12th International Conference of the Immersive Learning Research Network
iLEAD Proceedings iLRN2026

DOI: https://doi.org/10.56198/k69y8h52

Teaching Approach for the Concept of Electromagnetic Induction and the Operating Principle of a Generator for Primary School Students

Theodoropoulou Maria

Laboratory Teaching Staff, Department of Educational Sciences and Social Work, University of Patras, Greece
mtheodo@upatras.gr

Abstract. This extended abstract focuses on teaching concepts of Electromagnetism to students in the 6th grade of Primary School. Specifically, an educational scenario has been created, which focuses on teaching the concepts of electromagnetic induction and by extension, the principle of operation of the generator. The proposed teaching scenario is based on the Inquiry Based Learning Model. The teaching stages in the proposed approach are initially an introductory stimulus with the formulation of hypotheses, followed by experimental treatment with the extraction of conclusions and ending with the consolidation and generalization of knowledge. Initially, a comic was created using the free Pixton application. Different students play a character from the comic, ending with an introductory question, which is the trigger for formulating hypotheses and introducing new knowledge. In addition, simple devices were constructed where by rotating a magnet it is possible to turn on an LED bulb. These devices were used by the students during the experimentation stage in addition to an online simulation. In the consolidation and generalization stage, students complete a crossword puzzle created for this purpose and answer specific questions through an interactive video. The proposed teaching scenario was implemented in the 6th Grade of the 3rd Primary School of Patras and the sample was 16 students, 10 boys and 6 girls. The completion of this specific scenario required 2 teaching hours. Finally, an evaluation worksheet was completed by the students and the results are discussed and analyzed.

Keywords: Induction, Electromagnetism, Generator, Digital Games, Inquiry Based Learning.

1 Introduction

Play has been recognized as an important factor in cognitive development and learning in both children [1] and the elderly [2]. The concept of game-based learning includes activities that follow the characteristics and principles of the game and have specific goals aimed at enhancing knowledge and skills [3]. Other researches state that [4], game-based learning can include digital simulation, video games, interactive tasks, games, role-playing, and modeling. It often includes gamification elements, such as leaderboards, points, and badges, to enhance competition, interaction, and therefore motivation for learning. In science teaching, game-based learning is an effective method to support students' learning of scientific knowledge [5]. Studies report that game-based learning not only has positive effects on learning, but can also enhance students' self-efficacy [6–8]. With these advantages, more and more researchers and educators are beginning to emphasize the integration of game-based learning into science teaching. Furthermore, the use of comics in science teaching is a useful teaching tool that helps teachers teach complex scientific topics in a short, appropriate and effective way [9]. They are also used to engage students in complex hypothetical scenarios before engaging them in experimental activities in the classroom [10]. One of the Physics concepts that students have difficulty understanding is electromagnetic induction. The vast majority of students have difficulty accepting that it is possible to generate current in a circuit without a battery. Because they are used to changing batteries in everyday devices, they believe that these are the only sources of electrical energy, even if there is a bicycle that is electrically autonomous with the help of a generator. This work studies the effectiveness of Inquiry Based Learning in teaching the concepts of electromagnetic induction and, by extension, the principle of operation of the generator, using both interactive-experiential activities and didactic digital tools such as comics, simulations and interactive videos.

2 Teaching Scenario

This teaching scenario is proposed to be carried out in two (2) teaching hours and is addressed to students of the 6th grade of Primary Schools in the context of the "Physics" course and specifically in the chapter on Electromagnetism. Before implementing the scenario, students should already know the magnetic properties of magnets, the magnetic properties of a conductor carrying current, and how to construct an electromagnet coil. After the end of the lesson, students should be able to explain in simple terms the phenomenon of induction and, by extension, the operating principle of the generator, to recognize the factors on which the induced voltage depends, to distinguish the two main types of electricity generation plants and list some of the main machines they use. Finally, be able to connect electrical with magnetic phenomena, understanding the word "Electromagnetism". This specific teaching proposal has been implemented based on the inquiry learning model [1] which is a model of guided inquiry and consists of the following stages: 1) Student orientation - Provoking interest - Formulating hypotheses, 2) Experimental treatment - Drawing conclusions and 3) Consolidation - Generalization. Students in the first phase of teaching, namely that of introductory activities and hypothesis formulation, work individually, while in the remaining phases they work in groups, in collaboration with 3-4 other students. Regarding students' perceptions of electric generators and induced voltage, students have difficulty understanding that induced voltage is created in a metal coil not only by moving the magnet relative to the coil, but also by moving the coil relative to the magnet. Also, that in the generator the light is turned on by the movement of a magnet inside a coil or vice versa and not by the movement of the foot or hand. Finally, that the magnetic field exists not only around a magnet, but also around a conductor through which current flows. To implement the activities, a computer, video projector or interactive whiteboard, and a handheld flashlight are required. Also, in the Experimentation phase, self-made devices are used (Fig. 1), specifically electric generators, which are shared among the children's groups and have been constructed either by the teacher or by the students depending on the time available to carry out the scenario. In this work, they were constructed by the teacher and consist of copper wire, cardboard, magnets, metal rods and LED lights. The purpose of the self-made electric generator is for students to comprehence how the movement of the magnet inside the coil produces electric current. Furthermore, in order for students to understand that the induced voltage is created by the relative motion of a magnet and a coil, a simulation was performed.

