Chapter #17

UNDERSTANDING THE CONCEPT OF ENERGY IN HIGH SCHOOL: THE USE OF A ROBOTIC SYSTEM AND VIDEO ANALYSIS AS TEACHING RESOURCES

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ABSTRACT
This article presents a work carried out to improve students' understanding of the concept of energy using a robotic platform and video analysis software. The electronic system made it possible to monitor a movement with characteristics similar to those of a simple harmonic motion, through a looping device, allowing the demonstration of the law of conservation of energy. The monitoring of the experimental configuration was carried out using the Arduino® platform. Demonstrations involving the use of the apparatus as well as the video analysis software were made for Physics students from a high school. The results showed that the automation of a simple experiment can become an interesting tool for both the teaching and learning process, triggering social interactions among students useful to assist in the fixation of physical concepts, even the most abstract ones such as Energy. In addition, the use of video analysis software provides students with experiences of collecting data, analyzing graphs and tables, which supplements the understanding of the nature of science and scientific practice.

Keywords: educational robotics, physics experiments, Arduino® projects

1. INTRODUCTION

Education is the backbone of any developing society and improving its quality is a key factor that defines advancement in a world parameterized by science and technology. Educational researches, especially those aimed at teaching Science, has dedicated special attention to the innovation of methodologies that contribute not only to allow a greater understanding of the concepts by students, but also provides the means to develop skills and competences useful to the exercise of citizenship. In this direction, many researches have drawn attention to the use of so-called digital technologies of "Information and Communication", as well as robotic platforms in the teaching of Physics and Science in general.

It should be noted, in this context, that Physics is a vast field of study involving several theories and concepts that can be represented mathematically and demonstrated through practical experiments. The teaching of Physics in general begins in primary schools and is a matter of great importance. Thus, it is necessary to ensure that it is developed in the best possible way to enhance students' understanding of real-world phenomena.

However, concepts built within Physics to study natural phenomena are extremely abstract and therefore bring many difficulties for students' learning. In relation to this point, the concept of Energy stands out, which, in addition to being very abstract, is of great importance for understanding many phenomena. Therefore, the use of experiments can be

important and is recommended as a resource to facilitate the understanding of knowledge that requires a high degree of abstraction.

In this context, this article presents some results of a project in which an automated looping experiment has been used to help high school students understand the types of energy as well as the energy transformation processes found in the system. Thus, the experiment facilitates discussions regarding the principle of energy conservation, as well as the practical limitations of theoretically conservative systems.

The paper is organized as follows. Section 2 aims to contextualize the work carried out, initially presenting some elements of the Brazilian basic education curriculum guidelines, related to the use of digital information and communication technologies. It then highlights the importance of implementing educational robotics, using low-cost platforms like Arduino®, in educational tools, and lists some works using technology similar to that emphasized in this project. Section 3 describes the work carried out in relation to the development of the experiment, which deals with the automated monitoring of energy in a looping setup. Section 4 initially discusses the results obtained with the developed system, regarding the monitoring of the motion of a small sphere in one of the looping tracks and the visual analysis of this motion using a video analysis software tool. Then, the results of a demo session performed for a class of high school students are presented. The discussion details the demonstration and an assessment tool used to obtain students' feedback on the experiment, along with a succinct presentation of the results obtained from student responses. The section ends with the discussion of some pedagogical issues related to the potential of the developed work to assist in the teaching of Physics concepts. Finally, section 5 includes some conclusions of the work.

2. CONTEXT OF WORK DEVELOPMENT

2.1. Digital technologies in science teaching: Brazilian curriculum guidelines

The Common National Curriculum Base (under the acronym BNCC in Brazil) is a document of the Brazilian Federal Government (Ministry of Education) which contains the curriculum guidelines that must be followed by Brazilian schools of basic education (Ministry of Education, 2018). The learnings defined in the document should enable students, at different stages of basic education, to develop ten general competencies. The emphasis on digital information and communication technologies - ICT is included in these competences. For instance, competency 5 advocates the importance of:

> Understand, use and create digital information and communication technologies in a critical, expressive, reflective and ethical way in various social practices (including school practices) to communicate, access and disseminate information, produce knowledge, solve problems and exercise protagonism and authorship in personal and collective life. (Ministry of Education, 2018, p. 9)

As will be described in section 3, this competence is worked on in the experimental system presented in this article mainly using digital technologies for knowledge production and problem solving. Note that the emphasis on digital technologies also appears in competency 4, which refers to the use of various languages, including digital, by students, "to express and share information, experiences, ideas and feelings [...]" (Ministry of Education, 2018, p. 9). The project also includes aspects of competency 2, which aims to enable the student to "use the appropriate approach to science, including investigation,

reflection, [...] to investigate causes, develop and test hypotheses, formulate and solve problems and create solutions (including technological) from the knowledge of different areas" (Ministry of Education, 2018, p. 9).

