comments of the researcher are in italics. The source of the information is written at the end.

3.1 Timing, appropriate number of ConcepTest questions

- The teacher expects that ConcepTest questions will be easy for students, more ConcepTest questions in class will be discussed.

(teacher) "These ConcepTest questions are easy, I could pose them in the third year (*of eight-year program*). It will be only repetition for you." (From lesson observation, mentioned at the beginning of the work to students of seventh year of eight-year program.)

(teacher) "They do not understand it. I thought that this must be already known to them." (From an interview after the lesson, feedback about the lesson.)

(teacher) "Six ConcepTest questions planned for one lesson (*45 minutes*) is too many. Next time I am planning one or two ConcepTest questions." (From an interview after the lesson, feedback about the lesson.)

- It is useful to implement the method to the proper part of learning.

(teacher) "It has been a longer time since we studied this part of topic ... and only now I can see that they did not understand it. It would be better to use the method immediately after the introduction of a new topic." (From an interview after the lesson, feedback about the lesson.)

3.2 Creating groups

- The teacher creates groups according to the students' answers.

The teacher created groups of students for discussion according to the letters on flashcards showed during the first answer so that in one group there were not only students with the same answer. *If there were only students with the same answer in one group, there was no reason to discuss their solutions, because they agreed with each other.* Changing seats lasted about 20 seconds. (From lesson observation.)

- Gender balance in group has a minimum impact on the discussion.

6 mixed and 18 homogenous groups of student were observed, students in all groups worked actively, there was not a visible difference. Only in two girl-groups it was observed that they only said "I do not know" and they did not discuss the solution any more. (From lesson observation.)

3.3 Choosing a voting system

- The teacher prefers flashcards to electronic voting system.

(teacher) "The first reason (*why she prefers flashcards prior to electronics*) is price but the very next one is immediately visible answer from everyone useful for grouping students. I need to solve the situation in the class, I do not need long term statistics now." (From an interview after the lesson, feedback about the lesson.)

3.4 Following steps of method

- The teacher improves herself in instructing students.

The teacher explains how to work to students during lessons better: "During the first answering answer by yourselves, try to find an explanation." (From lesson observation.)

(teacher) "When nobody speaks up, we go on. It means you do not need more time to think individually about solution." (From lesson observation.)

- Students should have enough time to think after reading the ConcepTest question.

The teacher reads aloud the ConcepTest question displayed by projector on the board, then she tries to hasten the work and asks students to answer immediately after the reading. (From lesson observation.)

- The teacher checks the time during following lessons.

The teacher counts thirty seconds using a watch, during that time she does not communicate with students, she gives them time to think about the answer to the ConcepTest question before the first answering. (From lesson observation.)

- Showing answer by flashcard during the first answering affects the active students' work.

6 out of 50 students admitted that with cards they decided to reply and without it they did not (Answer A, Question no. 1, Appendix) and other 6 students in the comments added that they decided to answer in both cases, but with cards it was more motivating (Answers B, D, E, Question no. 1, Appendix). Responses of all students are in the graph in Figure 2. (Students' opinions from questionnaire.)