Fig. 1. Construction of an electric generator.

2.1 Phase 1: Student Orientation – Motivation – Hypothesis Formulation

Initially, there is a brief review of the concepts that the students have been taught and are necessary for the conduct of the lesson and the introduction of new knowledge. Then the teacher states that: "We talked about how from electricity we "get" to magnetism. That is, a conductor through which current flows acquires magnetic properties. But is the reverse also possible?" Then follows the 1st activity which concerns a Role Play. The teacher shows a comic and "assigns roles" to the students so that one student plays a character from the comic by reading his words aloud. At the end of the comic, they end up with the question "Is there something we could use to light up the space?" The purpose of this specific activity is to record students' perceptions regarding the production of electricity from alternative sources and not just from batteries. The teacher records the students' answers/assumptions on the board, without commenting on whether they are correct or incorrect. The comic was created using the free "Pixton" application and Fig. 2 shows its last page, with the introductory question. Afterwards, the teacher demonstrates a hand-held flashlight to the students (Fig. 3), removes its battery, moves the flashlight handle, causing the lamp to light up. The purpose of this specific activity is for students to see up close the production of electrical energy with the movement of the handle and to connect it to the previous activity where the children had their bicycles with them, in which the generator plays the same role. Then, he encourages them to complete the 1st Worksheet that has been given to them. Indicative questions mentioned in the worksheet are: “How do you think the light bulb turns on?” and “If we stop turning the handle, do you think the light bulb will continue to turn on?”

Fig. 2. Sample from the comic.

Fig. 3. Hand-held flashlight.

2.2 Phase 2: Experimental Treatment / Observations

In the Second Phase of the Teaching Scenario, students are divided into groups. Each group is given a self-made electric generator, which was mentioned previously (Fig. 1). The aim of this specific activity is for students to explain in simple terms the phenomenon of induction and, by extension, the operating principle of the generator and to distinguish the elements of which it is composed. Students are asked to rotate the handle (metal rod) and record their observations on the 2nd Worksheet. Together with the teacher, they draw their conclusion from the specific experiment and record it using the appropriate scientific vocabulary. Then, the teacher presents the layout of the generator to the students (Fig. 4) and asks them to distinguish two of its elements. He explains how it works (the light comes on with the movement of the wheel, which rotates a magnet) and states that this is the simplest form of generator. Then follows the 2nd Activity which includes a simulation regarding the electromagnetic induction https://phet.colorado.edu/en/simulations/faradays-law. This particular simulation aims to help students identify the factors on which the inductive voltage depends. Here some students can act as assistants, following the instructions in the 2nd worksheet and performing the individual stages of the simulation (leaving the magnet motionless inside the coil, moving it slowly or quickly, and adding a coil with more turns). The remaining students observe, record their observations and answer the questions.

2.3 Phase 3: Consolidation - Generalization

After conducting the experiments, students watch two interactive videos related to the process of generating electricity in a steam power plant and a hydroelectric power plant:

(https://content.e-me.edu.gr/wp-admin/admin-ajax.php?action=h5p_embed&id=1367403),

(https://content.e-me.edu.gr/wp-admin/admin-ajax.php?action=h5p_embed&id=1359868)

These videos have embedded questions that students must answer during their viewing. At this stage, students work individually. Then, in collaboration with their group, they find similarities and differences between the two factories, which they record in the table found on the 3rd worksheet. The aim of this activity is for students to comprehend the two main types of power plants and to name some of the main mechanical parts they have. Afterwards, the teacher displays on the interactive whiteboard a crossword puzzle found at the link: https://crosswordlabs.com/view/electrical-generator. Students answer individually and the teacher simultaneously fills it in. Finally, a quick recap is done with the help of a "mind map" that the teacher has prepared and displayed (Fig. 4).

