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PAPER

Implementing the Flipped Classroom Model in Science Lessons for Junior High School Students

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ABSTRACT

The present study refers to the idea of the flipped classroom. The flipped or otherwise called inverted classroom is a modern teaching concept, which essentially reverses the terms of the traditional learning method. The students study the lesson beforehand, outside the classroom using new technologies, while the time inside the classroom is mainly devoted to discussions and solving questions by the educator, hands-on activities that stimulate the students' interest and connect the acquired knowledge with everyday problems. Reversing the traditional teaching process appears to be paying off for students, as since utilizing classical teaching techniques, their performance seemed to decline over time. For this purpose, the flipped classroom method was applied in a junior high school class in Athens, Greece, for Physics lessons during the 2022–2023 school year. At the end of the school year, the students that participated in the flipped classroom completed a survey that was developed jointly with the cooperation of the respective teachers who taught the course in order to establish the degree of the students' acceptance of the specific method. The results of the survey and a correlation of the students' performance who participated in the flipped classroom with the performance achieved by the rest of the students that followed traditional teaching methods, as well as with the previous year's students' performance who also followed the classical teaching model, are analyzed and discussed.

KEYWORDS

flipped classroom, junior high school, learning, physics, teaching

1 INTRODUCTION

Just a few decades ago, it was difficult to imagine a time when someone could obtain information about anything from the comfort of their office chair, with a push of a button, in a minimum amount of time. Although the research previously had a more romantic flavor with the scent of well-worn paper, one had to search for hours in encyclopedias and school textbooks or in the bulky volumes in the corridors of a university library for what they were looking for. Our era is distinguished

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by rapid technological advancement as a massive electronic revolution has occurred in the last 30 years. Pupils who are still in school currently are born during this period. Millennials, the students born in the 2000s, who are also called "digital natives" [1], have an inexhaustible reservoir of information at their disposal due to their access to digital media. Presently, in front of a computer screen, one can flip through the pages of any book, attend lectures, and, in general, be digitally connected to knowledge, with no waste of effort or time. But, with so much ease being so generously offered, have people become complacent? Is it assumed that everything can be mastered easily and quickly without any effort. The truth is not quite that simple; one would think, it is the opposite. Students in schools and universities appear to be performing worse in traditional face-to-face teaching, which is widely used [2]. Teaching in person was once the only way to pass on knowledge. However, education is more than just knowledge transfer; the way knowledge is provided is also determined by the purpose. In the traditional teaching model, students are viewed as a blank canvas when they enter the classroom [3]. It appears that this idea is no longer bearing fruit. Students' monitoring abilities have not changed, but their needs and capacities have [4]. As a result, a new teaching model that can present the curricula in a more interesting way must be developed and implemented [5]. Knowledge is the interaction between what the student already knows and what the instructor teaches [6]. This resulted in recognizing the students' original ideas prior to teaching, which was then given various names, such as alternative ideas, alternative frameworks, children's science, etc. [7], [8], [9]. Unfortunately, students frequently memorize most things without delving into them. School knowledge is usually restricted to the boundaries of the classroom and is only activated in exam subjects [2], [10], [11]. Based on the constructive model of Posner et al. in the early 1980s [12], [13], Professor McDermott in the USA [14], [15] and Professors Driver and Oldham in England [16] introduced their own proposals for Science teaching. According to this model, students and their alternative ideas are prioritized. During the learning process, a set of activities is followed, while the traditional teaching is limited. The student is now the main character in education, while the teacher's role is more supportive and guiding. Students are introduced to the so-called conceptual change through hands-on activities, investigative and experimental procedures.

In continuation of recent research in new technologies in the area of teaching and learning [17], this paper aims to present how the implementation of the flipped classroom affects students' performance.

The rest of the article is organized as follows. In section 2, the concept of the flipped classroom is presented, as introduced by Bergmann and Sams [18], [19], [20]. In section 3, a reference to previous research on the application of the inverted order is attempted, while in section 4, it is applied to the physics course in our respective sample and similar research is conducted. Sections 5 and 6 follow, presenting the results of the research and a discussion on how beneficial and effective was the implementation for the students. The paper ends with some concluding remarks and pointers for future research.

2 NEW EDUCATIONAL MODELS ARE EMERGING

In an era when almost everything has gone digital, education could not remain untouched by this historic development. The Educational community must keep abreast of developments and work for the benefit of students. New ways of teaching should be proposed that are more efficient and in line with the requirements of students and the times in general. The concept of the flipped classroom is therefore recommended as a step towards a constructive model of teaching and learning.