In addition to the ten general competencies, the BNCC includes the description of specific competencies for High School. These competencies are linked to four areas of knowledge, related to (i) languages, (ii) mathematics, (iii) nature sciences and (iv) human and social sciences. For each competency, a skill set is presented. The project described here is in line with the area of nature sciences, which postulates "an articulated look at Biology, Physics and Chemistry" (Ministry of Education, 2018, p. 547). More specifically, the work meets competences 1 and 3 of the area of "Natural Sciences and its Technologies". The development of competence 1 aims, among other aspects, to enable the student to "analyze natural phenomena and technological processes, based on the interactions and relationships between matter and energy [...]" (Ministry of Education, 2018, p. 554). It is in this context that, among others, studies should be carried out on the principle of energy conservation. The skill related to this competence, emphasized in the project, aims, among other aspects, to allow the student to "analyze and represent, with or without the use of specific digital devices and applications, the transformations and conservations in systems involving quantities of matter, energy and movement [...]" (Ministry of Education, 2018, p. 555).

The development of the specific competence 3 aims, among other aspects, to enable the student to "investigate problem situations and evaluate applications of scientific and technological knowledge and their implications in the world, using procedures and languages specific to Natural Sciences [...]" (Ministry of Education, 2018, p. 558). In view of this competence, the developed system aims to enable the student to "investigate and analyze the operation of electrical and/or electronic equipment and automation systems to understand contemporary technologies and assess their social, cultural and environmental impacts" (Ministry of Education, 2018, p. 560).

2.2. Arduino®: Low-cost robotic platform

Solutions involving educational robotics, such as the system described in this project, allow aspects of competences and skills recommended in the curriculum guidelines for Brazilian education (BNCC) to be put into practice with students. However, as Scherer; da Silva, and de Oliveira (2020) point out, many of the kits available for educational robotics have costs that make them prohibitive for most schools, especially for public schools. Among these, one of the best-known kits is LEGO Mindstorms, developed from a partnership established between the Media Lab of the Massachusetts Institute of Technology - MIT and the LEGO Group.

To make this technology more accessible to schools, low-cost educational robotics resources can be used (Scherer et al., 2020). More specifically with respect to teaching Physics, low-cost educational robotics help to develop more interesting laboratory classes and expose students to several possibilities, including the building of new robots. In this context, a very used robotic platform today is Arduino®, an open-source platform offering both hardware and software support. Arduino® development boards offer a varied choice of microcontrollers, features and form factors, thus allowing for a wide range of applications.

Arduino® is one of the most popular platforms used by students and developers due to its low cost, multi-platform operation (compatible with Windows®, Mac OS®, Linux®) and its simple and clear programming environment, features that allow for its use relatively simply. Furthermore, it can be interfaced with various electronic components such as sensors, actuators, displays and electronic circuits, thus enabling the construction or automation of

laboratory experiments, used in teaching Physics in schools. Some works based on the Arduino® platform and aimed at helping in the understanding of Physics concepts are briefly described below.

Souza and Duarte (2015) discuss strategies that can be used in Physics teaching (secondary level) through a robotics show. Some of the experiments described were carried out using recyclable and low-cost materials. In addition, some projects used the Arduino®, considered as a low-cost alternative for building efficient robots with simplified programming. The authors argue that they used the enchantment caused by robotics to encourage students to understand physical phenomena.

Llamas Bello, Vegas, González Rebollo, and González Delgado (2018) present a low-cost open-source platform that can be used to carry out simple physics experiments both in high school and in universities. The authors claim that the developed system presents a greater possibility of customization, compared to similar commercial systems. The platform includes a mobile unit, based on the Arduino® Nano, containing sensors, which can be attached to a mobile body to study its movement.