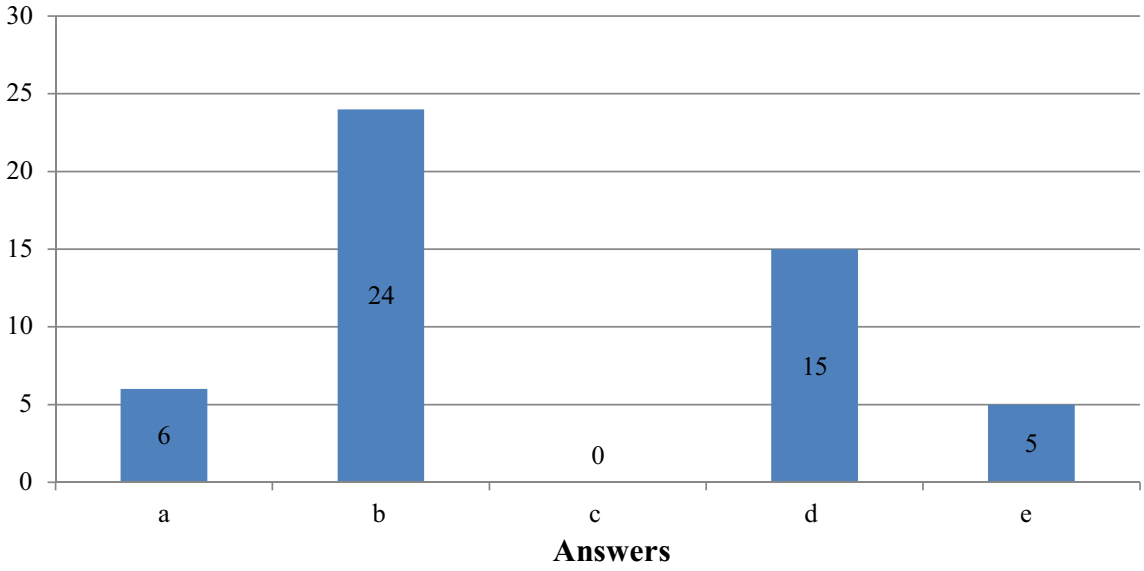

Figure 2: Does showing answers by cards before discussion affect students' work? Question no. 1, Appendix

Students' comments

(Letters in brackets are answers to Question no. 1, Appendix)

"I thought about the arguments deeper when showing the answer on flashcard." (D)

"Raising the card definitely forced me to think about it more than if I did not have to raise the card." (D)

"In the second case (*with card*), I thought about it more." (B)

"Raising the card forced me to at least try to think and come up with something." (E)

"The card does not affect judgment." (B)

"I think that with higher pressure — raising a card, I was trying to think more." (B)

"I went out on a limb — It motivated me more." (D)

"But when I could not understand the question at all, it forced me only to guess." (A)

"Raising the card was too forced, it worsen the quality of work." (D)

"In both cases I decided by myself." (B)

"It does not matter whether we answer using cards, but how the teacher explains it. And it usually does not affect each other." (D)

"I do not know if it helped me, it is great that we practice, but cards are according to my opinion useless." (D)

(Students' opinions from questionnaire.)

- The teacher should not interfere with students during discussion.

The teacher walked through the class during discussion. When she joined some group, students stopped talking, they listened to her, eventually spoke only one student, probably the one who was sure of his/her answer. (From lesson observation.)

- The teacher sometimes omits the second answering.

In some cases teacher omits the second answer and after group discussion moves to the explanation, which takes a form of discussion in whole class, when different students justify different answers. (From lesson observation.)

(teacher) "When I first used the method (*last school year*) we probably worked incorrectly. I let them answer for the first time and discuss in groups, then we justified their solutions together." (From an interview after the lesson, feedback about the lesson.)

- Students can justify their answer by experiment.

(student) "It is the same!" (A reaction to building a circuit that confirmed the right solution. From lesson observation.)

- The teacher plans to improve the way of explaining the solution.

(teacher) "Next time I should distinguish better when I only repeat a student's idea and when I certify the correct answer." (From an interview after the lesson and a discussion about the student questionnaire.)

3.5 Emotions and students' opinions on the method

- The method allows students to experience positive emotions associated with finding the correct solution during the lesson.

(student) "I knew that." (A comment to the solution, from lesson observation.)

There are happy smiling girls who chose the correct answer, but during the lesson they were looking forward to next lesson of social science. (From lesson observation.)

- The method gives students an opportunity to think about questions that they would not otherwise consider.

(student) "So the statement that "an electricity is consumed" is a nonsense." (Linking the topic to the commonly used phrase in Czech language, from observation of lesson.)

(student) "Is the button metal?" (Part of the discussion about a part of a bulb, from lesson observation.)

- Student expects "ready truth" in lesson.

(student) "We convince others about misconceptions, someone tells me his opinion, which may not be true but I can trust it. As a repetition it is fine, but we should be sure about the topic, now we only confuse each other." (From the student questionnaire.)

- The method helps students to understand the topic.

30 out of 48 students answered (Question no. 2, Appendix) that they understand the topic thanks to the method better than during other lessons, 2 students understand less and 16 as well as during other lessons. (From the student questionnaire.)

- Students like learning using this method.

32 out of 50 students answered (Question no. 3, Appendix) that they like the lesson more than usually, 3 students like it less and 15 as much as usually. (From the student questionnaire.)