2.1 The constructivist model foreshadows the flipped classroom

Millennial students have grown up in a world where they can access information at any time and from any location, are active on social media, and have a general interest in the digital world [21]. The rapid advancement of technology has opened up new avenues and brought new perspectives in learning and teaching [22]. As a result, a teaching model that addresses these students' concerns, understands their interests, and engages them in the pursuit of knowledge would be more effective.

Any change, as commonly stated, is difficult and takes time to accept [23]. It has been evident in the recent years that students are dissatisfied and tired of school; therefore, it is a first-rate opportunity to re-engage them, re-establish lost confidence, and return the school to its proper place in society. Everyone, both teachers and students, must contribute to this effort. The concept of the flipped classroom is introduced in the footsteps of the constructive models envisioned by Driver, Oldham, and McDermott [14], [16], which are guided by the needs and alternative ideas of the students.

2.2 Flipped classroom

The concept of the flipped classroom has become a modern and popular teaching model in recent years, but it isn't entirely new. Our educational television, shows like "eureka" on Canadian television, or our teachers' instructions to read some small piece of material before hearing it for the first time from them could be considered a forerunner of this new model of teaching. What is truly novel is the systematic application of this asynchronous environment in the process of knowledge and learning through the use of new technologies [24]. In fact, combining the traditional teaching model with asynchronous education increases the likelihood of learning [25].

The research team of Associate Professor Lage had already been using the teaching method of the inverted classroom in an Economics Department of the University where they taught since 2000 [26]. Then, in 2007, another group of researchers implemented something similar in the Chemistry course of a high school in the United States [19]. This method became known as the "flipped classroom" [23], [27]. According to Bergmann and Sams [19], their concept began with listening to their students' needs and peculiarities. There were students in their classes who had abandoned the traditional classes due to their involvement in sports, students who were absent for any reason other than illness, students who couldn't keep up with the course's pace and sought assistance outside of class hours and students who were frequently unable to take proper notes. As Mazur mentioned, what is said and written on the blackboard often goes straight to the students' notebooks without first being filtered through their minds [2]. It was impossible for the teachers to personalize the lessons every time it was required, therefore, they considered creating a series of videos containing their lessons. As a result, an educational platform was created and all of this information was uploaded to it. Today, various platforms that are widely used by schools and universities have been exploited in order to promote proper interaction among the educational community, and thus students become more responsible towards their obligations. Google Classroom, Blackboard, Moodle, and other similar platforms are nowadays commonly used [28], [29].

According to Bergmann and Sams' flipped classroom model, students can watch beforehand videos of the lectures related to the lesson that will follow in the classroom. It is critical for the entire lesson to be condensed into a video that is no more that 4 to 6 minutes long [23]. These videos, in fact, do not have to be created by teachers, but can be derived from videos already posted on free platforms such as YouTube, TeacherTube, Technology - Entertainment - Design (TED), and Khan Academy, which contain an extensive amount of material. However, it has been observed that students feel more familiar and secure when they hear their own teacher's voice in the videos [30], but they also resent videos that are longer than 15 minutes [5]. There is so much material available through a quick internet search that it would be interesting for students to watch videos from different teachers to get a more rounded view of the subject and see how the same subject is approached from different perspectives. This type of research could be the first step in cultivating their scientific interests. In other words, Bergmann and Sams proposed an alternative for the traditional model of teaching; what is due in class will be completed at home and what is due as homework will be completed in class [19] (Figure 1). As a result, each student, present or absent, can now receive individualized instructions. Also, every student in each class, each day, may be addressed by the teacher, rendering this method of teaching more efficient [18], [20], [23].

