

Applying Peer Instruction to Teaching Physics in Grade 7: Impact on Student Achievement and Misconceptions

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Abstract Considering the challenges students face in learning physics, exploring the use of peer instruction in primary school could provide teachers with a valuable new teaching strategy. This research encompassed teaching the topics Balance and Energy, with the aim of examining the impact of peer instruction on student achievement and its role in reducing misconceptions. The respondents were 132 Grade 7 students (13 years old) from two primary schools in Subotica, Republic of Serbia. A pedagogical experiment was conducted with an experimental and control group, using a pretest-posttest design. Statistical analysis included the Mann-Whitney U test, independent samples *t*-test, paired samples *t*-test, and calculation of *n*-gain and the percentage of students understanding the concepts. The results showed that the application of peer instruction leads to better student achievement (the *t*-test results showed a significant difference between the experimental and control groups at the end of the pedagogical experiment, $t = -3.86$, $p < 0.001$), however does not spontaneously lead to a reduction in misconceptions (Mann-Whitney U test showed no significant difference in misconceptions between groups after the pedagogical experiment, $U = 721.50$, $p = 0.432$). Additionally, this teaching method is equally effective in fostering deeper learning and engagement for both genders.

Keywords alternative conceptions, peer teaching method, physics performance, understanding

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1. Introduction

In the Serbian education system, primary education comprises eight grades and includes students aged 7–15. Therefore, students in Grade 7 (typically 12–13 years old) are classified as primary school students. Physics is introduced as a separate subject in Grade 6 (age 12), while basic concepts are covered earlier through integrated subjects. PISA (Programme for International Student Assessment) results [OECD, 2019] showed that 15-year-old Serbian students had below-average competence in science, indicating insufficient preparation for critical thinking and problem-solving in high school. To improve this, foundational knowledge and misconceptions need to be addressed early in education.

Various studies have provided valuable insights into effective strategies for addressing students' misconceptions. For example, research has shown that engaging students in hands-on experiments, interactive lessons, and discussions can effectively challenge and correct misconceptions [Adilah, Ngazizah, Nurhidayati, 2025; Eryilmaz, 2002; Pacaci, Ustun, Ozdemir, 2024; Resbianoro, Setiani, Koranto, 2022]. Other studies have focused on using conceptual change strategies to help students recognize and overcome incorrect ideas about fundamental physics concepts [Ding et al., 2024; Duit, Treagust, 2003; 2012; Posner et al., 1982]. Some researchers suggest that dialog-based approaches may be effective in addressing misconceptions [Buteler, Coleoni, 2016; Gafoor, Akhilesh, 2010; Leinonen, Asikainen, Hirvonen, 2017; Pulgar, Spina, Ríos, 2020]. However, the potential impact of peer instruction on reducing misconceptions, especially in primary education, is underexplored. Specifically, evidence is lacking on whether peer instruction encourages students to question their understanding, leading to spontaneous reduction of misconceptions. This research aims to fill the above gap by examining the effectiveness of peer instruction in improving the achievement of Grade 7 students in physics, enhancing their understanding and fostering the spontaneous reduction of misconceptions in physics without directly addressing them.

Peer instruction is an interactive teaching method where students discuss and clarify misunderstandings in physics through paired conversations. Working together, they exchange ideas, identify ambiguities, and help each other better understand the topic [Haataja et al., 2022]. During discussions, students argue why they believe their answers are correct and challenge their peers' answers, which may reveal gaps in their knowledge and dissatisfaction with it. This process helps students recognize their misconceptions. Even if both students in a pair hold different misconceptions, their exchange can be mutually beneficial. By challenging each other, they may realize that neither fully understands the concept yet, prompting collaboration toward deeper, more accurate understanding.

2. Misconceptions in Physics

The idea of misconception refers to incorrect understanding of concepts, specifically beliefs inconsistent with scientific explanations [Tippett, 2010]. Misconceptions may arise from misinterpretations of daily experiences, inaccurate media information, everyday language, or cultural traditions, becoming ingrained and creating learning barriers [Guerra-Reyes et al., 2024; Kulgemeyer, Wittwer, 2023]. They are strongly resistant to change, even with structured teaching [Tippett, 2010]. Two main strategies address children's misconceptions in science. The first one corrects faulty beliefs by introducing accurate concepts, while the second one encourages students to engage with their misconceptions, using them as a basis for deeper learning [Pine, Messer, St. John, 2001]. Conceptual change offers a pathway to overcoming misconceptions by transforming students' initial beliefs into scientifically valid conceptions. However, facilitating this change requires more than simply presenting correct information. It involves actively engaging students in a process of reflection and comparison, where they evaluate their existing ideas against new, more coherent scientific explanations [Duit, Treagust, 2012]. Correcting misconceptions requires an active process of reconstructing ideas, which happens when students find new concepts more convincing [Duit, Treagust, 2012; Posner et al., 1982]. Cognitive conflict, when students' established beliefs are confronted with new information, plays a key role in this process [Limon, 2001]. While dissatisfaction with their own understanding may cause anxiety, conceptual change often occurs, though it can be superficial in some cases [Lee, Byun, 2012].

Research indicates that misconceptions are an inherent part of the learning process for many physical phenomena and are often persistently present among both students and teachers [Kikas, 2004]. In some cases, science teaching itself can reinforce misconceptions [Duit, Treagust, 2012]. Ignoring them only perpetuates the problem across generations [Letić, 2017].

Students often struggle with grasping basic concepts of static equilibrium, whether in experiential or academic contexts [Newcomer, Steif, 2008; Ortiz, Heron, Shaffer, 2005; Palmer, 2001]. Their understanding of equilibrium and stability is further complicated in the context of moving reference frames. For instance, students often struggle to differentiate stable and unstable equilibrium, particularly when systems are analyzed in inertial or non-inertial reference frames [Canu, de Hosson, Duque, 2016]. Many students confuse constant velocity motion with equilibrium [Halim, Yong, Meerah, 2014] and fail to recognize neutral equilibrium [Roncato, Rumiati, 1986]. Additionally, they often mix scientifically accurate and inaccurate concepts of static equilibrium [Palmer, 2001], and the concept of center of gravity further complicates their understanding [Roncato, Rumiati, 1986]. Despite using force and moment summation in explanations, students inconsistently apply these principles [Newcomer, Steif, 2008]. Tenzin [2024] showed

that diagrams can aid in understanding balanced and unbalanced forces, while Canu, Duque, de Hosson [2017] demonstrated that active learning can address misconceptions about equilibrium. Misconceptions are also common in buoyancy, with various strategies proposed to address them [Buteler, Coleoni, 2016].

