CZU: 37.02:53:373.5.046.12 **https://doi.org/10.59295/sum9(176)2024_31**

APPLYING THE FLIPPED CLASSROOM METHOD IN STUDYING ROTATIONAL EQUILIBRIUM IN 7TH GRADE PHYSICS

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This paper analyzes the results of applying the Flipped Classroom method to teaching the „Rotational Equilibrium" unit in 7th-grade physics. It characterizes several research-based constructivist methods and demonstrates that the Flipped Classroom is fundamentally constructivist but differs in lesson structure, with students' cognitive effort exceeding and anticipating the lesson timeframe. The method features pre-class preparation, high interaction between students and teachers, personalized learning, critical thinking development, and digital technology use. The alternative hypothesis was that significant differences exist between the Flipped Classroom and conventional methods, showing a 20% higher average score in the experimental class. The calculated impact factor is 0.48, aligning with visible learning theory.
Keywords: *flipped classroom, constructivist learning, formative feedback, video presentations.*

APLICAREA METODEI CLASA INVERSATĂ ÎN STUDIUL ECHILIBRULUI DE ROTAȚIE LA FIZICĂ ÎN CLASA A VII-A

În lucrarea de față se analizează rezultatele aplicării metodei Clasa Inversată la predarea capitolului Echilibrul de rotație din cursul de fizică de cl. a 7-a. Este caracterizată o serie de metode constructiviste bazate pe cercetare și este arătat că metoda Clasei Inversate este eminamente constructivistă dar diferă de aceste metode prin structura lecției, efortul cognitiv al elevului depășind și anticipând cadrul temporal al lecției. Este arătat că metoda Clasei Inversate se caracterizează prin: pregătirea elevilor înainte de lecție; un grad înalt de interacțiune între elevi și între elevi și profesor; învățare personalizată; dezvoltarea gândirii critice; utilizarea tehnologiei digitale. Ipoteza de alternativă a fost „Există diferențe semnificative în rezultatele testelor de după experiment între metoda Clasai Inversată și metoda convențională". S-a obținut că în clasa experimentală nota medie la evaluarea sumativă este cu 20% mai mare decât în clasa de control. De asemenea, procentul calității s-a dublat în clasa unde s-a aplicat metoda Clasa Inversată față de clasa unde s-a aplicat metoda frontală de predare. Factorul de impact calculat este de 0,48 – în corespundere cu factorul de impact calculat în cadrul teoriei învățării și predării vizibile.
Cuvinte-cheie: *clasa inversată, învățare constructivistă, feedback formativ, lecții video.*

Introduction

Traditional approaches to teaching physics, based on the one-way transmission of information from teacher to student, have often proven ineffective in facilitating a deep understanding of scientific concepts. In contrast, constructivist teaching and learning methods, which emphasize the active role of the student in building knowledge through direct experience and reflection, have gained recognition as being more effective in promoting a profound understanding of physics. There is a whole range of constructivist methods that we will list and briefly characterize below.

Inquiry-based learning is one of the most fundamental constructivist methods, which emphasize the role of student's direct experimentation and observation. According to Piaget, students construct their knowledge through active interaction with their environment, within activities that allow them to observe, experiment, and draw their own conclusions [23]. In the context of teaching physics, exploratory learning can manifest through experimental activities that allow students to directly observe and test physical laws. For example, studies show that the use of hands-on experiments, such as simulations of motion or forces, helps students better understand the basic concepts of physics and apply these concepts in new situations [19].

Problem-based learning (PBL) method proves to be extremely effective in learning physics because it emphasizes the promotion of critical thinking and the practical application of concepts. For example, a study conducted by Hmelo-Silver suggests that PBL helps students develop problem-solving skills and apply concepts in authentic contexts, thus improving a deep understanding of physics [12]. This method is an active learning approach, where students work in groups to analyze and solve real problems, thereby acquiring valuable skills such as collaboration and communication. Additionally, PBL helps students understand the practical applicability of physical concepts, thus strengthening their theoretical knowledge.

Project-based learning is another constructivist method that integrates physical concepts with other disciplines and allows students to tackle complex problems in an interdisciplinary manner. Projects provide opportunities for exploring and applying knowledge in a practical and creative setting. Studies suggest that project-based approaches not only enhance the understanding of physical concepts but also contribute to the development of general problem-solving skills and critical thinking [27]. For example, in a project, students may be required to design and test a device that uses physical principles to solve a specific problem. This type of activity not only allows them to apply concepts in a real-world context but also to develop project management and teamwork skills.