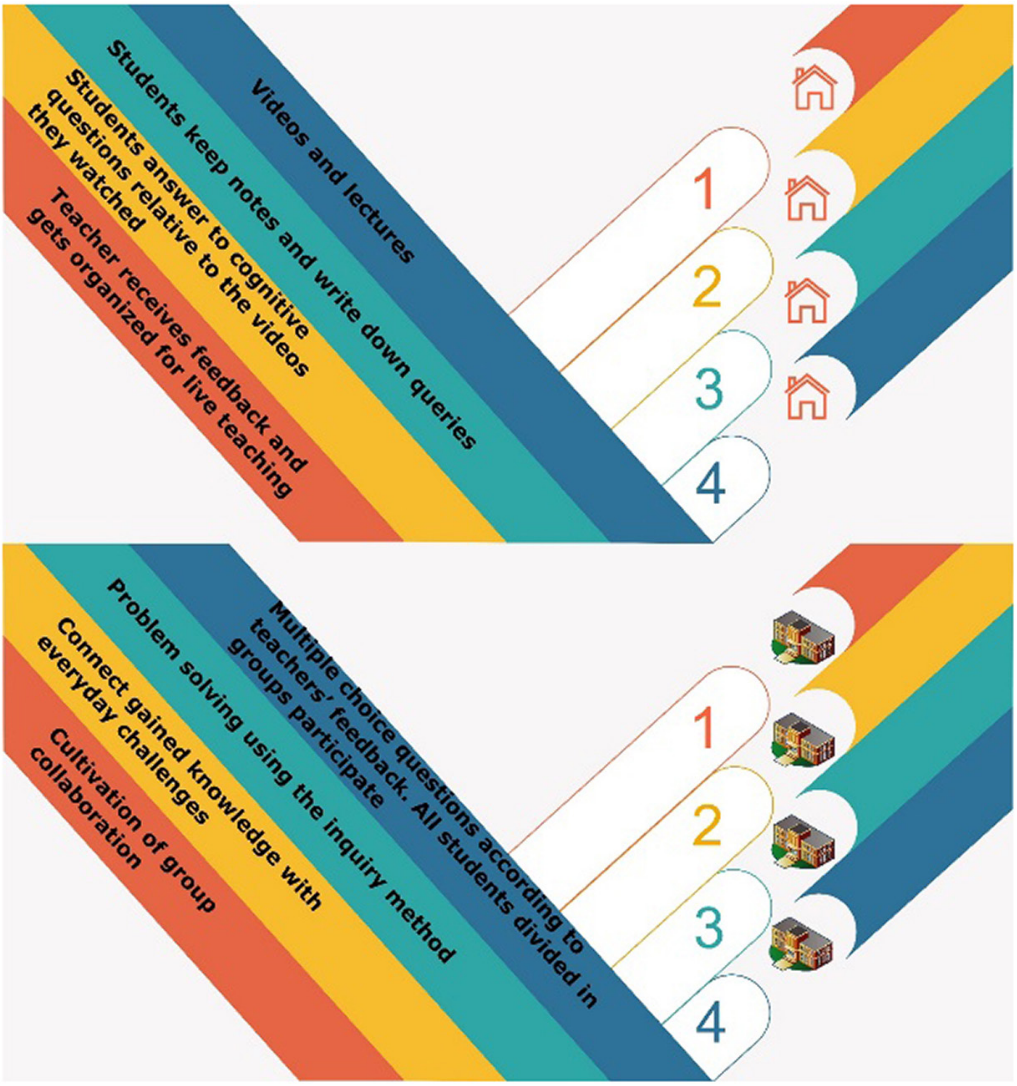

Fig. 1. The model of the flipped classroom

Simply watching videos and passively reading the supporting material is meaningless. Students should take notes on what they see in the videos and write down any questions they have [31]. Students are given the opportunity to better organize their study time in this manner, and as a result, they become more responsible [32]. The benefits of the flipped classroom include the fact that the supporting material is always available on the educational platform and, as a result, students can watch it as many times as they want [33], again and again, learning with their own rhythms and, ultimately, achieving better results [34]. In the asynchronous teaching phase, the flipped classroom model includes completing questionnaires along with the videos that students watch to get them more actively involved in the teaching and learning process [27]. As a result, the teacher can better organize the live teaching based on the weaknesses he discovers in his students [30]. The purpose of the flipped classroom, however, is to ensure valuable time in the classroom for more meaningful topics of a higher level, problems of daily life, and hands-on activities [32], [35], [36]. To summarize, the flipped classroom improves and promotes active learning [37]. Additionally, a short questionnaire is a common way for the teacher to begin his live lesson. Students can use their clicker devices to answer the teacher's short quizzes in a modern and fun way [2]. A clicker device, also known as a classroom response system or student response system, is a tool used in educational settings to engage students and promote active participation during a lesson. The device typically consists of a handheld remote that allows students to respond to questions or prompts presented by the teacher. The teacher immediately receives their responses on the computer, and based on the feedback, new challenges for the students are prepared and the points that are not as clear and easy to understand are clarified. Of course, there are cost-effective solutions, such as the Socrative software [30]. Students then respond to the new challenges using a computer or a mobile phone app, and the teacher receives the responses instantly, automatically extracting statistics that help provide an indicator of how students are responding to cognitive challenges.