Students' comments

(Letters in brackets are answers to Question no. 2 and Question no. 3, Appendix)

"I get the topic more 'under the skin', when not only the teacher solves the problem at the blackboard." (A, A)

"Thanks to the discussion and thorough explanation I understand the topic better." (A, A)

"It's nice when we give to concrete questions concrete answers, compared to regular lessons, when it is the theory that I cannot imagine." (A, A)

"I am more confused by opinions of other classmates. Although I am confused, it is fun." (B, A)

"I do not understand as well as usual because I do not understand physics at all." (C, C)

"It sways the opinion more." (C, C)

"A proper explanation must follow, not only a discussion." (A, A)

"Students unfortunately convince others about misconceptions, but it is fun." (C, A)

"I understand the topic more, I like it more but on the other hand it takes too much time." (A, A)

"But from two questions I will not understand all topic." (A, A)

"I do not like it as much as usually." (C, C)

"I like getting to know how my classmates think." (A, C)

"I think that it is good when during a competition more students are involved than usually. It means more opinions and more points of view." (C, A)

(Students' opinions from questionnaire.)

(Note from teacher in reaction to student questionnaire: "The method was used at the end of the topic to repeat, not at the beginning of a new topic.")

3.6 Size of a class

- There are differences in the use of the method in whole and cut class.

More students speak in whole class at the same time, so during the discussion it is noisier than in cut class. Even in whole class the teacher was able to move students into groups (in smaller area, not over the entire class). Compared to cut class the whole class seemed to be more passive, maybe confused. Students answered and discussed, but in larger number of students it was not possible to observe the enthusiasm and involvement of individuals such as in a cut class. (From lesson observation.)

3.7 Organization of seats

- The arrangement of seats affects discussion.

Figure 3 shows an inappropriate placement of chairs at the desk. Student one was speaking during the discussion. Student two was observing an explanation of student one, student three had to bend forward to hear and student four had stand up to hear the explanation. (From lesson observation.)

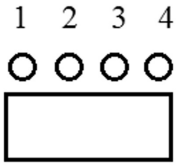

Figure 3: Inappropriate placement of chairs at the desk

3.8 Teacher's opinions

"It is great that students are active and have the possibility to think and speak about the problem, which could deepen their knowledge of physics and develop their communication skills."

"At the beginning it takes time to explain students how they should work, when they are allowed to communicate with classmates and when communication is not allowed."

"It was not easy for me to be quiet, I wanted to help them (*students*), to hasten their work."

"Some student questions (*posed thanks to ConcepTest questions*) were really unexpected for me, I had to improvise."

"I do not know whether students really discuss the ConcepTest question or something else."

"With electronics I must install a program and learn to work with it, questions must be set for collecting the responses."

"I can easily see which answer students choose, because flashcards are colored."

(From feedback after the lesson via email.)

(*Teacher's other comments are mentioned in previous subchapters.*)

4 Discussion

4.1 Timing, appropriate number of ConcepTest questions

The teacher, after the experience with the method, decided that in the future she will use only 1–2 ConcepTest questions at most during one lesson. This fact is consistent with the recommendation for using the method, because the cycle with small lecture and one ConcepTest question usually takes at least 15 minutes (Mazur, 2014) and our lessons commonly have a length of 45 minutes.

Although ConcepTest questions seem to be simple for an experienced teacher, they are often posed the way that students had to think about the solution and the solution is not obvious for them at a first glance. ConcepTest questions also focus

on common students' misconceptions. Therefore, even for "simple" ConcepTest questions, it is not possible to significantly accelerate a solution.

We found out that it is appropriate to use the method after the explanation of a new topic when students are already informed about the topic and they should be able to answer the ConcepTest question.

Thanks to the ConcepTest question students have an opportunity to realize whether they understand the explanation correctly and whether the explanation is consistent with their opinion, etc. This fact is also consistent with the recommendation for using the method (Mazur, 2014).

Therefore suitable rate of using the method in these conditions is about once a month.