Discussions and reflection are constructivist methods that allow students to analyze and integrate accumulated knowledge. In group discussions, students have the opportunity to share ideas, debate concepts, and clarify their understanding. According to Vygotsky, this promotes a collaborative learning process [29].

Reflective journals are another constructivist method that helps students analyze their own learning processes and identify areas needing improvement. Through reflection, students can better understand how they reached certain conclusions and how they can apply these lessons in the future [22].

Simulations and Models. The use of computer simulations and physical models provides students with a way to explore abstract concepts in a visual and interactive manner. Simulations allow students to visualize complex physical phenomena and experience their effects in a controlled environment [31]. Physical and visual models are useful for representing abstract concepts, providing students with a concrete framework for understanding and applying them. This type of visual learning is particularly effective in physics, where many concepts are abstract and difficult to understand without visual representations.

Formative assessment and permanent feedback are crucial components of the constructivist methodology. Continuous feedback helps students adjust and improve their understanding, while self-assessment allows students to reflect on their own learning processes [3].

In conclusion, these practices contribute to creating a learning environment where students are actively engaged in their educational process, developing critical and reflective skills that are essential for academic and professional success long time after school graduation.

A method that differs from the constructivist methods presented here, primarily in the structure of the lesson, is the Flipped Classroom, which offers students the opportunity to explore physical concepts at home and apply these concepts in class. In this method, students study the basic material (e.g., video lessons or text) outside of class hours, and classroom time is dedicated to practical activities, discussions, and practical applications of the concepts [1].

It is worth mentioning that teaching physics in school is a constant challenge, as students often have difficulties understanding complex concepts [9]. An approach that has gained popularity in recent years is the constructivist approach, which emphasizes the active involvement of students in the learning process. The Flipped Classroom (Flipped Classroom) fits within this approach. Thus, this article will focus on examining the flipped classroom model, assessing its effectiveness on student learning compared to traditional teaching methods [8], based on the pedagogical experiment conducted in the 7th grade at Hyperion High School in Chișinău, Moldova.

The flipped classroom model is essentially a constructivist approach, as it allows students to interact with content outside of class hours, freeing up valuable class time for active learning and problem-solving [14]. By working on materials, mostly recorded video lectures, before class, teachers can dedicate class time to guiding students through practical activities, discussions, and collaborative analysis of problem situations [10]. This shift in the traditional structure and conduct of the classroom has proven effective in learning physics, as it allows students to better prepare for class activities and develop a deeper understanding of the material [16-18, 21, 30].

The flipped classroom is in full alignment with the constructivist philosophy, which emphasizes the active construction of knowledge by students through meaningful interactions and problem-solving [15]. The flipped classroom model promotes a learning environment where students take a more active role in their own learning, engaging in inquiry-based and personalized activities that deepen their understanding of physics concepts [2].

In a study examining the implementation of the Flipped Classroom method in an introductory physics course, researchers from the University of British Columbia in Vancouver found that students in the experimental group, where the flipped classroom method was applied, scored significantly higher on conceptual understanding assessments compared to those in the control group based on traditional teaching [7]. Additionally, the flipped classroom method was associated with higher attendance and interest, as students were more actively engaged in the learning process [24].

Other constructivist teaching methods similar to the Flipped Classroom, such as Engaged Pedagogy, have also demonstrated positive outcomes in learning physics. Engaged Pedagogy emphasizes the use of interactive and collaborative learning activities, which can help students develop critical thinking and problem-solving skills. Studies have found that, alongside the Flipped Classroom, Engaged Pedagogy can lead to improved student performance and a more positive attitude toward physics [25].

Although the constructivist approach, including the Flipped Classroom method, has demonstrated its effectiveness in teaching physics, it is important to note that the success of these methods depends on both the level of student engagement and the teacher's mastery of the method. Thus, teachers must continually ensure that their students are adequately prepared for class activities and that the materials and resources provided for pre-class preparation are engaging and relevant.

Theoretical Framework

In this paper, we will analyze the application of the Flipped Classroom method to the teaching of middle school physics, a method that was proposed relatively recently, in the early 2000s, by American educators Jonathan Bergmann and Aaron Sams [1].