At this point, the exercises that would normally be completed at home are carried out. The teacher's role here is not simply to provide information to the students, but mainly to be supportive and encouraging. The instructor poses closed-ended questions for students to answer individually or in groups, guiding, consulting, and explaining the difficult questions. Students' homework assignments, which were previously completed at home, are now completed on the board with the participation of all students and the assistance of the teacher through an investigative process. Through this process, the social role of teaching is highlighted in addition to its constructive nature [38]. Students interact and socialize with one another. In general, they are activated by taking an active role in the process. Mazur [39] used a similar method in the classroom with student-to-student interaction. Even the most hesitant students are encouraged to express their opinions, participate in the classroom, and regain their lost motivation for the lesson [21]. The more advanced students serve as mentors to the less advanced students. Teaching is becoming more inventive, so that learning is acquired through a fun mental game.

The reduction of knowledge from the theoretical to the practical level in the classroom and its simultaneous connection with everyday life is a key component of the flipped classroom. Students are now asked to apply what they've learned to real-world problems rather than paper exercises. Physics is a living science that is inextricably linked to everyday life and can provide such challenges because students are constantly wondering what all of this information is for. Is it just useless information, or is it directly applicable to our lives? As a result, when students are confronted with real-world problems, they will perceive the corresponding lessons in a new light and recognize their significance. Blended learning is therefore defined as the above-mentioned combination of a modern environment with students present in the classroom and simultaneous asynchronous teaching with digital facilities provided by technology [24].

3 PREVIOUS STUDIES

In general, the opinion of students in schools, particularly universities, in relevant research leave a positive impression on the operation of the flipped classroom. While Blair's research [40] found no differences in the results of students taught using the traditional model versus those taught using the flipped classroom model, a number of other studies highlighted students' remarkable improvement and understanding of concepts. The flipped classroom appears to favor student involvement and active participation in the teaching process over the traditional model's passive attitude [5], [27], [33], [36], [41], [42], [43], [44], [45]. The negative aspect of the entire process is the potential difficulty in accessing the internet, as it may not be attainable for all students [46], [47], as well as their lack of technological knowledge [48]. The flipped classroom model is used in a variety of academic fields. However, because of their unique ability to interpret what happens around us in a practical way and through hands-on activities, sciences may be the area where the inverted classroom has the greatest impact [49]. Following the COVID-19 pandemic and the upgrading of students' skills via online courses via the Webex platform, the need to implement the flipped classroom became increasingly important.

The aim of this work was to conduct a similar study to see how students in a junior high school of Athens, Greece, perceives the implementation of the flipped classroom in Science and in particular in Physics. As previously stated, the science of Physics is appropriate for the application of this model. Traditional teaching that fills the blackboards with formulas, laws, symbols, and numbers reinforces students' negative attitude towards a meaningless lesson. Pythagoras was the first to argue that mathematical equations can describe the works of Nature. It is, therefore, time to emphasize the importance of Physics, gradually deconstructing students' perceptions and making them understand how practical science is and applicable in everyday activities.

4 IMPLEMENTING THE FLIPPED CLASSROOM

At the end of the school year, students involved in the flipped class process completed a questionnaire, the statistical analysis of which resulted in the collection of estimates regarding their opinion of the new teaching technique.

4.1 Participants

The specific junior high school in Athens has three classes with a total of 64 students. The flipped classroom was chosen as a teaching method based on the most populous one. As a result, the class with 22 students was chosen as our research sample. Physics was chosen as the subject to follow the flipped classroom model, always in accordance with the curriculum. The other two classes, with 21 students each, used the traditional teaching method.

4.2 Process

At the beginning of the school year, it was announced to the students that they were chosen to follow the model of the flipped classroom in Physics, always following the current curriculum. According to the curriculum, Physics is taught twice a week. In the first week, the teacher informed the students about the way the lesson would be conducted. The educational platform used was Google Classroom, as almost all students already had Google accounts. Thus, they were informed about the respective application and were instructed to install it on their mobile phones, tablets or computers. It was also ensured that all students faced no difficulties connecting to the internet at home. Thus, everyone could watch the material that would be uploaded to the platform. A video related to the subject, not exceeding five minutes in length, was uploaded to the platform prior to each lesson. Khan Academy, the YouTube channel "Noesis Science Center" and other sources were used to present everyday subjects, while several presentations were made by the teacher himself, who videotaped the lesson in OneNote of the Office suite. As a result, the teacher's voice reached the students' homes as if they were in the classroom. Also, relevant material in PowerPoint or PDF format containing theory elements was posted on the platform alongside with the video. Students were instructed to study what was uploaded and to take notes on course characteristics and mark any questions they may have. In addition, students could watch videotaped experiments from the instructor's channel. At the end of each video presentation, the students were required to answer a short questionnaire related to the material given to them. The questionnaire basically contained multiple choice questions to easily evaluate students; short answer questions were thus avoided. The questionnaire had to be completed by the evening before the lesson. In this way, the teacher could receive the feedback directly on the computer, record the statistics of each question and accordingly prepare the next day's lesson.

