THE EXPERIMENTS WITH A TRANSFORMER IN HIGH SCHOOL

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Abstract: This article describes the education of secondary school pupils in relation to a set of experiments using a school transformer and the Tesla coil. The set of practical experiments consists of 9 that can be used in the teaching of pupils of physics at secondary school in the thematic unit relating to electricity and magnetism. Each experiment contains a description of the relevant section of the International Standard Classification of Education in which it can be used. These descriptions include a motivational title, pedagogical goals, new keywords, a device list, and a level of difficulty based on the devices used. It also includes an experimental procedure, its physical explanation and experiment note, and supplementary questions for pupils. The research focuses on increasing the interest of pupils and improving their understanding of theory on the subject of electricity and magnetism by way of theoretical lessons connected to practical experiments using the Tesla coil. The research involved a special questionnaire for evaluation using the Thurstone method, which measures the preference of the respondent group. The results are analyzed using a modified Thurstone method of paired comparison with the software, Mathematica.

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Introduction

Gaining students' attention and motivating them in specific studies is an arduous task for many a teacher. Reaching this goal in a thematic unit of electricity and magnetism, where connecting learned theory with practical experience is challenging, is even more difficult. In general, demonstrating a physical phenomenon using experiments helps students better understand the subject. For this reason, and because of the growing interest of young people in Tesla's inventions, the Tesla coil is the subject of this paper. The increased interest in this subject is supported by a high number of scientific publications, popular movies, and the worldwide convening of enthusiastic Tesla coil designers (known as Teslatron). This increase of interest has led to an idea of an education program using a set of practical experiments about electricity and magnetism using the Tesla coil and its features. The main goal would be to create wonder and increase the interest of students in electromagnetic phenomena produced by high-frequency magnetic fields. It would also provide a better understanding of related theories taught within the teaching guidelines of study programs.

The Tesla coil is a high-frequency transformer invented by physicist Nikola Tesla in 1891. It consists of two circuits, resonantly tuned. The secondary circuit is made of a coil wound on a cylinder that is the supporting pillar of a 'toroid-like' capacitor which is the source of electrical discharges (Feynmann et al, 2000). To technically realize these experiments, the tester coil kit, OneTeslaCoil, meant for didactic purposes, was later used (Wang, 2014). With this tool, nine experiments were performed, including one focusing on skin effect, one on an ion motor, and others on explaining lightning flashes, the ladder of Jakub, an electromagnetic gun, the Tesla coil with fluorescent lamp and bulb, Kirlian's photography, plasma loudspeaker, and a phenomenon called 'teslaphoresis' (Koubek, 1991).

Data and Methodology

The Tesla coil and a school breakdown transformer were used in the experiments. The assumptions and hypotheses connected with the impact of experiments on students were tested in two classrooms of a high school and the obtained data were evaluated using a modified Thurstone method of paired comparison.

The first hypothesis was that experiments using Tesla's transformer are able to attract students based on their physical and visual point of view. The second hypothesis was that use of a transformer with the experiments will help students to understand the problematics of electricity and magnetism.

The research was carried out at the Piarist Gymnasium of St. Joseph Kalazanski, Nitra, in 2017 as part of the author's continuous pedagogical practice. The research group consisted of 54 students, with 46 from second grade and 8 from the tertiary class of year eight. The second grade of high school was

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chosen, based on the State Educational Program and respective ISCED 3A. The thematical units of electricity and magnetism are taught in these grades and thus, applying the submitted experiments with a Tesla coil was most applicable. These levels of secondary education are governed by ISCED 3A protocol submitted by the Ministry of Education. Presentations of prepared experiments focused on electricity and magnetism using a Tesla coil. They were realized within the subject of Physics in lessons of the thematic unit of Alternating currents. The presentation was given in the 2.A classroom to 22 students, the 2.B classroom to 24 students, and in the Tertiary A classroom to 32. The experiments were chosen to cover the standard teaching unit (i.e., of 45 minutes) while complying with the principles of simplicity (transformation from simple to more difficult) and demonstrating an experiment using a Tesla coil.