The Flipped Classroom method is based on the following constructivist principles:

1. **Pre-class preparation of students:** Students review material prepared by the teacher (e.g., textbook, video, presentation) or engage in exploratory preparatory activities before the lesson. It should be noted that other teaching methods also assume that students come to class with a basic level of knowledge, such as Peer Instruction developed by American educator Eric Mazur [20].
2. **High degree of students – students and students – teacher interaction:** With students already familiar with the subject, most of the lesson time is dedicated to analyzing problem situations, discussions, practical activities, and problem-solving, all in a group work format facilitated by the teacher. Thus, the Flipped Classroom is also a form of Inquiry-Based Science Education [13].
3. **Personalized learning:** Students study at home at their own pace, according to their needs and abilities. Therefore, cognitive effort in the Flipped Classroom is not just a declarative title but emphasizes the true constructivist nature of the method. By focusing on student learning effort, the Flipped Classroom shares many aspects with Problem-Based Learning, which, when systematically applied, develops critical thinking, metacognition, and lifelong learning skills [5].
4. **Development of critical thinking:** Through active interaction and practical application of theoretical concepts learned at home, the Flipped Classroom fosters critical thinking and analysis skills. This approach aligns with Reflective Learning, which is based on continuous self-assessment by the student [26].
5. **Use of digital technology:** For both preparing and delivering content in advance, as well as facilitating classroom interactions. The Flipped Classroom can be implemented in any learning environment: physical classroom or online (synchronous or asynchronous). This requires collaboration tools, online platforms, digital resources, short videos, and offline and online assessment systems to ensure both instant feedback on formative assessments and processing of final assessment results. It should be noted that digital teaching tools themselves have minimal impact on students' academic success [28].

It is important to highlight an interesting point: compared to the aforementioned constructivist methods, the Flipped Classroom has a smaller impact on students' academic success. For example, according to the Visible Teaching and Learning theory developed by New Zealand educator John Hattie [11], the Flipped Classroom has an impact factor of 0.5, Reflective Learning has 1.29, Problem-Based Learning has 0.68, Peer Instruction has 0.74, and the use of digital or online resources has 0.29. To put these numbers into context, it should be noted that if an experienced teacher uses the conventional method - frontally teaching - for two years in the same class, the impact factor is about 0.40, meaning that students' academic success increases by 40%.

Research Questions and Objectives

The aim of this research is to assess the effect of applying the Flipped Classroom method during the study of a chapter in the 7th-grade physics course on a range of parameters related to students' academic success.

The main objectives of the research are:

- To compare the effectiveness of the Flipped Classroom method with that of the conventional method in terms of impact on students' academic success.
- To compare the research findings with results obtained previously by other researchers.
- To implement the Flipped Classroom method and determine how to plan a lesson or a series of lessons in this style to achieve maximum effectiveness.
- For further research, to familiarize students with constructivist teaching methods that emphasize cognitive effort.

The research question is: „Would the implementation of the Flipped Classroom method improve students' results in physics compared to the conventional method?"

Hypotheses of the experiment:

- Null Hypothesis (H0): There are no significant differences in post-experiment test results between the Flipped Classroom method and the conventional method.
- Alternative Hypothesis (H1): There are significant differences in post-experiment test results between the Flipped Classroom method and the conventional method.

Methodology

The experiment took place during the 2022–2023 academic year at the "Hyperion" Theoretical High School in Durlești, Chișinău, Republic of Moldova. The experimental group consisted of 35 students (21 girls, 14 boys) from Class VII B, while the control group comprised 36 students (18 girls, 18 boys) from Class VII C. In the experimental class, 33 students participated in the pre-test, and 32 students participated in the post-test. In the control class, 32 students participated in the pre-test, and 34 students participated in the post-test. The experimental class was taught using the Flipped Classroom method, whereas the control class followed traditional frontal teaching.

The experiment covered the entire study period of Chapter V, Rotational Equilibrium, in the 7th-grade physics course [4]. According to the curriculum [6], this chapter involves studying simple mechanisms such as levers, pulleys, and inclined planes, and conducting a laboratory work titled Determining the Work of the Applied Force, the Work of the Resistive Force, Comparing the Obtained Values. This chapter is allocated 9 academic hours or 4.5 weeks of study.

Since the Flipped Classroom method emphasizes collaborative learning, the experimental class was divided into 6 groups of 5-6 students each. The control class was not divided into groups.

Before the lesson, students studied the theoretical part of the topic from the textbook and watched a video lesson on the educationonline.md platform. The video lasted about 15 minutes and included two solved problems that students analyzed at home and transcribed into their notebooks. Additionally, students answered questions from the Check Your Knowledge section at the end of each topic.