Mesquita, Sena, and Ferreira (2018) present a method for organizing an Educational Robotics course, in which each class is structured in a sequence of steps that include, among others, the contextualization of the problem, assembly, programming, and discussion of results. Based on the proposed structure, a course, using the Arduino® platform, was organized, and applied to groups of high school students from the Brazilian public school system. The work presented in Sena, Mesquita, Monteiro, Muniz-Junior, and Oliveira (2019) also describes a training program in Educational Robotics, based on Arduino®, which was applied to Physics students from two public high schools. Classes in general were organized according to the method proposed in the previous work, but the activities were planned to follow the guidelines of a project-based learning model. In this training, students worked on the various stages of developing a mobile robot.

3. DEVELOPMENT

3.1. Experiments with the looping apparatus

The simple pendulum experiment is a very basic physics laboratory activity in schools. The main idea behind the experiment is to study the periodic motion of a moving body attached to a rod, demonstrating simple harmonics and the principle of energy conservation. It also describes the transformation of energy from one form to another, illustrating the concept that energy is never destroyed. Another interesting theory that can be observed from this experiment is the independence between the period of oscillation and the mass of the moving body.

Figure 1 below shows the Looping device used in the project. As it can be seen, it is composed of two tracks, which can be used to demonstrate various concepts in Physics laboratory activities (http://labdemo.if.usp.br/looping-2/). The work described here is based on an experimental setup that simulates, to some extent, the characteristics of a pendulum, using an object of predetermined mass - a small sphere (snooker ball), which must move in the front track (1) of the device. As we are not monitoring the movement in the rear track (2), we can say that the system described here corresponds to the first of a series of experiments that can be studied with an adaptation of the configuration discussed in the current work.

One should notice that the rear track (2) is the looping track itself. The objective with this trail is to study the characteristics of a body with constant mass that must complete the movement along a curved or circular trail, without deviating from its trajectory, i.e., the body must travel around the loop without falling. This concept, in addition to being interesting, is

functional in many real-life applications, such as amusement park roller coasters. Physical properties related to the concepts of energy and force are studied in this experiment. A specific amount of potential energy is needed to allow the body to circle around the loop, completing its entire trajectory. This is expected to be achieved by starting the movement from a height of twice the radius of the loop, but in practice a minimum height of 2.7 times the radius is required, i.e., the body must be placed at a height greater than 2.7 times the radius to complete the entire looping path (Varieschi, 2006).

Figure 1.
Looping experiments bench.
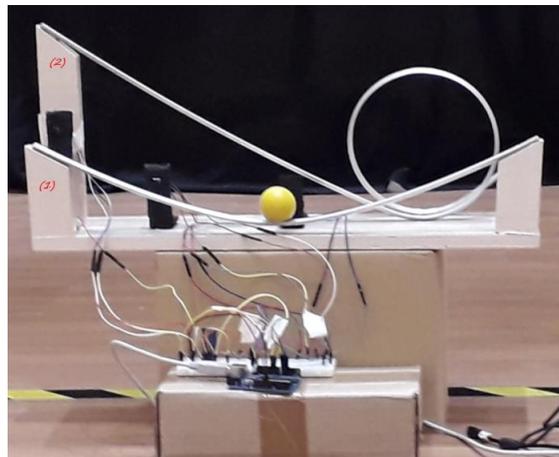
As will be seen in the work description, experiments related to looping can be automated using proximity sensors and a suitable robotic platform. Thus, properties related to the movement of a body along the loop – such as its speed at different points on the trajectory – can be monitored through a suitable electronic configuration.

3.2. Energy conservation in the looping experiment

As mentioned, this project aimed to monitor the movement of a small sphere (snooker ball) on the track 1 of the looping apparatus (Figure 1), in order to help the students with the understanding of the principle of energy conservation.

Demonstrations carried out with the experiment should emphasize several concepts related to energy transformations in the physical system, some of which are mentioned below. Firstly, it should be emphasized that potential energy is more static in nature, while kinetic energy is dynamic. A body at rest has associated with it an amount of kinetic energy equal to zero since the velocity is zero. It is when a body starts to move and therefore has a non-zero velocity, which then has a non-zero kinetic energy value associated with it. As the small sphere moves along the looping track, the potential energy associated with it, stored in the gravitational field, is transformed into kinetic energy and vice versa. The total energy, mechanical energy, which is the sum of potential and kinetic energy values, in an ideal situation, remains constant at any point in its motion.