The experiment included a research form of a questionnaire that was evaluated using a modified Thurstone method of paired comparison. This method involves an interval scale, as developed by Louis Leon Thurstone (1887–1955) and has significant application in sociology can sort individual statements, as per certain criteria, on a conceivable scale. A criteria priority statement that was easily identifiable to many students was chosen. Each respondent had the choice of two options and the order of individual statements in the questionnaire was different for all. For purposes of this research, respondents did not associate numbers with statements. The analysis involved paired comparison of the answers was performed by using the software Mathematica and functions created by author of article. The method of Thurstone assumes a normal distribution of scale values set by respondents. The resulting interval scale was obtained from a bulk file generated by counting the individual options of all responses.

The questionnaire was distributed to students at the end of their lesson after the exposition of experiments. The task of the student was to indicate their alignment with any of two statements by any symbol. The nine chosen statements, based on the Thurstone method of paired comparison, resulted in 36 pairs. Table 1 shows the statements used in the questionnaire (Sitkey, 2017).

Table 1: Statements used in the questionnaire

No.	Statement
1	I liked experiments with Tesla coil because they were interesting to observe.
2	I liked experiments with Tesla coil because of physical point of view.
3	Experiments with Tesla coil have motivated me to learn more about this topic.
4	I remember the physical essence of the experiment explained via Tesla coil.
5	Within my oral answer at the blackboard, I will remember the experiment done within our lecture.
6	Checkup questions during experiment help me to understand the essence of this issue.
7	I would like to realize simple experiments with Tesla coil also alone at home.
8	I like experiments within classroom because there are no tests at the same moment.
9	Thanks to experiments with Tesla coil I understand the better physical phenomenon.

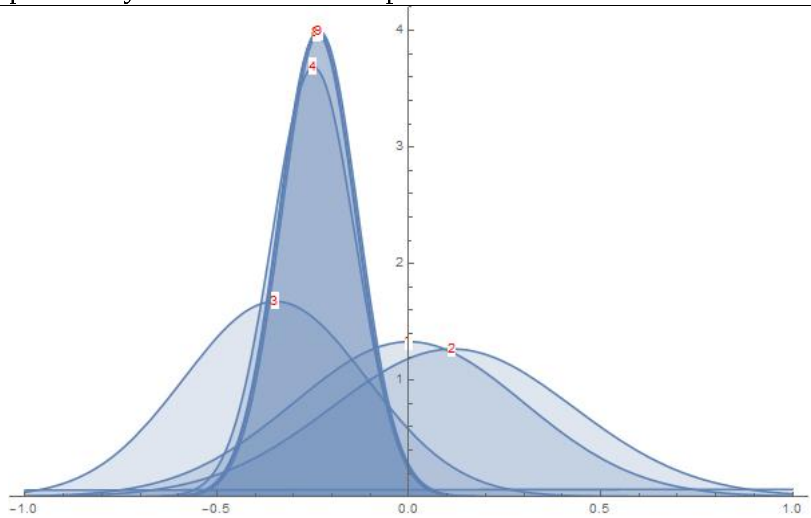
Source: Author

Each experiment consisted of 10 parts, including the methodology and the steps in carrying out the experiments. Also described were the State Educational Program (ŠVP), the propagation motto of the experiment, the difficulty of using the instruments within the range of 1–3 points, the pedagogical goal, new terms connected to the experiment, necessary tools to realize the experiment, and the physical explanation. The student's understanding was assessed through 'check-up' questions and additional remarks. The set of experiments was performed as per the guidelines of ŠVP, part PHYSICS and the respective International Standard Classification of Education (ISCED) 3A for high schools, and year eight of grammar schools, mainly in part Usage, considering the ŠVP and pedagogical goal.

As Thurstone's method of scaling, developed in the year 1929, was not suitable, scale values were determined in a modified Thurstone method of paired comparison using the Wolfram Mathematica for plots of the normal distribution and related to each other (Figure 1).

For the calibration statement, the study used the first statement of Figure 1, i.e., μ_1= 0,000 and the median deviation σ_1 = 1,000. Choice of the calibration statement did not affect the ranking in the resulting scale. While plots 6–9 overlapped (Figure 1), the plots 5 and7 showed a high range for the given set-up, with the line of the graph almost parallel to the x-axis (Tóth, 2010).

Figure 1: Gauss probability of distribution of responses for individual statements of form



Source: Author

Results and Discussion

The results of the modified Thurstone method of paired comparison are shown in Table 2.