In the traditional classroom, the theoretical background presentation inevitably leads to the minimization of experimental time, activities and communication in the school environment, since face-to-face teaching often monopolizes the lesson. The students, who would be taught using the flipped classroom method, understood from the beginning of the school year that the lesson would be presented each time in the school's science laboratory.

Worksheets (see Appendix) with lab exercises were distributed at the beginning of the lab lesson. The students were divided into groups of four and given 15 minutes to complete the worksheet. Each group had to present the exercise to the class, along with their proposed solutions. The result was a fruitful dialogue with the entire class as each student voiced his or her opinion, in an atmosphere of cooperation and respect. In any case, the teacher, passing through each group, listened to their opinions and guided them in the right direction. For example, the 3rd year junior high school students gained special familiarity with electrical circuit construction, as the videos they had already watched contained instructions for it. A worksheet of this type can be found in the appendix.

Following the completion of problem solving, a brief knowledge test was given to the pre-existing groups. The platform's content included questions and exercises for students to complete in their spare time. The teacher then examined the students. In the final minutes, the teacher was attempting to clarify the complex parts of the lesson, pointing out the students' errors and misconceptions and connect the knowledge gained to everyday problems, with the aid of PowerPoint presentations whenever necessary to make it more illustrative.

4.3 Survey

At the end of the school year and to determine the degree of agreement of the students taught with the flipped classroom teaching method, a printed questionnaire of five questions with four possible choices based on a Likert scale was handed to them (Table 1). The survey results are then tabulated, presented in pie charts and statistically analyzed.

Table 1. Survey addressed to the 22 students who completed the school year 2022–2023 and were taught according to the flipped classroom model in Physics

No	Questions	Strongly Disagree	Disagree	Agree	Strongly Agree
1	Watching the videos and receiving supporting material before the lesson helped me understand the course.				
2	The videos and supporting material were clearly prepared and aided in adapting the course's more difficult points.				
3	The lesson in its classic form of teaching is preferable to hands-on activities.				
4	Classroom activities and teacher questions seem equally difficult despite the help of asynchronous teaching.				
5	The supporting material presentation in asynchronous teaching can reduce the teacher's need for synchronous teaching.				

5 RESULTS

The survey responses are presented in Table 2 that exhibits the number of students who gave each answer (n_i), as well as their percentage (%). It should be noted that all students (22) answered all the questions.

Table 2. Results and response rates (%) to each question

Questions	Strongly Disagree	Disagree	Agree	Strongly Agree
No	n_i (%)	n_i (%)	n_i (%)	n_i (%)
1	2 (9%)	4 (18.2%)	6 (27.3%)	10 (45.5%)
2	3 (13.6%)	5 (22.8%)	7 (31.8%)	7 (31.8%)
3	8 (36.3%)	6 (27.3%)	5 (22.8%)	3 (13.6%)
4	5 (22.8%)	9 (40.9%)	6 (27.3%)	2 (9%)
5	11 (50%)	7 (31.8%)	3 (13.6%)	1 (4.6%)

The above results could be summarized in Figure 2, where the percentage ratio (%) of each response to the corresponding questions is shown.

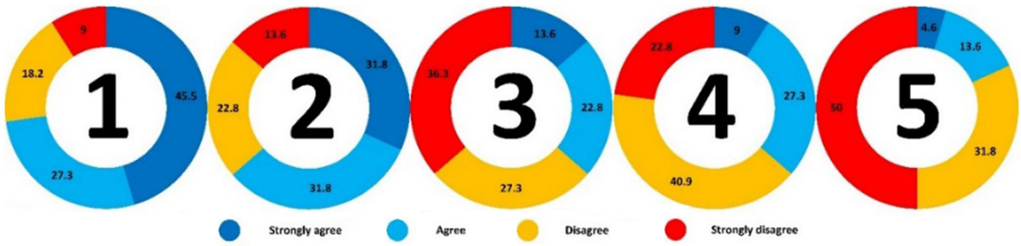

Fig. 2. Percentage ratio (%) for each response to questions (1–5) (strongly disagree: red, disagree: orange, agree: light blue, strongly agree: blue)

6 DISCUSSION

Figure 2 contains five numbered diagrams, one for each of the questions. Each diagram has the corresponding number of the question in the center, and the percentages of each answer are shown in a different color circle depending on the answer (Strongly disagree: red, Disagree: orange, Agree: light blue, Strongly agree: blue).