As can be seen in Figure 1, the front track (1) of the looping apparatus is designed in the form of an open curve that is symmetrical with respect to the middle position and whose height gradually increases as the curve unfolds from the center. This implies that the body's maximum potential energy is at the extremes of the track and its minimum value is in the middle position. On the other hand, the maximum value of the kinetic energy that can be reached by the body occurs in the center – middle position of the track, and the minimum values (equal to zero) occur at the extremes of the track.

Regarding the principle of energy conservation, it is observed that a fraction of the mechanical energy is transformed into other forms of energy, due to friction and air resistance and, therefore, the values of total mechanical energy at different points in the system decrease with time. This illustrates that, although the system used can theoretically be considered conservative, certain imperfections in its realization lead to results that produce a margin of error. Thus, the apparatus was also used in this project to illustrate to the students the practical limitations of theoretically conservative systems.

3.3. Basis for experiment automation

As can be seen in Figure 1, three sensors mounted on supports were positioned at three different heights corresponding to the extreme left position, the medium position of the apparatus, and the midpoint between the two previous ones. Other sensors could be added at different locations to further validate the results (will be included in extensions for this project). In the current work, the three sensors were used to detect the presence of the sphere in each of the three positions. The way the sensors are arranged in the project is similar to that used in the platform described by Llamas Bello et al. (2018), in which four infrared transceivers are placed in vertical beacons and connected to the platform's portable unit.

An Arduino® platform is used in the project experiment setup to collect data from the sensors and calculate experimental values based on the input data. In this project an Arduino® UNO board was used, which is based on the ATmega328P microcontroller. The experimental system, coupled to the looping structure, monitors the movement of the sphere using a sensor circuit composed of three reflective optical sensors (TCRT5000). The information from this data acquisition system is processed by a program developed in the Arduino® IDE (Integrated Development Environment) to provide the desired outputs. The results of the experiment can be viewed on the IDE serial monitor and/or on a device that supports communication via Bluetooth, such as a smartphone. The interface between the Arduino® UNO and the Bluetooth device is established using a Bluetooth wireless communication module (HC05). The Google Play Store makes available, in the category "Bluetooth Terminal", several applications classified as free that can be used to display the results on the screen of an Android smartphone.

4. RESULTS

4.1. Experimental system results

In the current version of the system, the movement of the sphere is monitored by recording the instants of time when it is detected in each of the three sensors, here identified by 1, 2 and 3. Remembering that the sphere moves cyclically from the sensor 1 to sensor 2 and from sensor 2 to sensor 3, the latter located at the midpoint of the experiment. The sphere then moves to the right side to a point on the trajectory (ascending) where it stops and the movement is reversed, returning to sensor 3. From there, the sphere returns to sensor 2 and, in the initial cycles, it is still detected by sensor 1. Based on the instants of time in which it

is detected in each of the sensors, the program calculates and displays the values of the average speeds, vel_{ij}, corresponding to the ball movements from sensor i to sensor j (i, j=1,2,3). Students can view the ball movement data on the Arduino® IDE serial monitor or on a smartphone screen (Bluetooth communication).

The movement is monitored until the sphere is no longer detected by two different sensors (sensors 2 and 3) in which case it still oscillates for some time around the sensor located at the midpoint (sensor 3). The program then presents the value of the initial potential energy as well as, for each cycle of the movement, the value of the kinetic (translational) energy determined from the maximum value of the average velocities calculated for the cycle. Thus, the student, using the device, can verify, with a more qualitative than quantitative emphasis, both the aspect of energy transformation – from potential to kinetics and vice versa, as well as the effect of dissipative forces, since the energy values decrease with each cycle of movement, causing the sphere to finally stop moving after a few cycles.

An analysis of the movement of the sphere on the trail was carried out using the Tracker software, a free video modeling and analysis tool developed by Douglas Brown (https://physlets.org/tracker/), using the Open-Source Physics (OSP) environment from Java language. For the analysis of the movement with the Tracker, a filming (video) of some cycles of the movement of the sphere in the Looping was made, from the beginning of the movement, using the camera of a common smartphone.

After loading the video, some settings were made in the tool. Note that we chose to use the basic features of the tool, so that it could be used quickly to carry out the motion study. Thus, using a "calibration tape", a measurement reference was introduced: in the case of the looping, the length of the base of the experiment was specified. A system of coordinate axes was fitted to the experiment in such a way that its origin coincided with the midpoint of the front track (1) of the experiment. A mass point was created and associated with the small sphere, which was the object whose motion would be analyzed by the tool. In addition, its mass in kg was specified.