4.2 Choosing a voting system, creating groups and gender balance in group

The research described in (Lasry, 2008) shows that the use of flashcards and electronic devices is equally effective for the method. This case study shows that the teacher prefers flashcards. The reasons are that when using electronic voting system the teacher must install a program and learn to work with it, questions must be set for collecting the responses, etc. Using flashcards the teacher only brings sets of cards to the class. If the teacher is not also a researcher, it is not important for him/her to store the data about students' answers. Moreover, the price of electronic voting system is much higher than the price of flashcards. Another advantage of flashcards in relatively small classes of students is the fact that the teacher can immediately, after the first voting, see whether students sitting at the same desk have different answers and so the teacher can very quickly create groups for the discussion. It was not clearly established whether it is better to create mixed groups (boys and girls together) or homogeneous for the discussion.

4.3 Following steps of method

Each step in the method has its important role so therefore the teacher has not to omit any of them. Students must know how they should work, when they are allowed to communicate with classmates and when communication is not allowed. Students must have enough time to think about the answers after posing the ConcepTest question.

24 % of students in the questionnaire noted that showing an answer by flashcard encourages them to think about the answers more than when students have only to think about the answer, without any expression of it.

This study showed, that the teacher should not get involved in students discussions because then students stop working. There could be different students in other classes who would not be able to work in a group. In this case help of teacher can be welcomed. The teacher in the group can take a role of a student and try to explain that for example answer A might be right, because (followed by his/her explanation). This way the teacher can teach students how to discuss.

It is important to keep the second answering after the discussion because every student should get an opportunity to realize whether they still agree with their first answer or whether his/her response was changed during the discussion.

If the teacher asks students to justify different responses during the solution, not only correct answer, and repeats these justifications aloud, there is a risk that

students "will believe what the teacher says, because the teacher always tells the truth". So it is important to emphasize when teacher only repeats students' answers and when explains and confirms the correct solution. It is possible to highlight the correct answer by circling it on the board.

Some answers of ConcepTest questions were verified by student experiments in class.

It is important not to evaluate the correctness of student responses. If students worked under the threat of assessment, their goal would be to find the correct answer from other students, not to think about their own opinion. This fact is consistent with the recommendation for using the method (Mazur, 2014).

4.4 Emotions and students' opinions on the method

Students have time to think about the topic during the lesson and they can discuss solutions of ConcepTest questions with classmates. All students are asked to work actively and each student gets immediate feedback to his/her work. The questionnaire shows that 62.5 % students realize that through this active approach they understand the topic better. 33.3 % respondents stated that they understand the topic as well as before. Only 4.2 %, that means two students, reported that they understand less then usually. These students are probably more willing only "to record and reproduce the solution later" than invent a solution independently.

Students evaluated learning using this method positively. 94 % students stated that they like the lesson more or the same as usually.

In questionnaire about the method students mentioned, that this way of learning takes more time and that the justification of solutions by students can be confusing.

The method is time consuming. Therefore in classes where Peer Instruction is used more often, it is usually implemented with reading study materials prior to the lesson. More about the home preparation of students can be found for example online at (Schell, 2016).

Justification of solutions by students helps them to develop critical thinking and communication skills.

Students' emotions associated with their success in finding the correct solution seemed very positive during lesson observations.

4.5 Size of a class and organization of seats

Smaller number of students speaks during the discussions in cut classes, therefore cut classes seemed to be calmer. Since the method was developed and effectively used for tens to hundreds of students in a lecture hall (Mazur, 2014), there should not be significant difference in learning gain of students between whole and cut class. The teacher has a better overview and can easily organize transfers of students between groups in smaller classes. It seems to be more pleasant for the teacher to make the first steps with this method in cut class.

The study showed that the arrangement of seats around the desk for discussion is important. If more than three students are sitting side by side in a row, students at the end of the line cannot follow the discussion because they obstruct each other's view. More appropriate arrangement is "two and two" students sitting against each other, or placement in a circle around the desk. This fact is consistent with the recommendation for using the method (Mazur, 2014).

4.6 Teacher's opinion

The teacher thinks that at the beginning it took time to explain students how to work. She was surprised that some students did not understand the topic and they were not able to answer "simple question".

It was not easy for her to stay quiet and not to help students during the work.

According to her opinion, the discussion is good for developing students' communication skills and can help students understand physics better.

It was not easy for her when she had to improvise because she got some unexpected questions.

She could not control discussions, so she did not know whether students really speak about the topic and it was not pleasant for her.