According to the data above, a percentage of 75% (27.3% replied "agree" and 45.5% replied "strongly agree") finds the supporting videos useful, while more than 60% (31.8% replied "agree" and 31.8% replied "strongly agree") believes the specific videos achieved their purpose, as they were precise and clarified easily misinterpreted points. Our research has confirmed what was hypothesized; students are becoming dissatisfied with face-to-face instruction and would prefer a method that involves them more actively in the learning process. Thus, more than 60% of the students (36.3% replied "strongly agree" and 27.3% replied "agree") want to switch to a more constructive teaching model. Students in the flipped classroom had the opportunity to use the laboratory and pass from theory to practice with the activities they had to carry out. Despite the change in teaching flow, several students, at a rate close to 40% (27.3% replied "disagree" and 9% replied "strongly disagree"), still seem to struggle with the Physics questions. However, what is strongly highlighted is the need for a face-to-face teaching in the classroom, as reflected in the fifth question with an overwhelming percentage of 80% (50% replied "strongly disagree" and 31.8% replied "disagree").

So, after a school year of using the flipped classroom model in Physics, it was found that such a teaching method produces more responsible and consistent students. Both students and teachers became more involved and hardworking. Of course, the teachers needed organization, coordination, and time to prepare while students had to keep their ears and brains tuned to receive their teachers' messages. On both sides, there was a constant preoccupation with the subject. The students' trust in the teacher was strengthened and the interaction between students, as well as the interaction between teacher and student, was encouraged. Time spent in classroom became more efficient. The students' passive attitude was abandoned as the new activities enabled them to play a more active role in the teaching process. Cooperation is gaining traction, with even the most hesitant and introverted students now putting themselves forward without concerns or limitations.

As a result, the students appear to have regained their lost interest. The use of digital technology in the classroom, which has now become an integral part of students' lives, is bearing fruit. This can be further supported not only by comparing the mean scores from quizzes of the flipped classroom with the corresponding mean scores of the other two classes, but also with the mean scores of previous year classes that were taught using the traditional model. Of course, the sample size was small and the students' performance varies from year to year, but no one can deny the increased student participation and the freshness brought about by the implementation of flipped class in the minds of the students.

As a result of this investigation, the application of the flipped class could be expanded to more fields of Physics, as well as other courses of the curriculum. At the same time, teacher trainings related to this method should start, so that they understand in depth the significance of technology in their teaching. Perhaps the most important stake is a higher quality and more substantial involvement of students in the learning process.

7 CONCLUSIONS

To summarize, all changes require persistence and time to be successful. Not everyone is open to change, both students and teachers, who are accustomed to teaching in the same manner in which they were taught. Any resistance on either side can be overcome with proper explanation, guidance, and training. Certainly, the task is difficult, time-consuming, and demanding. It necessitates more responsibility on the part of students and teachers, but all of this effort results in more substantial knowledge. Students are more motivated as they are more interested in the subject, and one of the school's main goals, which is socialization, is being met to a large extent. Thus, everything is done for the students' needs and in the right direction [50], and the only requirement is that teachers must encourage their students to use technology to their advantage in the learning process. The greatest bet for teachers will be the expansion of the application of the flipped classroom to more fields of Physics, but also more broadly to more subjects of the curricula.

To this end, we plan to continue in this direction, using the outlets provided by technology to regain students' lost interest in learning. The flipped classroom is one such tool, which can, in fact, offer personalized teaching according to the requirements and specificities of the students. Future research will be required to establish and highlight its significance as reflected in student performance.

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9 APPENDIX

9.1 Worksheet on Ohm's law

Aim

Investigate how electric current, electric voltage and resistance are related in circuits due to fixed resistors and light bulbs.

Theory

The resistance R of a fixed resistor or light bulb is given by: $R = \frac{V}{I}$

Apparatus

1.5 V cells
Ammeter
Voltmeter
100 Ω fixed resistor
6V light bulb
Knife switch
Connecting wires

Procedure

Set up the circuit shown in Figure A1 using 1.5 V cell and measure the electric current I.

Add a second 1.5 V cell in series with the first and record the measurement for the current I.

Continue adding 1.5 V in series and record the new measurement for the current.

Using the mathematical equation for the resistance, compute the quotient for each case.

Fill in the Table A1.

