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PHYSICS TEACHING COMBINED WITH DIGITAL TECHNOLOGICAL RESOURCES (RTD): the contributions of the Arduino platform in the classroom

O ENSINO DE FÍSICA ALIADO A RECURSOS EDUCACIONAIS DIGITAIS (RED): As contribuições da plataforma Arduino em sala de aula

EDUCACIÓN FÍSICA ALIADA A LOS RECURSOS EDUCATIVOS DIGITALES (RED): Los aportes de la plataforma Arduino en el aula

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ABSTRACT:
This study aimed to identify the literary production on the use of the Arduino platform as a digital technological resource (RED) for teaching physics concepts in high school. This is an exploratory study carried out in databases of recognized scientific journals in the areas of teaching and exact sciences. From the survey of 32 works that were characterized by the scope of this study, fourteen articles stood out that brought the results of experimental projects developed for the teaching of scientific concepts with the help of Arduino. The results of these studies indicated that the use of this RED in the development of experimental activities in the classroom, in addition to providing autonomy and the development of the student's scientific, critical and creative thinking, also proved to be a technologically viable and economically sustainable resource for low cost, but with quality and versatility equal to or greater than commercial options.

KEYWORDS: Physics teaching. Digital Educational Resources. Arduino; Experimental Activities.

Introduction

The world has gone through several transformations in the field of technologies as a result of scientific advances and the intensification of trade relations between nations, given the process of economic globalization. The inclusion of digital technologies in the daily lives of organizations and in people's lives changed not only the dynamics of the world of work, but also impacted the forms of consumption, interpersonal relationships and the way of accessing cultural goods historically produced by humanity (CORDOVA; TORT, 2016; GALERIU *et. al.*, 2014).

However, for more positive and/or negative influences that technologies can generate, there is still a portion of society excluded from its reach. In 2016, the

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Continuous National Household Sample Survey (PNAD) collected, for the first time, information on the access of the Brazilian population aged 10 years and over to the Internet, television and mobile phone for personal use. The survey identified that among the 69,318,000 households surveyed across the country, 2.8% still did not have access to televisions; in 5.4% of them there was no type of telephone equipment; in 54.7% of the households did not have microcomputers and that the domestic use of the Internet was confirmed in 69.3% of the surveyed households (BRASIL, 2016).

These data indicate challenges to be overcome to ensure universal access to technological resources by the Brazilian population, ranging from the need for investments in infrastructure to ensure connection quality, to the adoption of public policies to ensure more affordable prices for available products and services, democratizing the acquisition and enjoyment of technological resources by the population.

In an initiative of a similar nature, the all pela Educação Movement carried out a survey in 2017 among four thousand public school teachers across the country, with the aim of identifying the use of digital technologies in the classroom. The data revealed that 55% of teachers regularly used the technology out of need or curiosity for new tools to help them on a daily basis.

However, when referring to the use of technology in the classroom, the survey identified some challenges: 67% of teachers stated that they had moderate or high need for professional improvement in the use of digital information and communication technologies (DICT); 72% of teachers who used some technological resource in the classroom did so as support to present information or demonstrate to students; 66% of teachers pointed out a gap in the quantity and obsolescence of the equipment available in their schools (MOVIMENTO, 2017).

Among the factors pointed out by teachers as limiting the use of technologies in the classroom, the following were mentioned: the perception of the impact on students, as they did not associate the use of technology with the improvement of students' academic performance; the lack of technological infrastructure in schools (hardware and software); the perception that the use of TDIC in the classroom would increase the teacher's work demand and the pressure on the teaching work, and the lack of specific training for the use of technology in the classroom (MOVIMENTO, 2017).

Faced with these challenges, some questions arise regarding the relationship between education and technologies: how can educational technologies contribute to more innovative pedagogical relationships that impact teaching and learning processes and contribute to the education of students? What is the political-social and pedagogical

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role of schools and teachers in terms of their responsibility for educating future generations? How prepared are teachers to break with the traditional model of teaching practices due to progressive and innovative practices that value the construction of knowledge by the student and the development of their cognitive, procedural/technical and attitudinal/ethical capacities?