The concept of energy is often misunderstood, with students displaying low comprehension [Dega, Govender, 2016; Dega, 2019]. Misconceptions about energy and force are common at all education levels, with students failing to clearly distinguish between the two concepts [Yuruk, 2007], confusing kinetic energy with momentum [Bryce, MacMillan, 2009], or struggling to understand the relationship between energy, power, and conservation [Goldring, Osborne, 1994]. Other misconceptions include misunderstandings about work [Anggrayni, Ermawati, 2019], applying energy and momentum conservation incorrectly in real-world scenarios [Singh, Rosengrant, 2003], and overly generalizing changes in energy [Dega, Govender, 2016]. Beliefs that energy is exclusive to living things, that objects at rest have no energy, and that energy is created by activity are also common [Meiring, Webb, 2012]. These misconceptions hinder deeper understanding of the concept of energy. Since traditional teaching appears insufficient for fostering deep understanding of the concept, various authors seek more appropriate strategies. Various instruction strategies, such as the 'idea factory', are designed to more effectively address misconceptions and promote deeper comprehension of energy (e.g. [Koma et al., 2021]). For example, Fortus et al. [2019] proposed a new approach that improves the understanding of the concept of energy compared to the traditional method, regardless of students' prior knowledge. This new approach to teaching about energy eliminates the need for discrete energy forms, emphasizing the fundamental connections among energy, systems, and the fields that mediate long-range interactions.

3. Peer Instruction

Peer Instruction (PI) was devised by Harvard University professor Eric Mazur, the author of the manual *Peer Instruction: A User's Manual* [Mazur, 1997]. The major focus in the PI method is discussion, and in order to provide time for discussion between paired students, the teacher's role in a PI class is less detailed than it would be in teacher-centered instruction (traditional teaching). Therefore, the students are given the task of familiarizing themselves with the topic in advance, before the class, using the textbook and notes. At the beginning of the class, the teacher administers a quiz to assess the students' understanding of the pre-read material.

This is followed by the teacher's ten-minute presentation during which he or she highlights the most important points of the lesson. Then, the teacher gives each student the same Concept Test, consist-

ing of multiple-choice questions. Despite the name, the Concept Test does not serve to evaluate knowledge, but rather represents teaching material with short conceptual questions.

After reading the question, students independently think about it and record their answers. If 30 to 70% of students select the correct answer (Mazur did not explicitly state these percentage values; however, they were adopted for the purpose of our research), PI is applied: students with differing answers discuss their reasoning in pairs, aiming to 'convince' each other. Afterward, students record their answers again. To ensure understanding, one or more students (or the teacher if needed) explain their reasoning and provide the correct answer.

If less than 30% of students answer correctly, the teacher revisits and clarifies the concept to which the question refers, focusing on difficult areas. Students then re-record their answers (as if they were answering from the beginning), so the following procedure is the same as described earlier.

If after reading the question, more than 70% of the students answer correctly, it is considered that the students understood the concept to which the question refers. Then, a student or students provide the answer and explanation, with the teacher's help if needed, and the class moves on to the next question. The procedure is the same for all questions.

Most of the studies involving PI refer to research with university students, while less research has been done on primary school students [Woo, MohdRameli, MohdKosnin, 2022]. Woo et al. conducted a meta-analysis on the impact of PI on learning in both cognitive and affective domains, including primary, secondary, and university students. The research mainly focuses on cognitive aspects, such as student achievement and problem-solving skills.

The PI has been studied with primary school students in various STEM subjects, but research focusing on its use in primary physics classes is rather limited. Howe, Tolmie, Rodgers [1990] showed that PI improves primary school students' understanding of physics topics like floating and sinking. A case study in Slovenia with 9–10-year-olds also demonstrated advancement in knowledge of physics [Pavlin, Čampa, 2021]. A study that included students in the 6th grade of primary school (aged 11–12) in Turkey [Sencar Tokgöz, 2007] showed that PI approach leads to higher achievement and retention rates than does traditional teaching. A study of teaching Grade 9 students (aged 13–15) about motion and forces conducted in a Louisiana school demonstrated that in PI-taught classes student achievement was higher than in the traditional classes [Harvey, 2013].

4. Research Objective and Questions

PI is rarely used in primary school and, to the best of our knowledge, there is no research on its application in teaching physics to 7-graders. The aim of this research is to examine the impact of applying the

PI method in teaching physics on the achievements and misconceptions of Grade 7 students from two primary schools in Subotica, Republic of Serbia, especially in two teaching topics: *Balance* and *Energy* (more specifically, *Work, power, and energy*).

In order to realize the stated aim, the following research questions are proposed:

RQ1 — How does the implementation of PI in physics classes affect the achievement of Grade 7 students in physics?

RQ2 — What misconceptions related to the topics *Balance* and *Energy* are most common among Grade 7 students?

RQ3 — How does the implementation of PI in physics classes affect the ability of Grade 7 students to overcome difficulties in understanding concepts related to the topics *Balance* and *Energy*?

5. Methods

5.1. Research Design

A pedagogical experiment was conducted with a control group (CG) and an experimental group (EG). The EG applied PI as the experimental factor, while the CG continued with their regular traditional teaching, which was used in both groups before the pedagogical experiment. Student achievement was measured, and misconceptions were identified at three different time points during the study: before, during, and after the experiment. The research was conducted from the beginning of February to the middle of May 2024.

5.2. Research Sample

The research involved 132 7th graders (aged 12–13), who had knowledge of physics from the previous grade. The participants were from two primary schools in Subotica, Republic of Serbia. Six classes took part in the research, which was approved by the Ethics Committee of the University of Novi Sad, Faculty of Sciences, and the school management. All students were informed about the research and participated voluntarily, with their privacy respected¹.

Four out of six initially tested classes were selected for the pedagogical experiment (80 students). Since the classes were pre-formed within the educational system and students could not be transferred between them for the research, two classes were excluded as their competence in physics was significantly different from that of the other classes. Two classes formed the CG (39 students) and two other classes constituted the EG (41 students).

¹ Before the survey began, participants were informed about the data collection process, the type of data processing and the individuals who would have access to the data as part of the project. Participation was voluntary and anonymous. Participants had the option of withdrawing from the research at any time without giving reasons and without incurring any disadvantage. An additional approval was obtained from the Ethics Committee of the University of Novi Sad, Faculty of Sciences (No. 0601-91/24-2).

5.3. Research Instruments

Student achievement was evaluated using knowledge tests created for research purposes, and additional diagnostic tests were developed for identifying students' misconceptions.

5.3.1. Knowledge Tests

Three knowledge tests were developed as research instruments. The first test (Test 1) focussed on the topics that students had previously studied in their physics lessons, assessing their basic understanding of fundamental physics concepts. The second test (Test 2) referred to the topic *Balance*, which was covered during the pedagogical experiment. Finally, the third test (Test 3) evaluated the students' understanding of the topic *Energy*, also taught during the pedagogical experiment. These tests were reviewed by an expert team consisting of three university professors, three teachers, and a school counsellor, who confirmed the validity of the tests based on clarity, relevance, and alignment with the research aim. Additionally, students from a separate Grade 7 class, not included in the study, completed all the tests and found them clear, appropriately challenging, and easy to understand. Each test contained 11 questions, varying in type and complexity. The test included a combination of matching questions, essay-type questions, open-ended questions, alternative choice questions, multiple-choice questions, and calculation problems. These varied question types were designed to assess different levels of student understanding, from basic knowledge recall to higher-order critical thinking and conceptual analysis.