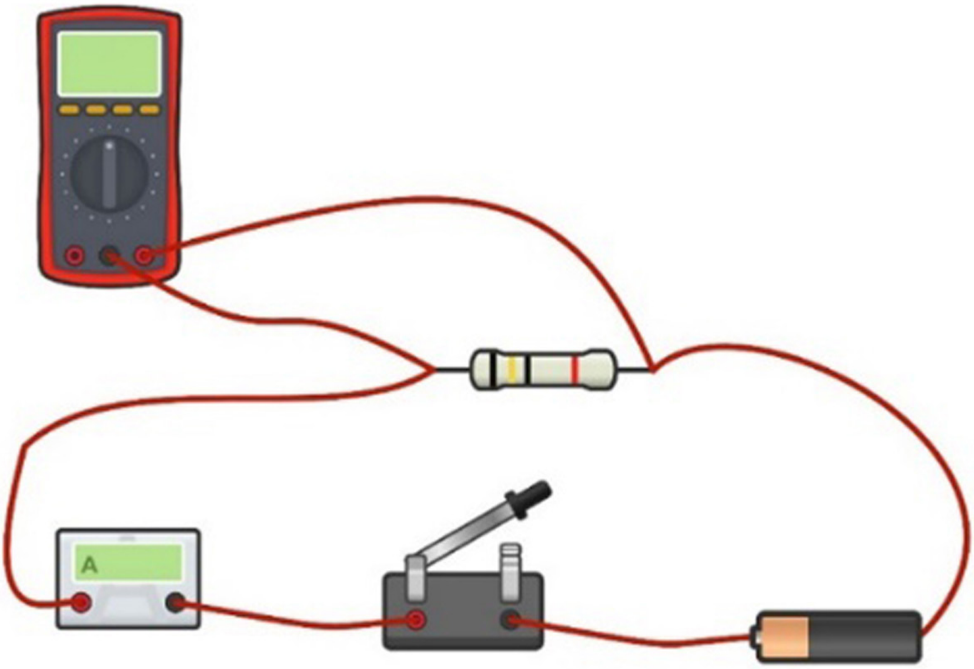


Fig. A1. Electric circuit with fixed resistor

Table A1. Experimental measurements of voltage, current and resistance of the fixed resistor circuit

Voltage (V)	Electric Current (A)	Resistance (Ω)

Write down your observations about the resistor's resistance values. How would you characterize the relationship between the voltage (V) and the electric current (I) for this fixed resistor?

Plot a graph to show how the current I varies with the voltage V.

Calculate the slope of the graph you plotted above to determine the resistance R.

What is the current through the resistor if the voltage across it is changed to 36 V?

Replace the circuit's resistor with a 6 V light bulb as shown in Figure A2. Record the measurements of the current in the circuit while varying the voltage and fill in Table A2.