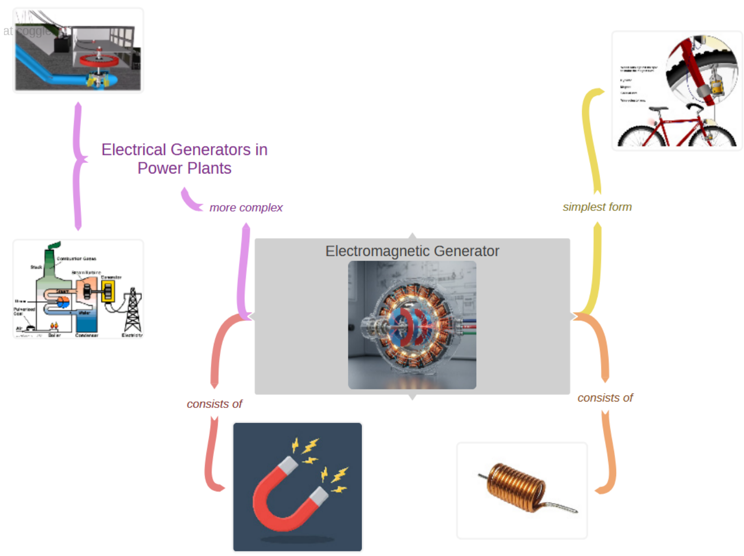

Fig. 4. Mind map.

3 Teaching Scenario Application-Results

The proposed teaching scenario was implemented in the 6th Grade of the 3rd Primary School of Patras in the context of the Practical Exercise of the 8th semester students. The sample consisted of 16 students, 10 boys and 6 girls. The completion of this specific scenario required exactly 2 teaching hours. The conclusions that emerged from the students' answers to the worksheets are as follows:

- In the 1st Worksheet and the question: "How do you think the flashlight turns on?" where the students' alternative idea regarding the handheld flashlight and the operating principle of the generator is recorded, the majority of students answered that the light turns on with the movement of the hand and only one student out of 16 thought that the movement of the hand is not enough but we also need something else (e.g. a magnet).
- In the 3rd Worksheet concerning the process of generating electricity from a steam and hydroelectric plant, to the question: "Does the movement of the turbine contribute to the production of electricity?" 50% (8 out of 16 students) answered that this sentence is correct. However, it is incorrect as the movement of the magnet and not the turbine is what contributes to the production of electricity. It seems that, even after the 2nd phase of the scenario concerning the experiment and simulation, a portion of the students continue to attribute the development of inductive voltage and current to a mechanical cause and to something they see with their eyes and not to the rotation of the magnet inside a coil.

This fact suggests that one of the teaching objectives was not sufficiently achieved. At the end of the lesson, students were given a quantitative teaching research questionnaire, which consists of 5 closed-ended questions and one open-ended question. The closed-ended questions follow the 4-point Likert scale with answers of "Not at all", "A little", "A lot" and "Very much". The results are as shown in Fig. 7. More specifically:

1. To the question Q(1): "The material taught was well organized", 14 students answered "Very much" while only 2 answered "Very".
2. To the question Q(2): "Were new technologies utilized for teaching the course", 11 students answered "Very much" while 5 answered "A lot".
3. To the question Q(3): "New knowledge and skills acquired", 12 students answered "Very much" while 4 answered "A lot".
4. To the question Q(4): "The teacher activated interest in the lesson", 14 students answered "Very much" while only 2 answered "Very much".
5. To the question Q(5): "The activities (experiments/simulations) help in acquiring comprehensive knowledge about the course", 11 students answered "Very much" while 5 answered "A lot".

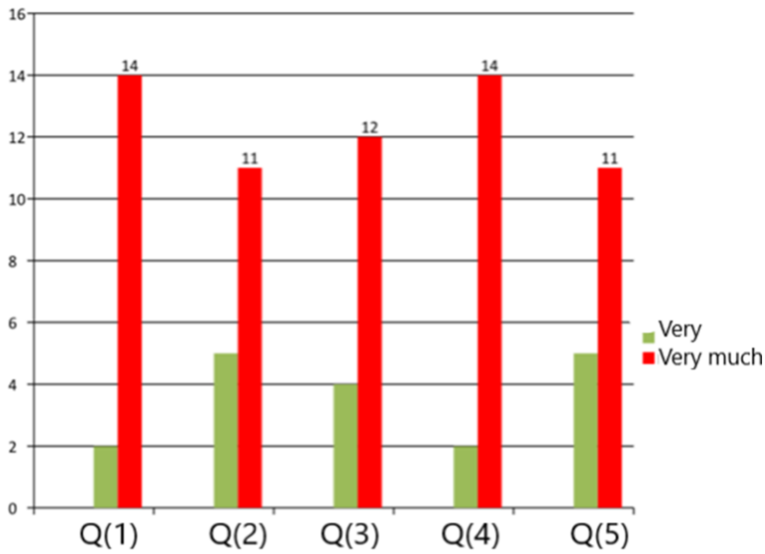

Fig. 7. Bar chart of distribution of students' answers to closed-ended questions.