The reliability of the knowledge tests was determined using Cronbach's alpha coefficient. Cronbach's Alpha coefficients for the tests are .71 for Test 1, .76 for Test 2, and .81 for Test 3.

5.3.2. Diagnostic Tests for Identifying Misconceptions

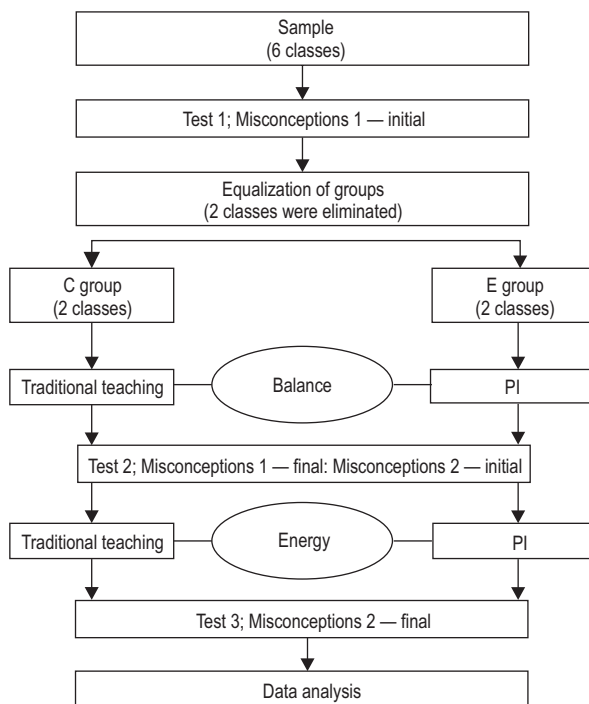
Two two-tiered diagnostic tests were developed for the identification of misconceptions — *Misconceptions 1* and *Misconceptions 2*, for teaching the topics *Balance* and *Energy*, respectively. The content and structure of the tests were carefully reviewed by an expert team. The team assessed the most common misconceptions in the literature and, guided by prior knowledge and experience, determined which misconceptions should be targeted and which distractors were most likely. These experts ensured that the conceptual focus of the tests was valid and aligned with the intended learning outcomes, ensuring that the tests effectively addressed relevant learning challenges. Additionally, similar to the knowledge tests, students from a separate Grade 7 class excluded from the study completed the diagnostic tests and provided feedback on their clarity and appropriateness. Since these tests were designed to diagnose specific misconceptions, standard reliability measures like Cronbach's alpha were not applicable as the internal consistency across items was not relevant. Instead, the focus was placed on accurate identification of particular misconceptions.

Both diagnostic tests consist of ten tasks, and for each task, students must choose the correct answer to the question and the reason behind their decision, with multiple-choice options for both. Sample questions are shown in Figures 2 and 3. Depending on the answers to both the question and reason, the test categorizes the students' understanding into one of the three outcomes: (1) if both the answer and the reason are correct, the student understands the concept; (2) if the answer is correct but the reason is incorrect (or vice versa), the student has a misconception; and (3) if both the answer and the reason are incorrect, or if there are no answers provided for either or both, the student does not understand the concept.

5.4. Research Procedure

Both CG and EG were subjected to an initial physics knowledge test (Test 1) before the pedagogical experiment and two more tests, Test 2 and Test 3, were conducted after teaching the topics *Balance* and *Energy*, respectively. The students took each of the tests for identifying misconceptions twice. Specifically, they completed the first test before (*Misconceptions 1 — initial*) and after (*Misconceptions 1 — final*) studying the topic *Balance*, and the second test before (*Misconceptions 2 — initial*) and after (*Misconceptions 2 — final*) being taught about the topic *Energy* (Figure 1).

Figure 1. Research procedure



Equalizing the groups was achieved by selecting two classes for the EG and matching them with two very similar classes in the CG. The two teachers who were the regular physics instructors for these classes were assigned to the CG and EG. Each teacher taught one class from the CG and one from the EG. Both CG and EG were studying the same coursebook units. In the CG, traditional teaching methods were used, while in the EG, PI was applied. The teachers were trained to apply the PI method in the EG as PI is not commonly used in schools in Subotica, making this training essential for the effective implementation of the pedagogical experiment. The PI training was conducted over eight sessions, each lasting one hour, within one month. The primary focus of the training was to equip the physics teachers with the necessary skills for implementing PI in their work. This included familiarizing them with the core concepts of PI, how the lessons are structured, and the roles of both the teacher and students during PI. Additionally, the training involved the teachers' active participation in preparing instructional materials, selecting appropriate content, deciding how thoroughly the content should be covered, and developing Concept Tests necessary for the successful implementation of PI. The researchers monitored the process, helping the teachers to prepare for the lessons and consulting them as necessary before and during classes.

All lessons were conducted during regular class periods. The research involved 24 class periods of physics instruction, in line with the curriculum, with students having Physics twice a week. Notably, classes were divided into two types: a 'new content' class, where most of the teaching concepts were introduced for the first time, and a 'review' class, which followed a 'new content' one and focused on consolidating and reinforcing the concepts learned. Each class period lasted 45 minutes, and each lesson was covered within two class periods — one for the 'new content' (a new content class) and the other for the 'review' (a review class). A total of eight lessons were taught, with four within the topic *Balance* (The action of two forces on a body — resultant force; The concept and types of equilibrium; Lever and moment of force; Archimedes' law, floating and sinking of bodies) and four within the topic *Energy* (Mechanical work; Kinetic and potential energy; Law of conservation of mechanical energy; Power). The remaining class periods were allocated for student assessment, which included evaluating their knowledge and understanding as part of the data collection process.

5.4.1. Control Condition

In the CG, the traditional approach was used, which, in addition to traditional teaching for the entire class, involved solving calculation problems, conducting demonstrations, and performing experiments in small groups of two or three students. The students actively participated in all activities: discussing the physics concepts being taught, independently solving calculation problems, and observing experi-

ments while drawing conclusions. The students were constantly encouraged to actively participate in the discussion and give conclusions, whereby their activity could result in higher grades.

5.4.2. Experimental Condition

Before the classes with PI began, the students were informed about all the important details related to these classes. Compared to the originally proposed classes with PI [Mazur, 1997], explained in the *Peer Instruction* section, in this research the classes in which PI was applied had certain changes. PI was applied only in the review classes, which followed the new content classes. The original concept of this method meant that the students read the material intended for the class in advance and took a quiz at the beginning of the class to determine the level of student understanding of the material read. However, in this research, there was no need for a quiz because the students learned the intended theoretical concept entirely in the new content classes, which preceded the classes with PI. Thus, this teaching method was used as an innovative approach in review classes.