Then, video cut adjustments were made, specifying the initial and final frames of the video excerpt that would be analyzed, as well as the frame interval for "marking" the movement of the ball. The marking process consists of "tagging" the positions of the mass point in its movement from the start to the end of the selected video excerpt. Next, we have chosen as dependent variables the variables x (horizontal coordinate), y (vertical coordinate) and v (translational speed of the mass point). The independent variable would be time, t(s). For each marked position of the mass point, the values of all variables would be displayed by Tracker software, as discussed below.

The graphics and data corresponding to the "marks" selected in the video clip for the movement of the ball are presented in the "Diagram" and "Data" windows, on the right of the software interface, as shown in Fig. 2. In the Figure, the graph in the Diagram window shows the variation over time of the x coordinate values, which correspond to the horizontal displacements of the mass point. In the data window, the values of the dependent variables x, y and v are displayed at each instant of time t.

In the Diagram window in Figure 2, the graph of mass point displacement as a function of time was presented. It is possible to change the dependent variable and thus visualize other graphics associated with the movement. It is also possible to view a graph in an independent window, which allows an enlarged view, the modification of some parameters and the carrying out of some analyzes (such as calculations of statistical parameters and curve fitting, for example).

The movement analysis carried out with the tool, from the selected video excerpt, generates data and graphics that can be compared with the results obtained with the automated apparatus. Both the results obtained with Arduino® and those produced by Tracker are experimental and subject to errors. This point should be drawn to the students' attention, thus contributing to their perception of scientific working methods. For example, Tracker results are sensitive to calibration, axes' positioning, and marking of mass point locations. Regarding the looping experiment, a difficulty of the experimental apparatus is related to the determination of time intervals corresponding to the movement of the sphere between the sensors, as it is not exactly a "material point".

Figure 2.
Video Analysis of the motion with Tracker.
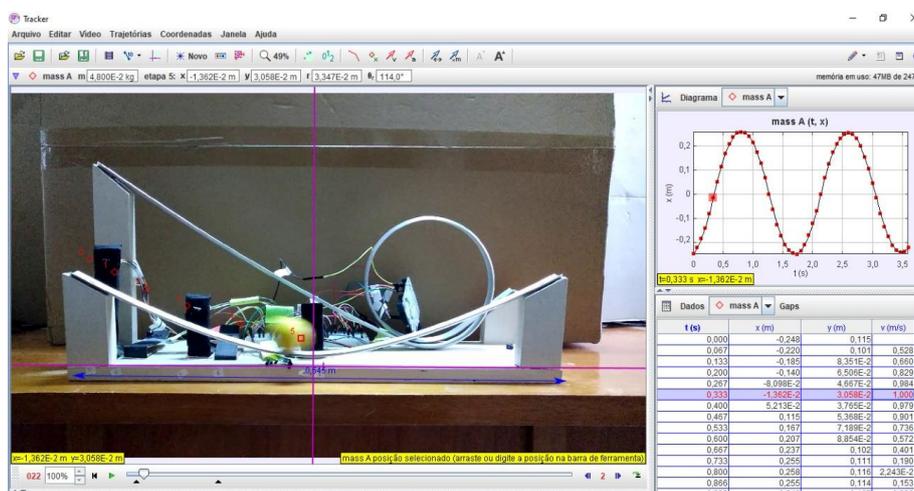
Even though it is not possible to directly compare the Tracker and Arduino® values with each other, it is possible to discuss with students the consistency observed in the results obtained with the two tools. Thus, a qualitative comparison is possible, in which the same behavior of the system can be observed in both approaches, allowing the confirmation that, although the system is theoretically conservative, the mechanical energy gradually decreases, due to the action of dissipative forces.

4.2. Students' Feedback
4.2.1. Demo class with the tool
To carry out a first evaluation of the tool, regarding its use in supporting the teaching of Physics for high school students, a demonstration was carried out for a group of 2nd year students from a public school of technical education in Electronics. In all, 23 students participated in the demonstration, held in an auditorium, in a face-to-face format, with a duration of two class hours. As second-year high school students, they should have already studied energy concepts in the Physics subject. The presentation took place just before the Covid-19 pandemic, with no other presentations for this or other classes of students.