Table 2: The results of modified Thurstone method of paired comparison

	1	2	3	4	5	6	7	8	9
1	x	26	42	26	26	38	31	31	28
2	28	x	38	33	23	34	40	36	32
3	12	16	x	24	24	22	35	26	31
4	28	21	30	x	23	22	37	22	20
5	28	31	30	31	x	29	41	25	25
6	16	20	32	32	25	x	35	32	17
7	23	14	19	17	13	19	x	24	14
8	23	18	28	32	29	22	30	x	14
9	26	22	23	34	29	37	40	40	x

Source: Author

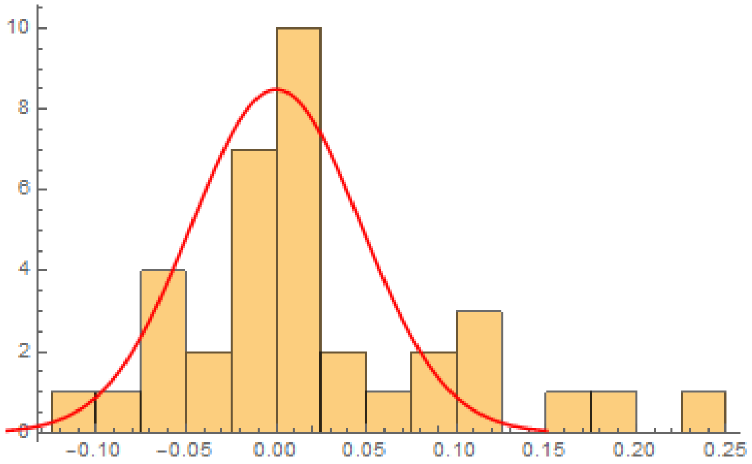
Table 2 shows the matrix of results from questionnaires after applying the modified Thurstone paired comparison. It shows, as an example, at the intersection of the 4th column and 6th row is 32, which is the number of students who preferred the statement 4 in comparison to statement 6.

Table 3: Scaled main values of the probability distribution of responses to individual statements from the questionnaire

The statement of questionnaire	The main value μ_k	The median deviation σ_k
5	2.214	30.654
2	0.114	1.074
1	0.000	1.000
9	-0.232	0.000
6	-0.237	0.000
8	-0.239	0.002
4	-0.248	0.042
3	-0.348	0.691
7	-53.515	123.733

Source: Author

Figure 2: The normal distribution of replies of respondents



Source: Author

In the method of Thurstone, both original and modified versions, a normal distribution of respondents' answers was assumed (Figure 2). The graph represents testing of the normality of variations experimentally measured probabilities from the theoretical values. This is a quantitative representation of variance of the measured values around the theoretical line market (Sitkey, 2017).

Analysis of the resulting graphs and their values show that statement 5 had the highest median value (Table 3). Most students responded that when they summarized the topic while standing by the blackboard, the experiment shown within the lesson had helped them. The assumption is that running experiments within lessons is important. However, the deviation of the median for the statement 5 was high, and therefore, students were not united on their preferences. In the next position, within the interval, were statements 2 and 1, which were about experiments with the Tesla coil. Students responded that these experiments were interesting because of the physical and visual point of view and this confers with the first hypothesis. Both statements displayed minor scattering, indicating that students mostly agreed on this preference. Results of statements 4, 6, 8, and 9 were closely related and therefore all results fitted within Figure1. This evaluation confers with hypothesis 2. However, the results also indicated that students preferred experiments within lessons because there was no coinciding test activity. At the end of the scale, are statements 3 and 7. The result for statement 3 is close to the previous values in the final scale. Thus, experiments within a certain range can motivate students. At the same time, the students did not have a clear position of preference for this statement. The resulting scale number for statement 7, referring to simple experiments with Tesla coil alone at home, suggests that students do not know how or want to use the Tesla coil at home. The median value was an extreme outlier and with a high variance, indicates that only a few students would attempt practical experiments with a Tesla coil at home.

Conclusion

The paired comparison of student questionnaire responses showed that, within an oral test, students valued and showed a preference for the support given from performing an experiment within the lesson. Results of other responses clearly showed that physical and visual aspects of experiments with Tesla coil are interesting for students, make it easier for them to recall facts, and support students in understanding the phenomena of electricity and magnetism. Thus, the results confirm the study hypotheses. In addition, it is noteworthy that a few students showed their interest in the practical experiments with Tesla coil at home within their 'free' time. Thus, it is concluded that this set of experiments is appropriately designed to serve teachers of Physics as a tool to improve the education process. A theoretical explanation of the problems of electricity and magnetism alone is often difficult for students to comprehend and memorize for better understanding and later recall.

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