5 Conclusions

Using the Peer Instruction method for learning at upper secondary school showed how to convey the benefits of the method with the least possible change of the existing lessons. As advantages teacher mentioned room for activating the students and opportunity to develop their communication skills, reasoning and expression. Students have a possibility to think about the problem, which could deepen their knowledge of physics.

As an obstacle the teacher considers the initial time-consuming part for the explanation to students how and why they should work in the method. Also, it is not easy to manage the lesson at the beginning when the teacher improvises.

As disadvantageous teacher considers that she is not able to determine whether students really discuss the ConcepTest question in groups.

The best time for application of the method was identified the time after the explanation of a new topic when students create ideas about the new topic and integrate new material into the already studied topics, or into ideas that they bring from the life outside of school.

It is appropriate to use one or two ConcepTest questions in one 45 minutes lesson.

Colored flashcards proved to be useful for collecting responses. Students choose the card by letter; the teacher recognizes responses by color of cards. Using paper flashcards appeared as easier than electronic voting systems for the teacher. There is no need to install and study some new software. Also the teacher can immediately see the distribution of responses in the classroom, which is useful for creating appropriate groups for discussion.

It appears difficult for teacher not to interfere with the work of students, not to hasten their work and follow all steps of the method. The teacher should not pass between discussing groups because in this case students stop working and expect the teacher's advice.

Whether the teacher repeats student incorrect justifications aloud, there is a possibility that students "will believe what the teacher says, because the teacher always tells the truth". So it is important to emphasize when teacher only repeats students' answers and when explains and confirms the correct solution.

It was shown that it is possible to confirm the solution by students experiment.

Students evaluate learning by Peer Instruction positively. 62.5 % students claim that through this method they understand the topic better. 94 % students stated that they like the lesson more or the same as usually. Students evaluate positively

that not only the teacher solves problems on the blackboard but also they can see how other classmates think about the solution. Also students feel more involved in the learning process. Students evaluate negatively that this kind of work takes a lot of time and it is easier to be fooled by a wrong opinion of a classmate.

24 % of students consider showing answers by flashcards before the discussion to be motivational.

We concluded that even though the method is suitable for large groups of students, it may be useful for teachers to make the first steps with the method in a cut class. We experienced that in a smaller group of students the teacher has greater insight into whether students work and discussions are not so loud.

It was not clearly established whether it is better to create mixed groups (boys and girls together) or homogeneous for the discussion.

The study showed that the arrangement of seats around the desk for discussion is important. Students must see each other in the group, so appropriate arrangement is "two and two" students sitting against each other, or placement in a circle around the desk. Inappropriate is more than three students sitting side by side in one row.

The motivation for this case study was the fact that the method has been proven as beneficial for students. The goal of the study was to determine how these benefits can be transferred to smaller classes and younger students and describe the process of this implementation. Such an approach in connection with Peer Instruction is not so common, therefore it is not possible to compare the results with a number of other similar research studies.

During further studies at upper secondary school it would be suitable to determine whether the effectiveness of the method changes in cut and whole classes for example by comparing the increase in correct answers before and after the discussion. It would also be useful to determine the youngest age at which pupils are able to learn using this method and which benefits the method can offer them.

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Jana Šestáková, Jana.Sestakova@mff.cuni.cz
Charles University, Faculty of Mathematics and Physics
Department of Physics Education
V Holešovičkách 2, 180 00 Prague, Czech Republic

Appendix: Questionnaire for students

Question no. 1

During answering the questions in one case you showed an answer before the discussion, in the second one you did not. How did that affect your work? Did showing the answer by flashcard force you to think of the answer?

a) Using the card I chose the answer, without it I did not.
b) In both cases I chose the answer.
c) In either case I did not choose the answer.
d) Choosing the answer depended on the question; it did not matter if I raised my card or not.
e) Other answer: (write)

Question no. 2

When working "with flashcards" (answering by myself, discussing solutions with classmates, answering again)

a) I understand the topic more than usually.
b) I understand the topic less than usually.
c) I understand the topic as well as ever.

Question no. 3

When working "with flashcards" (answering by myself, discussing solutions with classmates, answering again)

a) I like the lesson more than usually.
b) I like the lesson less than usually.
c) I like the lesson the same as usually.