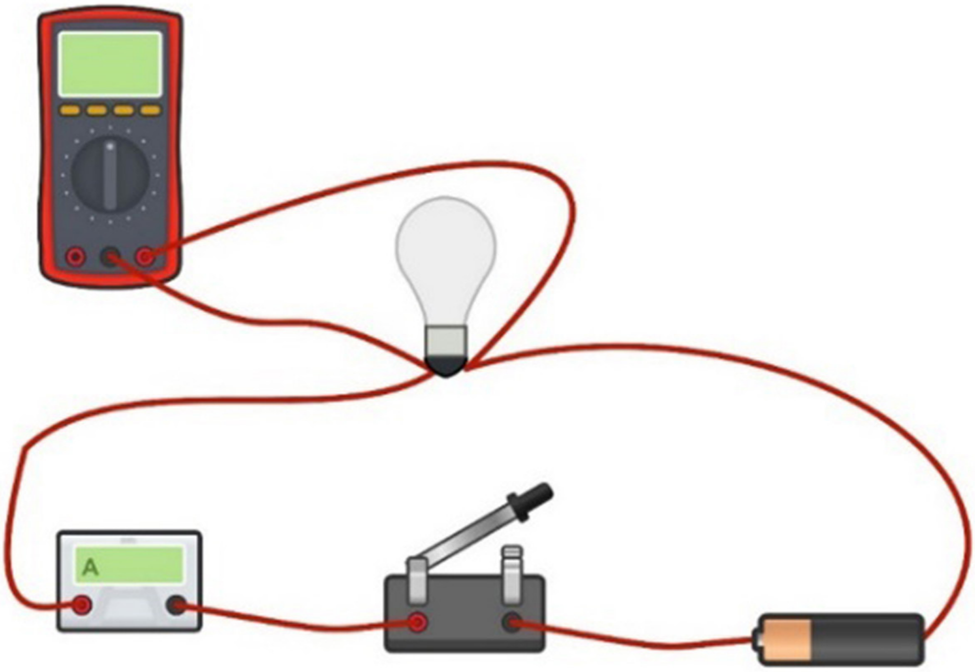


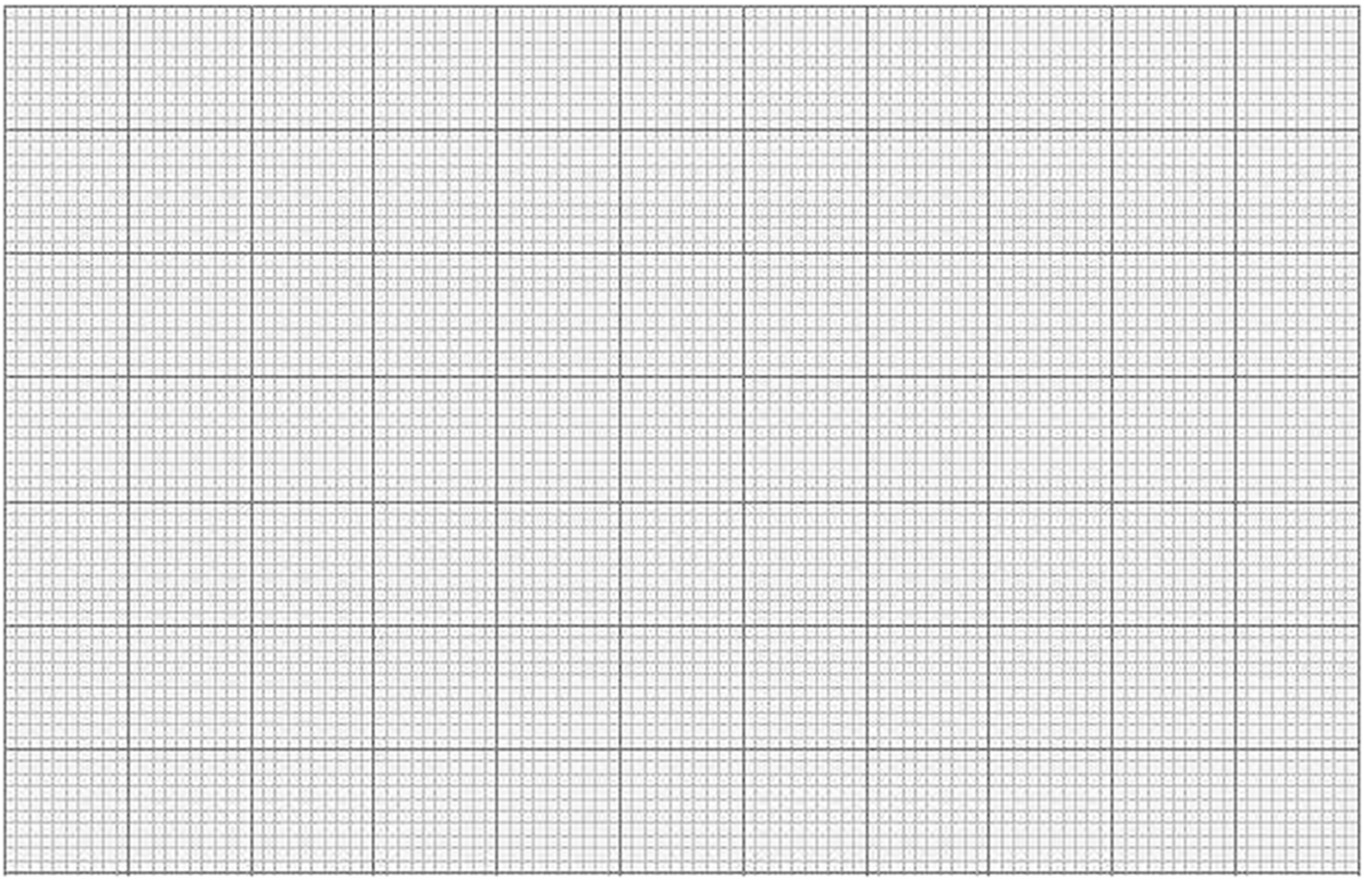
Fig. A2. Electric circuit with light bulb

Table A2. Experimental measurements of voltage, current and resistance of the light bulb circuit

Voltage (V)	Electric Current (A)	Resistance (Ω)

Write down your observations about the light bulb's resistance.

Plot a graph to show how the current I varies with the voltage V.



Does the light bulb obey Ohm's law? Explain your reasoning.

Contrast the behavior of the resistor and the light bulb in the circuits above. Give two reasons to support your answer.

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