During the introductory part of the class, which lasted approximately 10 minutes, the teacher presented the basic concepts that the students had to learn/review in class. The next 30 minutes were spent on the Concept Test. Approximately 10 minutes were allotted for each question. Each Concept Test was the same format as that in Mazur's version. All students of the EG took the same Concept Test, so each student had their copy on paper. The process with the Concept Test followed the original approach, as described in the *Peer Instruction* section. The remaining time in the review class was used for students and the teacher to discuss any unclear points about the material studied.

5.4.3. Concept Tests

Concept Tests were specifically designed for the implementation of the pedagogical intervention using PI. A total of eight Concept Tests were created, one for each lesson covered in the research. Each test contained three multiple-choice questions. Some of the questions were directly adapted from Mazur's manual, while others were newly designed to align with the intended concepts covered within the lessons. These teaching materials were reviewed in the same manner as the data collection instruments, by the expert team and students from a separate Grade 7 class excluded from the study. Their clarity and relevance were confirmed. The first Concept Test is presented in the Appendix.

5.5. Statistical Data Analysis

Statistical analysis was conducted to examine data distribution and relationships. Data normality was assessed with the Shapiro-Wilk test, and appropriate statistical tests were applied: parametric tests for normally distributed data and non-parametric tests for non-normal data.

Table 2. Results of independent samples *t*-test of physics test scores in EG and CG

Variable	Group	<i>M</i>	<i>Sd</i>	Levene's test		Independent samples <i>t</i> -test		
				<i>F</i>	<i>p</i>	<i>t</i>	<i>df</i>	<i>p</i>
Test 1	CG	46.4	15.8	.713	.401	-1.79	78	.077
	EG	52.3	14.0					
Test 2	CG	48.6	19.2	1.696	.197	-2.13	78	.036
	EG	58.5	22.2					
Test 3	CG	48.2	18.9	.000	.985	-3.86	78	.000
	EG	64.8	19.5					

Additionally, a paired samples *t*-test showed no significant difference in the CG between Test 1 and Test 2, nor between Test 2 and Test 3. In the EG, there was no significant difference between Test 1 and Test 2; however, a significant difference was found between Test 2 and Test 3 (Table 3).

Table 3. Results of paired samples *t*-test of initial and final physics test scores in EG and CG

Group	Variables	<i>t</i>	<i>df</i>	<i>p</i>
CG	Test 1-Test 2	-.87	38	.388
	Test 2-Test 3	.17	38	.865
EG	Test 1-Test 2	-1.99	40	.053
	Test 2-Test 3	-2.31	40	.026

The results of the independent samples *t*-test, conducted across three separate assessments (Test 1, Test 2, and Test 3), indicated that there was no statistically significant difference between the physics test scores of boys and girls in either the EG or CG (Table 4).

Table 4. Results of independent samples *t*-test of boys' and girls' physics test scores within EG and CG separately

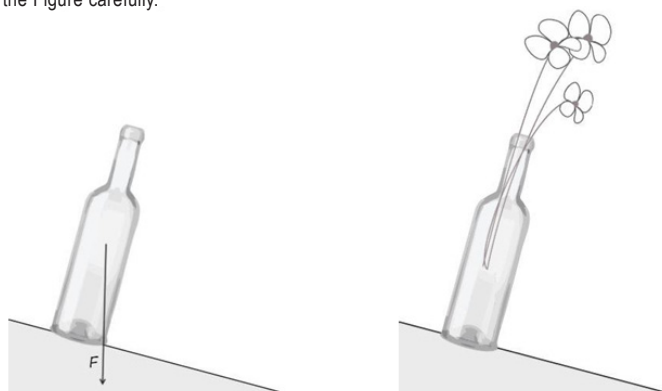
Group	Variable	Gender	<i>M</i>	<i>Sd</i>	Levene's test		Independent samples <i>t</i> -test		
					<i>F</i>	<i>p</i>	<i>t</i>	<i>df</i>	<i>p</i>
CG boys <i>N</i> = 17 girls <i>N</i> = 22	Test 1	boys	45.1	19.2	2.600	.115	-.46	37	.651
		girls	47.4	13.0					
	Test 2	boys	44.8	20.9	1.348	.253	-1.08	37	.288
		girls	51.5	17.7					
	Test 3	boys	46.8	20.3	.475	.495	-.38	37	.705
		girls	49.2	18.3					
EG boys <i>N</i> = 15 girls <i>N</i> = 26	Test 1	boys	56.1	16.6	.657	.423	1.33	39	.190
		girls	50.2	12.0					
	Test 2	boys	52.8	22.1	.014	.906	-1.26	39	.216
		girls	61.8	22.0					
	Test 3	boys	58.5	22.0	2.471	.124	-1.60	39	.117
		girls	68.4	17.4					

6.2. Students' Difficulties in Understanding Concepts

In order to explore RQ2, the percentage of students was first calculated in each of the three categories: those demonstrating understanding, those exhibiting misconceptions, and those who failed to understand the concepts. Questions in which a large number of students exhibited misconceptions or failed to grasp the concept, while only a small number demonstrated understanding, were labeled as those that students experienced difficulty in understanding. On *Misconceptions 1*, two questions stand out as having the most difficulty in understanding the concepts covered in the topic *Balance*, where both questions refer to the conditioning of the body's balance by the position of the point of application of force on the body. An example of one of those two questions is given in Figure 2. For *Misconceptions 1* — initial, 61.25% of students' answers to the question were misconceptions, and 25% of students did not understand the concept, while for this question an even worse result was achieved for *Misconceptions 1* — final, with 58.75% of students' misconceptions, while 32.5% students did not understand the concept.

Figure 2. An example question from diagnostic test for identifying misconceptions within *Balance*

Look at the Figure carefully.



A glass bottle is on an inclined plane, exposed to the force of the Earth's gravity (F), and is in a state of equilibrium. Will it remain in a state of equilibrium if a bouquet of flowers is added, as shown in the figure?

- a) yes;
- b) no.

The reason for your answer is:

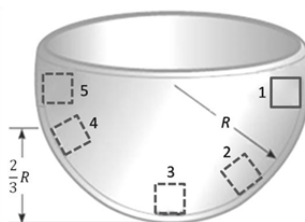
- a) It is harder to move a heavier object from a state of equilibrium.
- b) A heavier bottle experiences greater friction than a lighter one.
- c) The center of mass of a two-body system lies on the line connecting the centers of mass of the two bodies.
- d) None of the above. Add your answer.

Similarly, on *Misconceptions 2*, three questions show the most difficulty in understanding the concepts covered in the topic *Energy*, where these questions refer to the law of conservation of mechani-

cal energy. An example of one of those three questions is given in Figure 3. For *Misconceptions 2 Initial*, among the students' answers to the question, 45% were misconceptions, and 46.25% of students did not understand the concept, while for this question an even worse result was achieved for *Misconceptions 2 Final*, with 52.5% of students' misconceptions, while 40% students did not understand the concept.

Figure 3. An example question from diagnostic test for identifying misconceptions within **Energy**

Look at the Figure carefully.



A light body of mass 100g is placed in a heavy container in position 1. If the surface of the bowl is slippery, the body will have maximum velocity in position:

- a) 2;
- b) 3;
- c) 4;
- d) 5;
- e) None of the above. Add your own answer.

