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# THE INVESTIGATION OF STUDENTS' SKILLS IN THE MANAGEMENT OF LABORATORY WORK FOR STUDENTS AGED 15-16 YEARS

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**Abstract:** In this paper is presented a pilot study for the investigation of the relevant factors within some experimental works carried out by students, after going through the learning unit "Movement and rest", which can be found in the chapter "Principles and laws in classical mechanics", from the physics curriculum for the ninth grade in Romania. Through the proposed work tasks, the design and the development of the experimental works carried out by students were highlighted. At the same time, special attention was paid to the results obtained by the students in investigating the relevant factors through specific physics methods, not only during the classes but also within the homework.

**Key words:** Laboratory work, stages, students aged 15-16 years, experimental skills

## 1. Introduction

In current practice, the activities carried out in the laboratory can be: laboratory work, observational (experimental) activities, exploration activities and experiments. Those activities substantiate the strategies called experimental.

The activities within the physics laboratory classes are intended for the development of the students' interest and for the understanding the experimental physics by them (Wilcox & Lewandowski, 2017). The purposes of these activities are various: to realize detailed observations on objects or phenomena; conducting an investigation in which one variable is modified while all other variables are kept constant; the establishment of cause-effect relationships; illustrating or exploring the relationships that may exist between objects or phenomena in order to identify legalities; explicit theoretical constructs; the use of the properties of objects, materials or phenomena to classify, to identify or to construct concepts; elaboration of models based on scientific properties or principles (Aston, 2017; Trocaru, 2016; Sokołowska & Michelini, 2018).

The present study is based on the cyclical teaching-learning model based on the investigation proposed by Ciascai (coord.), Eşanu & Haiduc (2016), which had as a starting point the classical models proposed by Atkin & Karplus (1962), Kolb (1984), Bybee et. al. (1989) and Eisenkraft (2003). The aforementioned cyclical model is structured in four stages of learning (evocation – anticipation, exploration – experimentation, reflection – explanation and application – transfer), followed at the end by a sequence for evaluation (Ciascai, Eşanu & Haiduc, 2016).

The laboratory works were integrated in the teaching activities along with the generalization of the systematic teaching of science in schools. They are based on deductive reasoning and their role is that of illustrating and applying the theoretical knowledge acquired. The replacement, in school practice, of laboratory works with experimental activities aimed at building new knowledge by students is attributed to the reforms undertaken worldwide in education after 1960. These reforms changed the optics of teaching and learning the sciences, by imposing the inductive approach "The inquiry laboratory became the core of the science learning process" (Shulman & Tamir, 1973, cited by

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Hofstein, Kipnis, & Abrahams, 2013). The study conducted by Kuhn & Vogt (2013) highlights the fact that smartphones can be used as tools for carrying out experimental physics work. The models of physical systems facilitate the explanation or prediction of phenomena, while models of measurement systems facilitate the interpretation of data (Dounas-Frazer & Lewandowski, 2018). The results obtained by Kalthoff, Theyssen & Schreiber (2018) highlight the fact that the type of training cannot significantly influence the acquisition of experimental skills and the acquisition of content-related skills, but differences in experimental skills can be observed in the learning process of students. Oymak & Ogan-Bekiroglu (2021) and Ruhaisa & Jiradawan (2018) emphasized that students' attitudes and their participation in learning activities can be developed both through experimental activities themselves and through activities with virtual experiments.

Both types of experimental activity (laboratory work and experiment) serve the students to master the experimental approach, the laboratory works are favoring explicit learning, while in experimental activities implicit learning is characteristic. The introduction in some laboratory activities of results that are not known by students could have a significant impact on their understanding of experiments, as an important approach to the development of their scientific knowledge. (Zwickl, Hu, Finkelstein & Lewandowski, 2015).

In this paper we focused on the experimental works of classical mechanics studied by high school students, the major concern being the investigation of the relevant factors through specific physics methods. It is well known that the research experiments (through discovery) and those experiments for practical training which aim to acquire practical skills contribute to achieve an active, heuristic and creative education (Bocoș, 2002; Florian, 2004; Ionescu, 2005; Ionescu, Radu & Salade 2000; Stoenescu & Florian, 2015).

In general, laboratory works are used in education at high school classes and are proposed to students at the end of a thematic stage aimed at verifying the students' possibilities to use in practice the knowledge acquired (Ciascai, 1999; Ciascai, 2001; Ciascai (coord.), Florian & Florian, 2008; Florian 2004; Florian, Florian, Antonie & Rougier-Vasilescu, 2006; Stoenescu & Constantinescu, 1999; Stoenescu & Florian, 2015). Tekin & Mustu (2021) emphasized that the research-based strategies, in experimental papers, in the sciences, have a positive impact on the achievements, attitudes and abilities of students.