The presentation consisted of four parts: (i) a review of the physics concepts worked on in the experiment (energy, conservative systems, dissipative forces, etc.); (ii) a brief explanation of the monitoring system developed, presenting the main characteristics of the components used (sensors, Bluetooth module, etc.) and a general description of the monitoring software developed for Arduino®; (iii) demonstration of the experiment, moving the sphere in the previous looping track (track 1), showing the results obtained with the tool and discussing them with the students; and (iv) demonstration of the analysis of a video excerpt of the movement with the Tracker tool. The outputs produced by the program were directed to the Arduino® serial monitor but could also be viewed by students on a smartphone, through a Bluetooth communication application. During the demonstrations, students were able to interact with the presenters, questioning them about various aspects such as the development of the experiment and its use, among others.

4.2.2. Assessment

At the end of the demonstration, students answered an evaluation questionnaire organized in three parts: (i) multiple-choice questions about the content of the experiment; (ii) questions about the use of tools to support teaching in the classroom, such as those used in the demonstration: general statements about the use of tools and experiments with educational robotics in Physics teaching, as well as about the looping experiment itself , to assess the degree of agreement of students with them; and (iii) open-ended questions where they could, for example, give their opinion about what they liked and what they didn't like about the demonstration.

As mentioned, the first part of the assessment instrument included several multiple-choice content questions, all referring to energy concepts. Regarding this part of the questionnaire, the students demonstrated a good command of the concepts worked on in the experiment. However, they still had perception difficulties in relation to physical phenomena and the different forms of energy involved in the experiment.

Table 1.
Experiment Evaluation Sentences.

1	Experimental activities with Robotics (sensing) make Physics classes more creative, dynamic and motivating.
2	Robotics' classes facilitate the relationship between theory and practice.
3	The Looping experiment offers opportunities to reinforce, exercise and revise concepts related to energy conservation.
4	Experimental activities with Robotics contribute to increasing interest in Physics.
5	With the Looping experiment, it is easier to visualize the transformation of potential energy into kinetic energy and vice versa, compared to the theoretical explanation.
6	The content worked on in the experiment is related to the theory given in Physics classes (from this year or from previous years).
7	Demonstration classes with robotics' experiments are more interesting than classes with just theory and exercises.
8	Experimental activities with robotics are more motivating than classes with just theory and exercises.
9	The Looping experiment makes it easier to visualize the action of dissipative forces in systems that have an expressive conservative component.
10	One of the difficulties in employing robotics in experimental physics activities is the need to have a good understanding of programming (for example, in C language).

Regarding the second part of the assessment instrument, it contained 10 statements (shown in Table 1) related to the use of tools based on educational robotics to support the teaching of Physics concepts in the classroom, more specifically, to support the discussion of energy concepts. The objective was, through a survey of the students' degree of agreement with the statements, to assess their perception of the suitability of these tools and, consequently, of the digital ICT for learning Physics concepts. The students' degree of agreement with the statements was assessed using a 5-position Lickert scale, ranging from 1 = strongly disagree to 5 = strongly agree.

It was observed that, in general, most students agreed with the statements made. For example, most students expressed agreement with the first sentence (90%), with 55% expressing themselves totally agreeing and 35% only agreeing. The questionnaire also included more specific questions about the experiment, such as sentence 3: most students (95%) agreed with the statement, with 60% totally agreeing and 35% simply agreeing.

The third part of the questionnaire, as mentioned, included open-ended questions that sought to obtain the students' opinions on various aspects, such as what they liked and what they didn't like about the demonstration activities. Examples of these questions are shown in Table 2.

Table 2.
Examples of open-ended questions.

1	Briefly, comment on what you liked the most (or what piqued your interest) about the Looping experiment
2	Briefly, comment on what you didn't like (or think could be improved) about the Looping experiment.
3	Can you imagine any other experiments in which robotics could be used to improve understanding of the physical concepts involved? Or could you mention concepts in Physics that you think could be better understood with experimental practices with Robotics?