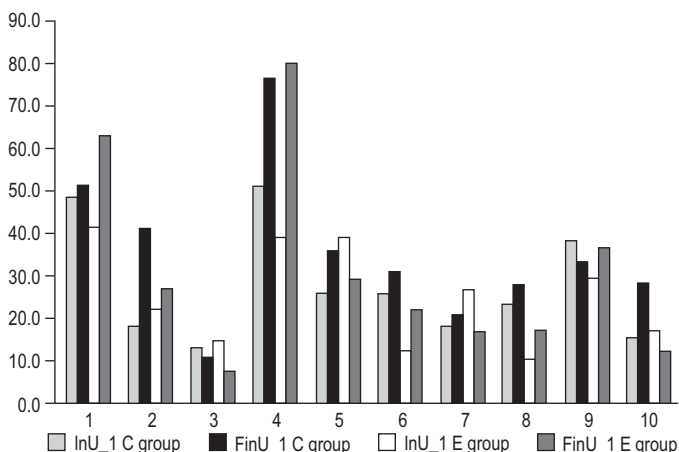
The reason for your answer is:

- a) When an object slides to the bottom of the container, it will stop because its energy is equal to zero.
- b) The mechanical energy at every point is constant.
- c) The farther an object is from its original position, the less energy it has. Therefore, at the start of the slide, the object has maximum speed because it has maximum energy.
- d) None of the above. Add your answer.

In the analysis of the data from *Misconceptions 1* and *2*, each individual question was evaluated separately (Figures 4 and 5). Since the application of PI should provide benefits for students' understanding of the topics covered by this teaching method, the emphasis in the analysis of results of the test for identifying misconceptions is on the change in the representation of students whose answers indicate that they have understood the concepts (variable U) covered by the questions. The following labels have been introduced for the variables: InU_1 and FinU_1 respectively represent the percentage of students who understand the concepts from *Misconceptions 1 Initial* and *Misconceptions 1 Final*, while InU_2 and FinU_2 represent the percentage of students who understand the concepts from *Misconceptions 2 Initial* and *Misconceptions 2 Final*.

RQ3 is partially addressed in Figures 4 and 5, which show the percentages of students in the EG and CG who understood the

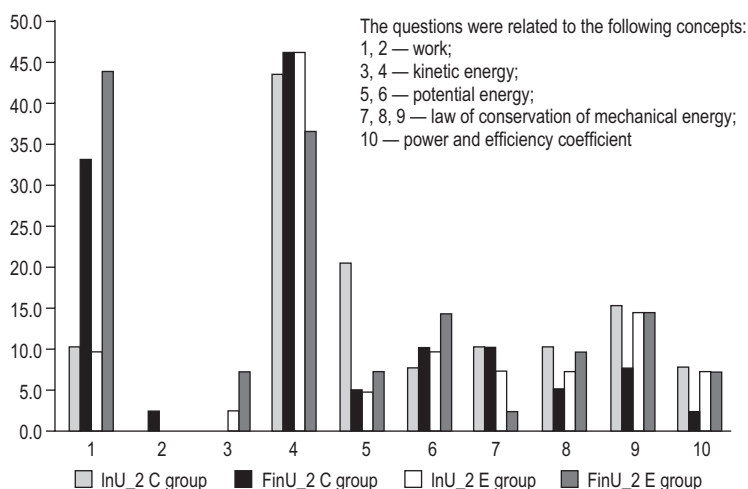
Figure 4. **Percentage of students who understood concept in question (InU_1 and FinU_1) in CG and EG**



The questions were related to the following concepts:

- 1 — types of balance;
- 2 — the resultant force;
- 3, 6 — the conditioning of the body's balance by the position of the point of application of force;
- 4 — center of gravity;
- 5 — moment of force;
- 7, 8, 9, 10 — average body density

Figure 5. **Percentage of students who understood concept in question (InU_2 and FinU_2) in CG and EG**



The questions were related to the following concepts:

- 1, 2 — work;
- 3, 4 — kinetic energy;
- 5, 6 — potential energy;
- 7, 8, 9 — law of conservation of mechanical energy;
- 10 — power and efficiency coefficient

concepts on *Misconceptions 1* and *2*. After being taught *Balance*, the CG students understood seven questions better, while the EG students had an advantage on three questions (Figure 4). Having studied *Energy*, EG students understood seven questions better, while CG students excelled on three (Figure 5).

The Mann-Whitney U test showed no significant difference between the CG and EG on any misconception test (Table 5). To further assess the impact of the PI, n-gain was calculated for both groups (Table 6). The n-gain, calculated as the ratio of the actual (reached) average gain to the maximum possible average gain (proposed by [Hake, 1998]), was computed for both *Balance* (with variables InU_1 and FinU_1) and *Energy* (with variables InU_2 and FinU_2) topics.

Table 5. Results of Mann-Whitney U Test for U values in EG and CG at the beginning and end of teaching both topics

Variable	Group	M	Sd	U	Z	p
InU_1	CG	2.8	1.7	731.50	-.67	.504
	EG	2.5	1.5			
FinU_1	CG	3.6	1.7	648.50	-1.48	.139
	EG	3.1	1.8			
InU_2	CG	1.3	1.1	746.50	-.55	.583
	EG	1.1	.8			
FinU_2	CG	1.2	.9	721.50	-.79	.432
	EG	1.4	1.0			

Table 6. N-gain Values for CG and EG students' understanding of concepts within both teaching topics

Topic	Group	n-gain
Balance (Misconceptions 1)	CG	.110
	EG	.081
Energy (Misconceptions 2)	CG	-.003
	EG	.038

CG showed better progress than EG in understanding concepts from *Balance*, while the EG made progress in understanding *Energy*, with CG regressing. According to Hake [1998], the n-gain values in Table 6 fall in the 'low-g' range ($< .3$).

7. Discussion and Conclusion

Numerous studies show that PI increases student achievement in university and high school settings, but few examine its impact on primary school students. In this research, PI was adapted for Grade 7 students to explore its effect on achievements in the topics *Balance* and *Energy* and its role in reducing the incidence of misconceptions. Achievement and understanding were the dependent variables, while PI application was the independent variable. Achievement was measured through physics tests, and understanding through tests for identifying misconceptions, in two groups: the CG taught in the traditional manner and the EG instructed with the application of PI.

Regarding RQ1, the results show that implementing PI in Grade 7 physics lessons improved student achievement. Prior to PI, there was no si-

significant difference between the EG and CG in physics achievement, overall performance, or grades (Table 1), indicating equivalent groups. After the intervention, the EG showed higher average test scores compared to the CG (Table 2) and improvement compared to their previous results (Table 3), demonstrating positive impact of implementing PI. These findings align with prior studies on effectiveness of PI in various physics topics [Howe et al., 1990; Harvey, 2013; Sencar Tokgöz, 2007].