In the control class, the lesson followed the usual teaching stages: recall, sense-making, reflection, and expansion. In the experimental class, sense-making was conducted through problem situations analyzed by students with guidance from the teacher.

At the end of the chapter, a summative assessment was conducted in the form of a test with six items, allocated 45 minutes. The results of this test represent the post-experiment test results. The pre-experiment test results were taken from the final test of Chapter III, Fluid Statics, which was allocated approximately 13 hours. In the Tab.1 the results of pre- and post-test în experimental and control classes are presented.

Tab. 1 The results of pre-test and post-test în experimental and control classes.

	Experimental class		Control class	
Mark „5”	1	2	3	1
Mark „6”	10	6	6	10
Mark „7”	12	5	15	9
Mark „8”	2	9	5	9
Mark „9”	6	7	2	1
Mark „10”	2	3	1	4
Mean	7,24	7,69	7,0	7,35
Std deviation	1,324	1,424	1,136	1,342
Skewness	0,642	-0,192	0,423	0,641
Shapiro-Wilk	0,874	0,933	0,908	0,889
p-value	0,001	0,004	0,01	0,002
Median	7	8	7	7
Mode	7	8	7	6
Academic quality	30.3%	59.38%	25.0%	41.18%

Discussion of Results

According to Table 1, the average grade in the experimental class increased from 7.24 to 7.69, or by 6.22%, while in the control class it rose from 7.0 to 7.35, or by 5.0%. The median grade in the experimental class increased from „7” to „8”, remaining “7” in the control. The mode shifted from „7” to „8” in the experimental class, while in the control it dropped from „7” to „8”. Academic quality, or the percentage of grades ≥ 8, nearly doubled in the experimental class, increasing from 30.3% to 59.38%, and rose from 25.0% to 41.18% in the control.

The impact of the Flipped Classroom method also is given by skewness analysis. Thus, pre-test skewness of 0.642 in the experimental class - this positive value indicates a slight left skew, meaning most students had scores below the mean, with a few higher scores raising the average. Post-test skewness of -0.192 in the experimental class - this slightly negative value, close to zero, indicates an almost symmetric distribution. This suggests an overall improvement, as most students achieved results around the mean, reducing the extremes and indicating uniform progress in performance. For the control class, a skewness value of 0,423 in the pre-test indicates moderate positive skewness, showing that most students scored below the mean, although there are a few students with higher scores. A skewness of 0,641 in the post-test indicates a more pronounced asymmetry, suggesting that despite improvements, the scores are still distributed such that many students perform below the overall average.

This is also confirmed by the Shapiro-Wilk test: both values from the experimental class, 0,874 in the pre-test and 0,933 in the post-test, indicate a normal distribution of the data, which allows for statistical analysis. Additionally, the reference p-values suggest an improvement in the distribution of grades around the mean in the experimental class. Regarding the experimental class, both p-value reference values are below 0,05, meaning that despite improvements, the distribution of grades remains asymmetric, with a significant number of students scoring below the overall average

Thus, in the experimental class, academic quality increased by 96%, and in the control class, it rose by 65%. Therefore, the effect of the applied method on academic quality is 48% higher than conventional teaching, and 20% higher on the average grade compared to conventional teaching.

Conclusions

The null hypothesis (H0) was not confirmed. The alternative hypothesis (H1) was confirmed, as significant differences were found in the post-test results between the experimental and control classes. The effect of the applied method on the average mark was found to be 20% higher than conventional teaching. If we consider that conventional teaching has an impact factor of 0.4 and Flipped Classroom has an impact factor of 0.5 according to the Visible Learning and Teaching theory [11], then our results show that the Flipped Classroom method has an impact factor of 0.48. Thus, the results of our research are confirmed by the results obtained previously by other researchers.

The application of the Flipped Classroom method resulted in an increase in the number of students with marks ≥ 8 from 10 to 19, effectively doubling the percentage of high-quality marks. Additionally, in the experimental class, the mark „8" was the most frequently occurring grade (9 students), whereas in the control class, the mark „6" was the most frequent (10 students).

To implement the Flipped Classroom method, only the lesson plans need to be adjusted, focusing on the new topic. For the chapter „Rotational Equilibrium" the structure of the lesson was modified for three out of nine hours.

However, the effective application of this constructivist teaching method can be influenced by various institutional constraints, such as limited time, availability of resources, and technological infrastructure.

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Presented on 19.07.2024