## 2. Materials and methods

The purpose of this paper is to analyze the progress made by students, by carrying out experimental works and to compare the results obtained by students with those envisaged by the operational objectives / competences derived from the learning unit "Movement and rest", which can be found in the chapter "Principles and laws in classical mechanics" in the physics curriculum for the ix-th grade in Romania (MECT, 2004).

In the research carried out within the learning unit "Movement and rest" participated by 60 students of the ninth grade, aged between 15-16 years. The classes took place online, on the Google Classroom platform. The duration of each experimental work was two hours. The activities took place in the school year 2020-2021.

At the end of the learning unit "Movement and rest" were administered two experimental works that are not in the list of mandatory experimental works provided in the physics curriculum for the ninth grade in Romania. The titles of the evaluated experimental works were: "Experimental study of the movement of a car in the horizontal plane" (EW1) and "Experimental study of the movement of a wax sphere in a bottle filled with water" (EW2). These experimental works have been chosen and adapted for the online classes.

The proper preparation of each experimental work was carried out by: (i) the study of the experimental theme; (ii) the choice of generic facts subject to observation/analysis; (iii) design of the experiment. Each of the laboratory activities carried out required the students' thinking and experimental skills.

The experimental work "Experimental study of the movement of a car in the horizontal plane" was carried out during the classes held online, and the experimental work "Experimental study of the movement of a wax sphere in a bottle full of water" was proposed as a homework assignment. The drawings for experimental works EW1 and EW2 are shown in Figure 1 and Figure 2.

Throughout the research, the choice of the experimental work, its design and the development were made in such a way to ensure the students' familiarization with the experimental methodology (Florian, 2004; Stoenescu & Florian, 2015).

The specific competences (SC) targeted in the unit "Movement and rest", chapter "Principles and laws in classical mechanics" of the physics curriculum for class 9th (MECT, 2004), were:

SC1: Describe and explain in a specific language the motion of bodies using the physical quantities vector speed and acceleration.

SC2: Identifying the conditions in which a body can be described as a material point.

SC3: Highlighting the fact that a mechanical state of bodies can be changed as a result of an interaction.

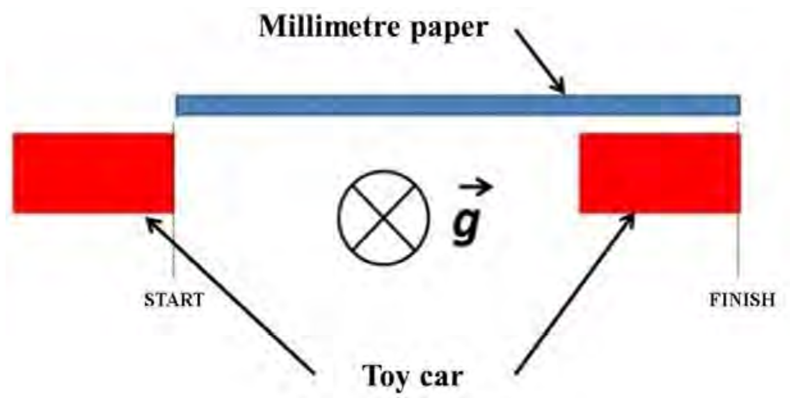


**Figure 1.** *Outline for "Experimental study of the movement of a car in the horizontal plane"*

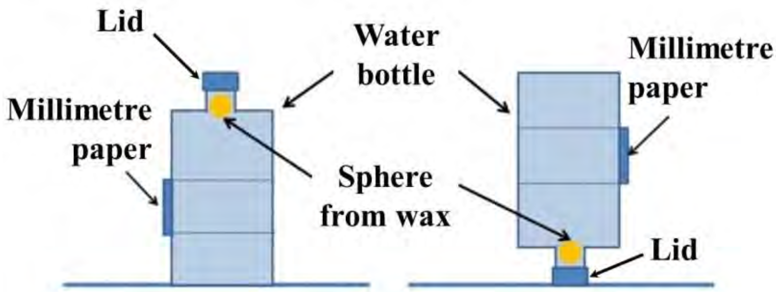


**Figure 2.** *Outline for "Experimental study of the movement of a wax sphere in a bottle filled with water"*

For the proposed experimental works, EW1 and EW2, each student had to make a report, both for EW1 and for EW2, which would include: "The theory of the work", "Way of working", "Necessary materials", "Data table and processing of experimental data" and "Errors and sources of errors" (Florian, 2004; Florian, Florian, Antonie & Rougier-Vasilescu, 2006; Frunzescu, Florian, Truţă & Cotfasă, 2016; Stoenescu & Florian, 2015).