Between Test 1 and Test 2, conducted before and after learning the topic *Balance*, no significant difference was observed in either the EG or CG. However, after learning the topic *Energy*, the EG showed significant progress, with notably better results on Test 3 compared to Test 2. In contrast, the CG showed no improvement (Table 3). While one might attribute the EG's progress to differences in topic difficulty, the lack of progress in the CG suggests that the improvement is more likely due to the application of PI rather than the above differences. This supports the conclusion that the EG's performance improvement was largely driven by increased proficiency with PI, highlighting the importance of practice and familiarity with instructional methods in enhancing student achievement.

Physics achievement may vary by gender depending on the teaching method. Since no significant difference was found between boys' and girls' test scores in either the CG or EG (Table 4), this suggests that traditional teaching and PI are equally effective for both genders. It is important that teaching methods work well for both genders, especially since instruction typically takes place in mixed-gender classrooms.

Concerning RQ2, certain concepts were identified where students encountered difficulties in understanding (i.e., where a large number of students exhibited misconceptions or failed to grasp the concept). It has been shown that within the two topics covered in the research, students particularly struggle with understanding conditioning body balance based on the position of the point of application of force and the law of conservation of mechanical energy. Previous studies also underline the complexity of balance and energy for students' understanding, revealing that misconceptions persist across various contexts (e.g., [Dega, Govender, 2016; Newcomer, Steif, 2008]).

With regard to RQ3, the results show that applying PI alone does not eliminate misconceptions. The Concept Tests in the research were designed to align with the concepts taught using traditional methods in the CG, without targeting the specific misconceptions identified in the EG. To address these particular misconceptions, PI would need to be specifically designed for that purpose. Had the study aimed at directly targeting these misconceptions, the results might have been different, potentially reducing misconceptions among students. The study aimed to determine whether mastering PI alone could help students evaluate and partially overcome misconceptions without explicitly addressing them. There were no significant differences in misconceptions between the CG and EG, both before and after applying

PI (Table 5), with insufficient progress in both groups (Table 6). Difficulties persisted in both groups likely due to the limited time for teaching abstract concepts, which makes it challenging for students to relate those concepts to real-life experiences. However, the CG showed improvement on more questions from *Misconception 1*, whereas the opposite was observed for *Misconception 2*, likely due to the time needed to master PI. Therefore, extended use of PI may help reduce misconceptions, or alternatively, adapting the material to specifically target the identified misconceptions could lead to quicker improvements. According to various studies, misconceptions are strongly resistant to change, even when traditional teaching methods are employed (e.g., [Tippett, 2010]). Some active strategies specifically targeting misconceptions about balance and energy and promoting conceptual change have proven useful (e.g., [Canu et al., 2017; Koma et al., 2021]). However, not all active learning strategies are equally effective, particularly when they are not designed to address identified misconceptions, as demonstrated in this study.

This research has its limitations, most notably those related to the sampling and the duration of the research. A convenient sample was selected due to the strict organizational structure of the school, where students are divided into classes. Additionally, teachers were required to undergo training for the implementation of a method that is not typically used. Besides, the research included only Grade 7 students and focused on only two teaching topics.

The following points highlight the implications for research and practice. Future research should consider expanding the analysis of PI to include a broader range of teaching topics and to be applied in classrooms with students of various ages. Also, it is recommended that research on the matter be done over the whole school year. This would allow students to sufficiently master the use of PI so that they would be able to recognize misconceptions on the spot. In that case, the application of PI itself might spontaneously lead to the elimination of a certain number of misconceptions. On the other hand, it would also be beneficial to carry out research on adapting this teaching method in order to eliminate the identified and established misconceptions. Accordingly, Concept Tests could be designed to address misconceptions identified before the research, allowing examination of how PI affects students' understanding when the material is adapted to their specific difficulties.

This research highlights the importance of PI in teaching, emphasizing that teachers should consider it as part of their instructional practices. Teachers should have a broad range of methods available in order to achieve the best results. Since PI has been found to improve student achievement, there is a need for developing appropriate teaching materials for its implementation in primary physics education. Providing appropriate training would also help teachers confidently integrate PI into their classrooms.

Appendix Concept Test — Action of force

Question 1

A cuboid is placed on top of three identical cubes, as shown in Figure 1A. Then, the two side cubes were removed, leaving one cube and the cuboid placed on top of it, as shown in Figure 1B. Let $\vec{N}_1$ be the normal ground reaction force acting on the middle cube in Figure 1A, and let $\vec{N}_2$ be the normal ground reaction force acting on the cube in Figure 1B. Then the intensity of force $\vec{N}_1$ is compared to the intensity of force $\vec{N}_2$:

1. less;
2. equal;
3. greater;
4. less if the cube is heavier than the cuboid;
5. greater if the cube is heavier than the cuboid;
6. cannot be estimated.



Figure 1

Your answer before the discussion: _____

Your answer after the discussion: _____

Question 2

Figure 2 shows the connection of nine identical dynamometers — four dynamometers in the first row, three dynamometers in the second row and two dynamometers in the third row. If the cube, weighing 12 N, is hanging from the dynamometers as shown in Figure 2, then:

1. the force acting on all dynamometers in the first row is **twice** the force acting on all dynamometers in the third row;
2. the force acting on all dynamometers in the first row is **twice less** than the force acting on all dynamometers in the third row;
3. the force acting on one dynamometer in the second row is **1 N greater** than the force acting on one dynamometer in the third row;
4. the force acting on one of the dynamometers in the second row is **1 N less** than the force acting on one dynamometer in the third row;
5. the **same force** acts on all dynamometers;
6. nothing can be inferred about the forces acting on the dynamometers.

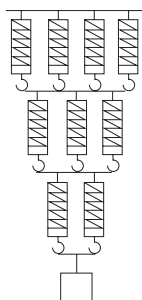


Figure 2

Your answer before the discussion: _____

Your answer after the discussion: _____

Question 3

Two vertical wooden sticks are positioned close to each other: one is stationary, and the other is movable. The goal is to bring the movable stick closer to the stationary one. To achieve this, a force of at least 300 N must be applied to the movable stick. However, Mia can only exert a maximum pushing force of 30 N directly on the movable stick. An inextensible rope is wrapped around both sticks (as shown in Figure 3). This rope is designed to slide smoothly along the surfaces of the sticks. Mia can pull the rope with a force of 30 N. What is the minimum number of coils of the rope needed around the sticks to ensure that Mia brings the sticks closer?

1. one coil;
2. five coils;
3. seven coils;
4. ten coils;
5. nine thousand coils;
6. one cannot estimate how many coils there are.