It was observed, in relation to what most caught the students' attention, that several points were highlighted, most of them referring to the demonstration itself, since it made it possible to experience in practice concepts of Physics that they had studied only theoretically. Other aspects were also highlighted, such as the relationship between Physics and the design of the system, programming and electronics involved in the experiment. As for what they thought could be improved, several points were suggested. For example, regarding the apparatus itself, there was a suggestion for the use of LEDs (Light Emitting Diodes), so that one could observe the instants of time when the sensors were detected. The use of a larger apparatus was also suggested, since the one used is relatively small. Another suggestion was to perform the sensing of the part related to the looping itself (track 2 in Figure 1). There were also indications from several students about parts (i) and (ii) of the presentation, suggesting greater dynamism and interactivity in the activity as a whole.

4.3. Pedagogical issues

The demonstration of the system described in this phase of project development aimed mainly to verify the adequacy of the tool to help students understand the concepts of Physics on the topic of energy: types of energy, conservative systems, and dissipative forces. In addition, the demonstration also aimed to show examples of how digital information and communication technologies can be emphasized by Physics teachers when working on

Physics concepts in the classroom. In this aspect, the work, by presenting ways of working with these technologies, is in line with what the BNCC advocates for Brazilian secondary education, as discussed above.

Regarding the automated system, this, in its current form, can be used by the teacher to demonstrate the concepts worked in it, as illustrated in this work. Another possibility would be for the students to automate the looping experiment, in the form of a teaching project. In this case, the activities could be performed using the method described in Sena et al. (2019). The advantage of this approach is that, in addition to providing an appropriate environment for a better understanding of the physical concepts related to the experiment, it would give students the opportunity to carry out basic training in educational robotics.

Aiming at a broader work with the system, it is worth mentioning that possible developments from the employed technologies can help to expound other topics of interest in the teaching-learning process, related to the concepts worked on in the experiment. Thus, regarding the Arduino®-based automation, the built prototype makes room for studies on electricity, electronics, and programming, among other subjects. With respect to Tracker, it is possible to modify the configuration parameters for video analysis and verify its influence on the obtained results. Furthermore, the data set obtained can be used to generate several graphs related to the movement, which can be compared with the behavior observed in the movement of the sphere in the experiment.

It is noteworthy that the technologies emphasized in this work can be used in a complementary way, so that one can count on different ways to visualize the results and data sets. Thus, a teacher who wants to make use of new technologies in the classroom can use them independently. For example, if the teacher is not able to assemble the circuits with the Arduino®, he can make simulations of experiments involving movement using the Tracker, since it is a free tool and the analysis can be done from an "amateur" video, obtained with the camera of an ordinary smartphone. Regarding the Arduino® assembly, the teacher could, at first, eliminate Bluetooth communication (used as an alternative to outputting results), since the Bluetooth module is a relatively expensive component.

5. CONCLUSION

The present work focused on the investigation of the use of specific digital ICT to support the teaching of Physics, regarding experimental demonstrations related to the principle of energy conservation in the looping experiment. One of the focuses, in terms of technology, was educational robotics, implemented using sensors interfaced to an Arduino® board, to collect data related to the cyclic movement of a small sphere along one of the tracks of the looping setup. A video analysis tool, the Tracker software, was also used to generate a set of movement data, from a simple filming of the experiment, carried out with a smartphone. A qualitative comparison between the results of both approaches is possible, in which the same behavior of the system is observed, showing that, although the system is theoretically conservative, the mechanical energy gradually decreases, due to the action of dissipative forces.

The use of new technologies in the classroom by itself, in general, is already a motivating factor for most students. In addition, as recommended in the competences of the BNCC, the use of digital ICTs should be part of everyday school life in Brazil. In this context, their use in teaching support systems can contribute to improving the quality of education. As Curto and Moreno (2016) point out, projects based on robots provide students, both in high school and at university, with a more interesting and fun view of Science and Engineering, enabling a practical view of the application of theoretical concepts. The authors

also highlight the inclusion aspect of educational robotics, which can help students direct their university careers to the STEM (Science, Technology, Engineering and Mathematics) knowledge areas. We argue that it can also help them visualize additional applications of theoretical concepts in real-life projects and scenarios. This process of contextualizing knowledge can help them to develop innovative projects and solutions to meet society's needs.

The experiment presented in this work, in addition to being useful in Physics teaching in high school, as discussed, can be used to allow the introduction of robotics and automation elements. Moreover, the use of Tracker makes it possible to obtain datasets that can be useful also for allowing different approaches to motion analysis, both in terms of graphs and data tables, as Tracker allows working with other dependent variables. Finally, it should be noted that the experiment also allows the realization of new research and development, since further experiments can be easily automated with few modifications, using the looping setup.

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