Also, the specifications and the work tasks were made (see Table 1), for each experimental work, all of which were made available to each student through experimental activity sheets.

The total score for each experimental work was 100 points, without ex officio points. The scores allocated in the scoring scale were: 10 points for "The theory of the work"; 10 points for "Required materials"; 20 points for "Procedure"; 50 points for "Data table and processing of experimental data" and 10 points for "Errors and sources of errors".

**Table 1.** *Specifications and work tasks for the experimental works proposed to be evaluated within the learning unit "Movement and rest", chapter "Principles and laws in classical mechanics", 9th grade, school year 2020-2021*

| Title of the experimental thesis | Clarifications | Work tasks |
|---|---|---|
| "Experimental study of the movement of a car in the horizontal plane" | ✓ The car must travel rectilinearly a fixed distance of 10 cm.<br>✓ You need to shoot the movement of the car with your phone, and then use the shooting for the moments of time you need to solve the work tasks, also taking into account the performance of the phone (number of frames/s).<br>✓ Graphic representations must be made on millimetre paper. | Plot:<br>✓ Coordinated position of the car according to time;<br>✓ The speed of the car depending on the time;<br>✓ The acceleration of the car depending on the time. |
| "Experimental study of the movement of a wax sphere in a bottle filled with water" | ✓ After inserting the wax sphere into the bottle (transparent, with the volume of 2 L) filled "eyes" with water, invert the bottle (mandatory must also be put the stopper) with 180$^{o}$.<br>✓ You need to shoot the movement of the wax sphere with your phone, and then use the shooting for the moments of time you need in solving the work tasks, also taking into account the performance of the phone (number of frames/s).<br>✓ From the filming made, a trajectory of the wax sphere is chosen, inside the glass, along the vertical axis that passes through the middle of the stopper and the bottom of the glass.<br>✓ Graphic representations must be made on millimetre paper. | Plot:<br>✓ Coordinate position of the wax sphere as a function of time;<br>✓ The speed of the wax sphere as a function of time;<br>✓ Acceleration of the wax sphere as a function of time. |

The evaluation of each experimental paper was carried out on the platform of the school where the papers were submitted, in the section on the Google Classroom platform, allocated to each student.

## 3. Results and discussions

The results obtained by the students for the experimental topics "Experimental study of the movement of a car in the horizontal plane" (EW1) and "Experimental study of the movement of a wax sphere in a bottle filled with water" (EW2) are also highlighted by the corresponding graphs, which provide an overview of this research. These graphs are shown in Figure 3 ("Theory of the work"), in Figure 4 (("Necessary materials"), in Figure 5 ("Working mode"), in Figure 6 ("Data table and processing experimental data"), in Figure 7 ("Errors and sources of errors") and in Figure 8 ("Total score").

From the analysis of the results presented in Figure 3 it is found that most of the students correctly presented the theory of the experimental work: (i) unsatisfactory 1.67% (EW1); (ii) satisfactory 5 % (EW1) and 6.67 % (EW2); (iii) well 30.00 % (EW1) and 31.67 % (EW2); (iv) very good 63.33 % (EW1) and 61.66 % (EW2).

Regarding the materials required for the experimental work, we can see that the students correctly identified these materials (see Figure 4), for EW1 the results of 16.67 % (good) and 93.36 % (very good) were obtained, respectively for EW2, the results were obtained 3.33 % well and 96.67 % (very good).

In the case of the experimental results shown in Figure 5, the students presented the way of working and carried out the experimental work and the results were obtained as mentioned below: (i) well 18,34 % (EW1) and 18.33% (EW2); (ii) very good 81.66 % (EW1) and 81.67 % (EW2).