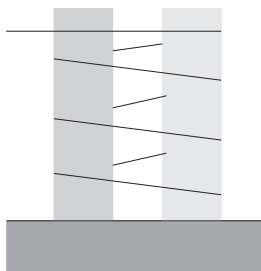


Figure 3

Your answer before the discussion: _____

Your answer after the discussion: _____

Shapiro-Wilk Test of Normality

Variable	Group	Students	<i>W</i>	<i>df</i>	<i>p</i>
Test 1	CG	all	.971	39	.391
		boys	.923	17	.164
		girls	.940	22	.198
	EG	all	.989	41	.959
		boys	.943	15	.422
		girls	.947	26	.192
physics grades at the end of Grade 6	CG	all	.794	39	.000
		boys	.802	17	.002
		girls	.788	22	.000
	EG	all	.759	41	.000
		boys	.817	15	.006
		girls	.671	26	.000
overall school achievement at the end of Grade 6	CG	all	.744	39	.000
		boys	.791	17	.002
		girls	.702	22	.000
	EG	all	.708	41	.000
		boys	.798	15	.003
		girls	.633	26	.000

Variable	Group	Students	<i>W</i>	<i>df</i>	<i>p</i>
Test 2	CG	all	.981	39	.740
		boys	.969	17	.798
		girls	.949	22	.302
	EG	all	.968	41	.300
		boys	.970	15	.855
		girls	.956	26	.319
Test 3	CG	all	.985	39	.881
		boys	.971	17	.839
		girls	.985	22	.973
	EG	all	.969	41	.329
		boys	.918	15	.178
		girls	.955	26	.305
InU_1	CG	all	.944	39	.052
	EG	all	.952	41	.081
FinU_1	CG	all	.960	39	.177
	EG	all	.900	41	.002
InU_2	CG	all	.883	39	.001
	EG	all	.780	41	.000
FinU_2	CG	all	.873	39	.000
	EG	all	.899	41	.002

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References

- Adilah N., Ngazizah N., Nurhidayati N. (2025) Analysis of Causes and Strategies to Reduce Student Misconceptions in Science Subjects at Elementary School. *Journal of Research in Instructional*, vol. 5, no 1, pp. 225–245. <https://doi.org/10.30862/jri.v5i1.537>
- Anggrayni S., Ermawati F.U. (2019) The Validity of Four-Tier's Misconception Diagnostic Test for Work and Energy Concepts. *Journal of Physics: Conference Series*, vol. 1171, Article no 012037. <https://doi.org/10.1088/1742-6596/1171/1/012037>
- Bryce T., MacMillan K. (2009) Momentum and Kinetic Energy: Confusable Concepts in Secondary School Physics. *Journal of Research in Science Teaching*, vol. 46, no 7, pp. 739–761. <https://doi.org/10.1002/tea.20274>
- Buteler L., Coleoni E. (2016) Solving Problems to Learn Concepts, How Does It Happen? A Case for Buoyancy. *Physical Review Physics Education Research*, vol. 12, no 2, Article no 020144. <https://doi.org/10.1103/PhysRevPhysEducRes.12.020144>
- Canu M., de Hosson C., Duque M. (2016) Students' Understanding of Equilibrium and Stability: The Case of Dynamic Systems. *International Journal of Science and Mathematics Education*, vol. 14, August, pp. 101–123. <https://doi.org/10.1007/s10763-014-9565-6>
- Canu M., Duque M., de Hosson C. (2017) Active Learning Session Based on Didactical Engineering Framework for Conceptual Change in Students' Equilibrium and

- Stability Understanding. *European Journal of Engineering Education*, vol. 42, no 1, pp. 32–44. <https://doi.org/10.1080/03043797.2016.1190689>
- Dega B.G. (2019) Cognitive Diagnostic Assessment of Students' Responses: An Example from Energy and Momentum Concepts. *European Journal of Physics Education*, vol. 10, no 1, pp. 13–23.
- Dega B.G., Govender N. (2016) Assessment of Students' Scientific and Alternative Conceptions of Energy and Momentum Using Concentration Analysis. *African Journal of Research in Mathematics, Science and Technology Education*, vol. 20, no 3, pp. 201–213. <http://doi.org/10.1080/18117295.2016.1218657>
- Ding Y., Zhu G., Bian Q., Bao L. (2024) Analysis of Students' Conceptual Change in Learning Newton's Third Law with an Integrated Framework of Model Analysis and Knowledge Integration. *Physical Review Physics Education Research*, vol. 20, no 2, Article no 020141. <http://doi.org/10.1103/PhysRevPhysEduRes.20.020141>
- Duit R., Treagust D. (2012) Conceptual Change: Still a Powerful Framework for Improving the Practice of Science Instruction. *Issues and Challenges in Science Education Research* (eds K. Tan, M. Kim). Dordrech: Springer, pp. 671–688. <https://doi.org/10.1080/09500690305016>
- Duit R., Treagust D. (2003) Conceptual Change — A Powerful Framework for Improving Science Teaching and Learning. *International Journal of Science Education*, vol. 25, no 6, pp. 671–688. <https://doi.org/10.1080/09500690305016>
- Eryilmaz A. (2002) Effects of Conceptual Assignments and Conceptual Change Discussions on Students' Misconceptions and Achievement Regarding Force and Motion. *Journal of Research in Science Teaching*, vol. 39, no 1, pp. 1001–1015. <https://doi.org/10.1002/tea.10054>
- Fortus D., Kubsch M., Bielik T., Krajcik J., Lehavi Y., Neumann K. et al. (2019) Systems, Transfer, and Fields: Evaluating a New Approach to Energy Instruction. *Journal of Research in Science Teaching*, vol. 56, no 10, pp. 1341–1361. <https://doi.org/10.1002/tea.21556>
- Gafoor K.A., Akhilesh P.T. (2010) Strategies for Facilitating Conceptual Change in School Physics. *Innovations and Researches in Education*, vol. 3, no 1, pp. 34–42.
- Goldring H., Osborne J. (1994) Students' Difficulties with Energy and Related Concepts. *Physics Education*, vol. 29, no 1, pp. 26–32. <https://doi.org/10.1088/0031-9120/29/1/006>
- Guerra-Reyes F., Guerra-Dávila E., Naranjo-Toro M., Basantes-Andrade A., Guevara-Betancourt S. (2024) Misconceptions in the Learning of Natural Sciences: A Systematic Review. *Education Sciences*, vol. 14, no 5, Article no 497. <https://doi.org/10.3390/educsci14050497>
- Haataja E., Malmberg J., Dindar M., Järvelä S. (2022) The Pivotal Role of Monitoring for Collaborative Problem Solving Seen in Interaction, Performance, and Interpersonal Physiology. *Metacognition and Learning*, vol. 17, no 1, pp. 241–268. <https://doi.org/10.1007/s11409-021-09279-3>
- Hake R.R. (1998) Interactive-Engagement versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses. *American Journal of Physics*, vol. 66, no 1, pp. 64–74. <https://doi.org/10.1119/1.18809>
- Halim L., Yong T., Meerah T. (2014) Overcoming Students' Misconceptions on Forces in Equilibrium: An Action Research Study. *Creative Education*, vol. 5, no 11, pp. 1032–1042. <https://doi.org/10.4236/ce.2014.51117>
- Harvey N.C. (2013) *The Effects of Peer Instruction on Ninth Grade Students' Conceptual Understanding of Forces and Motion* (Master's Theses). Baton Rouge: Louisiana State University and Agricultural and Mechanical College.
- Howe C., Tolmie A., Rodgers C. (1990) Physics in the Primary School: Peer Interaction and the Understanding of Floating and Sinking. *European Journal of Psychology of Education*, vol. 5, no 4, pp. 459–475. <http://www.jstor.org/stable/23422158>