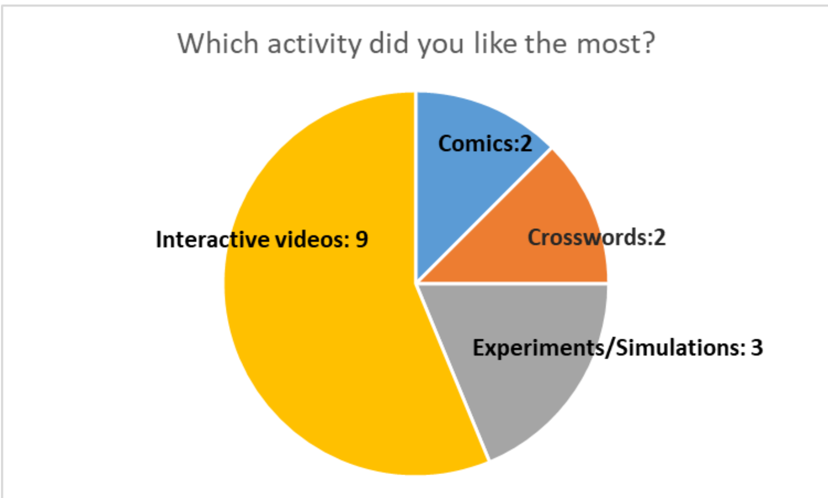

Fig. 8. Distribution of students' responses to the question: "Which activity did you like the most?"

The open-ended question was: "Which activity did you like the most and why?" Based on the students' responses, the activity they liked the most was interactive videos with a number of 9 out of 16 students. Experiments and simulations followed with a number of 3 out of 16 students, while last in the students' preferences were comics and crossword puzzles with a number of 2 out of 16 students. The students' responses are summarized in Figure

2. Regarding the reason why they liked each activity, the students' responses varied. Some chose the interactive videos because they saw them as a game, while others because of the good questions. Those who chose the experiments said they liked the fact that they worked as a team. Finally, they chose the comic book and the crossword puzzle because they were relaxing and fun.

In conclusion, after the implementation of the teaching scenario, students managed to understand the basic principles of the electromagnetic induction. They understood how they can produce an inductive current through a simple form of a generator (dynamo in a bicycle) and through the experimental process, they found out the factors on which the inductive voltage depends. The difficulty of the students was identified in distinguishing the basic parts of steam and hydroelectric power plants and also to recognize that the process of generating electricity is identical to the generators they have implemented on previous experiments. Furthermore, we believe that this educational scenario could also be applied to junior high school students, where according to the curriculum they should be able to comprehend the electromagnetic induction as well as the process of generating electricity from electrical generators.

References

1. Piaget, J.: Play, dreams and imitation in childhood, WW Norton & Co, New York (1952).
2. Oppl, S., & Stary, C.: Game-playing as an effective learning resource for elderly people: encouraging experiential adoption of touchscreen technologies, Univ. Access Inform. Soc. 19 (2), 295–310 (2020).
3. Qian, M., & Clark, K. R.: Game-based learning and 21st century skills: a review of recent research, Comput. Hum. Behav. 63, 50–58 (2016).
4. De Carvalho, C. V.: Is game-based learning suitable for engineering education? Proc. 2012 IEEE Global Eng. Educ. Conf. (EDUCON), 1–8 (2012).
5. Theotokatou M., & Theodoropoulou, M.: Reconstructing the Ideas of Students of Pedagogical Departments Regarding the Concept of Speed and Rectilinear Smooth Motion, Immersive Learning Research-Practitioner, 1-6 (2025).
6. Meluso, A., Zheng, M., Spires, H. A., & Lester, J.: Enhancing 5th graders' science content knowledge and self-efficacy through game-based learning. Computers & Education 59(2), 497–504 (2012).
7. Sung, H. Y., & Hwang, G. J.: A collaborative game-based learning approach to improving students' learning performance in science courses. Computers & Education 63, 43–51 (2013).
8. Hung, C. M., Huang, I., & Hwang, G. J.: Effects of digital game-based learning on students' self-efficacy, motivation, anxiety, and achievements in learning mathematics. Journal of Computers in Education 1(2–3), 151–166 (2014).
9. Morel, M., Peruzzo, N., Juele, A. R. & Amarelle, V.: Comics as an educational resource to teach microbiology in the classroom. Journal of microbiology & biology education 20(1), 1-4 (2019).
10. Upson, M., & Hall, C. M.: Comic book guy in the classroom: The educational power and potential of graphic storytelling in library instruction, Kansas Library Association College and University Libraries Section Proceedings 3(1), 28-38 (2013).
11. Σκορδούλης, Κ. & Σταφανίδου, Κ.: Διδακτική Μεθοδολογία των Φυσικών Επιστημών, Θεωρία και Πρακτική. Εκδόσεις Προπομπός, Αθήνα (2021).