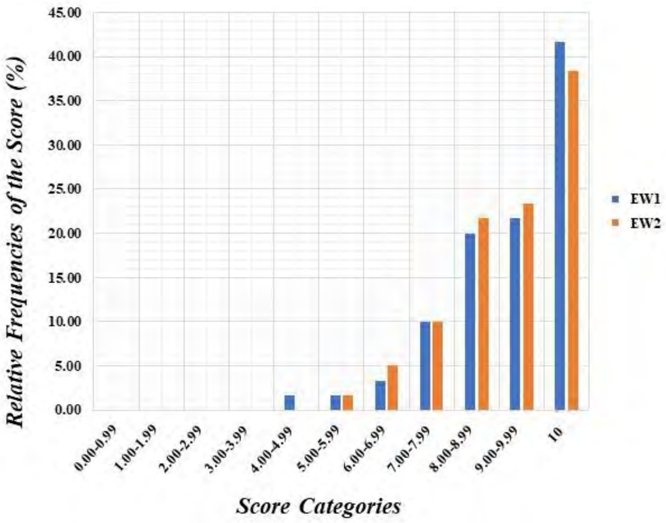


**Figure 3.** *Relative frequency distribution of the score: "Theory of the work"*

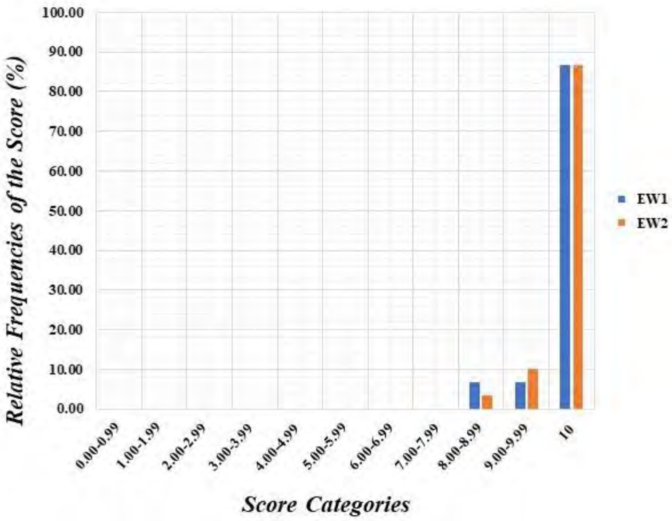


**Figure 4.** *Relative frequency distribution of the score: "Necessary materials"*

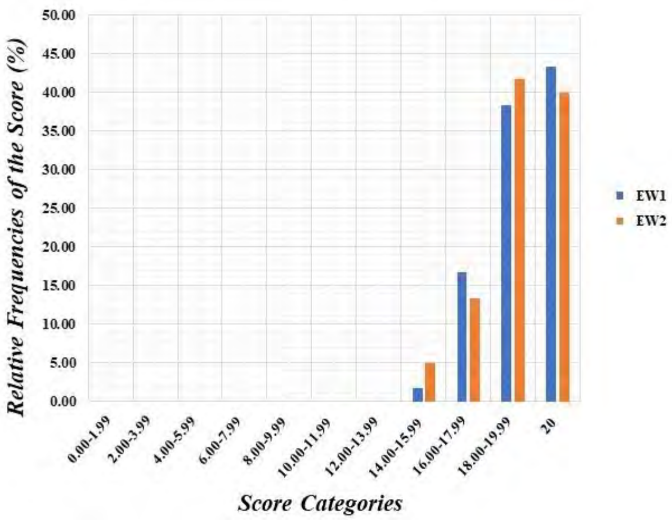


**Figure 5.** *Relative frequency distribution of the score: "Working mode"*

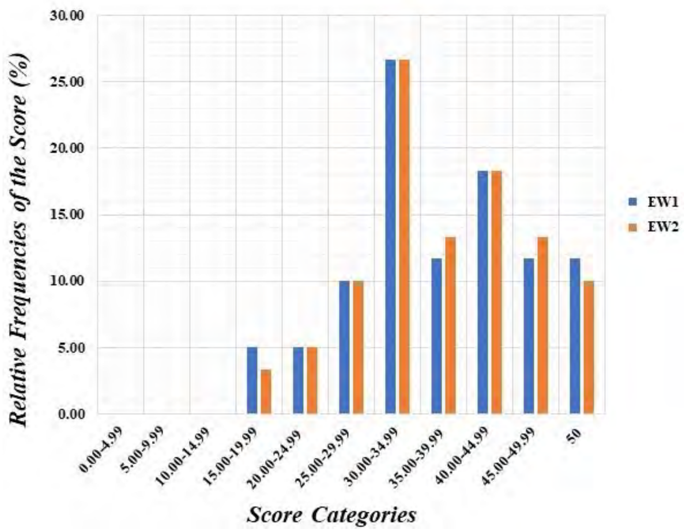


**Figure 6.** *Relative frequency distribution of the score: "Data table and processing experimental data"*

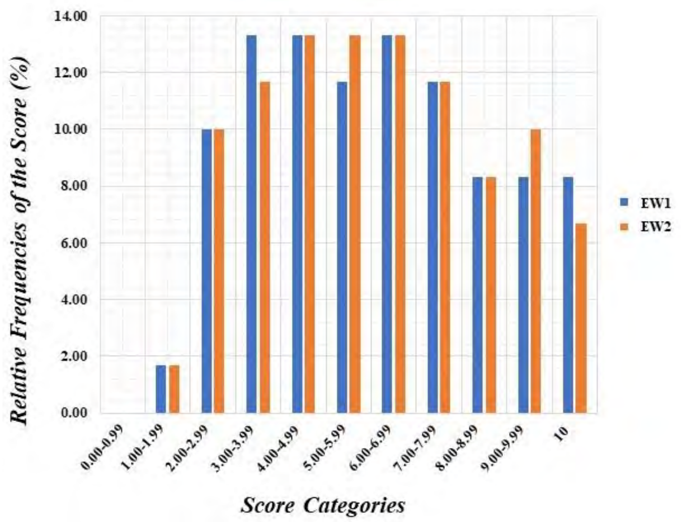


**Figure 7.** *Relative frequency distribution of the score: "Errors and sources of errors"*

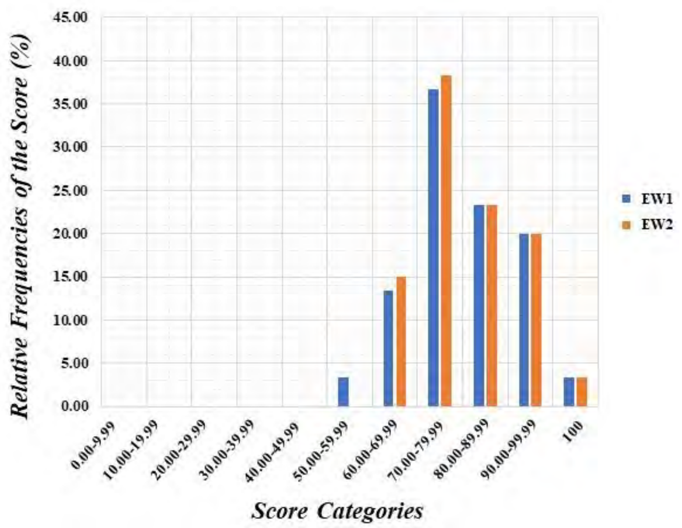


**Figure 8.** *Relative frequency distribution of the score: "Total score"*

As shown in Figure 6, some students (36.67 %) have had difficulty making graphs as well as tables with experimental data and processing them. In the case of the experimental work EW1, the students were not trained to use the phone to obtain some of the relevant parameters from the film made during the experiment.

As a result, some students (20.00 %) did not score the expected score because they had no skills in using and editing the films they made. The main reason lies in the fact that they did not understand how they can collect the experimental data for the moments of time necessary to solve the workloads, namely the correlation of the performance of the phone's camera (the number of frames/s) with the investigation of the relevant factors.

The difficulties encountered by the students were the collection of data on the position coordinate, after each time interval (conveniently chosen), the graphical representation of the speed and acceleration according to time.

The results for the two experimental works are not statistically differentiated for any of the analyzed aspects so the null hypothesis is confirmed.