- Kikas E. (2004) Teachers' Conceptions and Misconceptions Concerning Three Natural Phenomena. *Journal of Research in Science Teaching*, vol. 41, no 5, pp. 432–448. <https://doi.org/10.1002/tea.20012>
- Koma S., Mokuku T.E., Makatjane T.J., Balck C., Sermeus J. (2021) The Effectiveness of Teaching Energy in a Secondary School Using the "Factory of Ideas" Teaching Approach. *African Journal of Research in Mathematics, Science and Technology Education*, vol. 25, no 1, pp. 27–37. <https://doi.org/10.1080/18117295.2021.1893006>
- Kulgemeyer C., Wittwer J. (2023) Misconceptions in Physics Explainer Videos and the Illusion of Understanding: An Experimental Study. *International Journal of Science and Mathematics Education*, vol. 21, March, pp. 417–437. <https://doi.org/10.1007/s10763-022-10265-7>
- Lee G., Byun T. (2012) An Explanation for the Difficulty of Leading Conceptual Change Using a Counterintuitive Demonstration: The Relationship between Cognitive Conflict and Responses. *Research in Science Education*, vol. 42, May, pp. 943–965. <https://doi.org/10.1007/s11165-011-9234-5>
- Leinonen R., Asikainen M.A., Hirvonen P.E. (2017) Peer Discussions in Lecture-Based Tutorials in Introductory Physics. *Physical Review Physics Education Research*, vol. 13, no 1, Article no 010114. <https://doi.org/10.1103/PhysRevPhysEducRes.13.010114>
- Letić M. (2017) How Should Repeated Gross Mistakes in Textbooks Be Treated? *Advances in Physiology Education*, vol. 41, no 1. <https://doi.org/10.1152/advan.00145.2016>
- Limon M. (2001) On the Cognitive Conflict as an Instructional Strategy for Conceptual Change: A Critical Appraisal. *Learning and Instruction*, vol. 11, no 4–5, pp. 357–380. [https://doi.org/10.1016/S0959-4752\(00\)00037-2](https://doi.org/10.1016/S0959-4752(00)00037-2)
- Mazur E. (1997) *Peer Instruction: A User's Manual*. Upper Saddle River, NJ: Prentice Hall.
- Meiring L., Webb P. (2012) The Effect of Toys as Educative Material on Pre-Service Education Students' Understanding of Energy. *African Journal of Research in Mathematics, Science and Technology Education*, vol. 16, no 1, pp. 100–111. <https://doi.org/10.1080/10288457.2012.10740732>
- Newcomer J.L., Steif P.S. (2008) Student Thinking about Static Equilibrium: Insights from Written Explanations to a Concept Question. *Journal of Engineering Education*, vol. 97, no 4, pp. 481–490. <https://doi.org/10.1002/j.2168-9830.2008.tb00994.x>
- OECD (2019) *PISA 2018 Results. Vol. I: What Students Know and Can Do*. Paris: OECD. <https://doi.org/10.1787/5f07c754-en>
- Ortiz L.G., Heron P.R.L., Shaffer P.S. (2005) Student Understanding of Static Equilibrium: Predicting and Accounting for Balancing. *American Journal of Physics*, vol. 73, no 6, pp. 545–553. <https://doi.org/10.1119/1.1862640>
- Pacaci C., Ustun U., Ozdemir O.F. (2024) Effectiveness of Conceptual Change Strategies in Science Education: A Meta-Analysis. *Journal of Research in Science Teaching*, vol. 61, no 6, pp. 1263–1325. <https://doi.org/10.1002/tea.21887>
- Palmer D.H. (2001) Investigating the Relationship between Students' Multiple Conceptions of Action and Reaction in Cases of Static Equilibrium. *Research in Science and Technical Education*, vol. 19, no 2, pp. 193–204. <https://doi.org/10.1080/02635140120087722>
- Pavlin J., Čampa T. (2021) Is Peer Instruction in Primary School Feasible? The Case Study in Slovenia. *European Journal of Educational Research*, vol. 10, no 2, pp. 785–798. <https://doi.org/10.12973/eu-jer.10.2.785>
- Pine K., Messer D., St. John K. (2001) Children's Misconceptions in Primary Science: A Survey of Teachers' Views. *Research in Science & Technological Education*, vol. 19, no 1, pp. 79–96. <https://doi.org/10.1080/02635140120046240>

- Posner G.J., Strike K.A., Hewson P.W., Gertzog W.A. (1982) Accommodation of a Scientific Conception: Towards a Theory of Conceptual Change. *Science Education*, vol. 66, no 2, pp. 211–227. <https://doi.org/10.1002/sce.3730660207>
- Pulgar J., Spina A., Ríos C. (2020) Investigating How Students Collaborate to Generate Physics Problems through Structured Tasks. *Physical Review Physics Education Research*, vol. 17, no 1, Article no 010120. <https://doi.org/10.1103/PhysRevPhysEducRes.17.010120>
- Resbiantoro G., Setiani R., Koranto D. (2022) A Review of Misconception in Physics: The Diagnosis, Causes, and Remediation. *Journal of Turkish Science Education*, vol. 19, no 2, pp. 403–427. <https://doi.org/10.36681/tused.2022.128>
- Roncato S., Rumiati R. (1986) Naive Statics: Current Misconceptions on Equilibrium. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, vol. 12, no 3, pp. 361–377. <https://doi.org/10.1037/0278-7393.12.3.361>
- Sencar Tokgöz S. (2007) *The Effect of Peer Instruction on Sixth Grade Students' Science Achievement and Attitudes* (PhD Thesis). Ankara: Middle East Technical University.
- Singh C., Rosengrant D. (2003) Multiple-Choice Test of Energy and Momentum Concepts. *American Journal of Physics*, vol. 71, no 6, pp. 607–617. <https://doi.org/10.1119/1.1571832>
- Tenzin S. (2024) *Developing Conceptual Understanding through Diagrams: Year 7 Students' Learning of Balanced and Unbalanced Forces* (PhD Thesis). Perth: Curtin University.
- Tippett C.D. (2010) Refutation Text in Science Education: A Review of Two Decades of Research. *International Journal of Science and Mathematics Education*, vol. 8, no 6, pp. 951–970. <https://doi.org/10.1007/s10763-010-9203-x>
- Woo P.S., MohdRameli M.R., MohdKosnin A. (2022) A Meta-Analysis on the Impact of Peer Instruction on Students' Learning. *Sains Humanika*, vol. 14, no 3, pp. 21–27. <https://doi.org/10.11113/sh.v14n3.1943>
- Yuruk N. (2007) A Case Study of One Student's Metaconceptual Processes and the Changes in Her Alternative Conceptions of Force and Motion. *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 3, no 4, pp. 305–325. <https://doi.org/10.12973/ejmste/75411>