A positive aspect is that most of the students (80.00 %) were able to correctly achieve the graphical representation of the position coordinate according to time. Graphical representations of speed and acceleration as a function of time required greater effort on the part of the students to calculate the speed and acceleration sizes for each time interval.

In the case of the experimental work EW2, the results obtained by the students were significantly superior, because they learned the working method of the first work, EW1, after it was presented by the students and analyzed, together with the teacher, in class, online.

**Tabel 2.** *The average score, obtained by students aged 15-16 years, for the experimental works carried out at the end of the learning unit "Movement and rest".*

| **Average score** | **Stages of a laboratory work** | | | | |
|---|---|---|---|---|---|
| | Theory of the work | Necessary materials | Working mode | Data table and processing of experimental data | Errors and sources of errors |
| EW1 | 8.98 | 9.80 | 18.73 | 36.43 | 5.73 |
| EW2 | 8.97 | 9.82 | 18.69 | 36.79 | 5.76 |

The analysis of the averages, presented in Table 2, also shows us insignificant differences between the students' results in the two experimental works, regarding the analyzed aspects.

## 4. Conclusion

Through the experimental works proposed in this study, it was aimed the development of the capacity of experimental investigation of the students and the development of their spirit of observation, even if the classes were held online. The students realized that they could repeat the experiment several times if all the conditions were met.

The difficulties found in this research are also due to the online classes, on account of the coronavirus pandemic (COVID-19). Deficiencies were noticed in the case of the collection and processing of experimental data by students. Also, there were noticed difficulties not only in making graphic representations and their interpretation, but also in identifying errors and sources of errors.

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