Libâneo (2011) emphasizes that the school must ensure cultural and scientific training for the personal, professional and citizen life of students. The school must enable an autonomous, critical and constructive relationship with culture and its manifestations. In addition, it must offer a solid general education that provides the student with the ability to think critically and act ethically in the face of social, cultural, environmental, scientific and technological changes in society.

This school “needs to stop being merely an information-transmitting agency and become a place of critical analysis and production of information, where knowledge enables the attribution of meaning to information” (LIBÂNEO, 2011, p. 12). It is, therefore, a school that does not see the student as a recipient of information, but which enables the development of their cognitive abilities, which teaches them to think critically and reflectively and, above all, to access, master and to produce a set of knowledge necessary for their active participation in society.

Moran (2018) emphasizes that this tension for changes in education has demanded from educators more lively, creative, meaningful and experiential forms of the teaching process. It is expected that a school is not guided by a magistrocentric vision of teaching, based on the student's passivity and on the fulfillment of the different stages of schooling. An educational institution committed to the ominilateral training of subjects who, supported by a consistent and qualified theoretical training, enable them to identify problems and present viable solutions to solve them.

This school presupposes contextualized and meaningful learning, which implies that it will demand "from the learner and the teacher, different forms of internal and external movement, motivation, selection, interpretation, comparison, evaluation, application" (MORAN, 2018, p. 38) from simpler levels to more complex levels. This meaningful learning increases "cognitive flexibility, which is the ability to alternate and perform different tasks, mental operations or goals and to adapt to unexpected situations, overcoming rigid mental models and inefficient automatisms" (p. 39).

However, for this to happen, it is necessary to rethink the role of the school facing the challenges of contemporary society. It is necessary that public education is elected as a national priority, therefore, it is imperative to review investment policies for public

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education in this country, so that a school environment conducive to such changes is created.

In addition to ensuring that teachers have dignified and objective working conditions, investments in infrastructure and equipment are needed to expand Internet access to all public schools across the country and also guarantee the acquisition of technological equipment that expands the use of these resources in schools.

Equally important is the commitment to be made with the initial and continuing education of teachers so that they have the possibility of rethinking their teaching in the face of new digital technologies, enabling them to master the informational language and to develop more methodological practices. significant.

The interaction of the school and its subjects with digital technologies compels traditional teaching methods to be replaced by participatory methods that engage the student in the construction of their own knowledge through research, group work, task sharing and problem solving (LIBÂNEO, 2011; MORAN, 2018).

In order for DICT to be used as pedagogical resources and for digital culture to be instituted in the school context, it is necessary for the teacher to let go of already entrenched conservative teaching practices and assume a critical and receptive posture in relation to technology, also placing themselves , in the position of learning subject.

In the field of teaching Physics, the reality of teachers who work in basic education is not different from others. Pedagogical practices are generally centered on the teacher's figure, with outdated content and obsolete technologies that result in mechanical, decontextualized, tiring and reproducible learning. The focus is almost always on solving exercise lists and presenting correct answers, but without the necessary correlation with other areas of knowledge and contextualization with the daily lives of students (MOREIRA, 2017).

The introduction of experimental methodologies for data acquisition using the computer represents a viable alternative for exploration and statistical analysis of data in physics classes. The use of computers and microcontrollers has become increasingly integrated into Physics teaching activities, considering that the experiments conducted by these technologies become more attractive to students compared to classes in the traditional model (ATKIN, 2018; DWORAKOWSKI, et al., 2016).

Studies show that experimental methodologies in the teaching of Physics are enriching for students and can be facilitating strategies for learning scientific concepts. They allow the appreciation of the students' prior knowledge and the correlation between theory and practice, by carrying out the experiment, giving meaning to what is being learned, by bringing scientific knowledge closer to the elements of the student's

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reality (CARVALHO; AMORIM, 2014; DWORAKOWSKI et al., 2016; MORAES; SILVA, 2015; PEREIRA; MOREIRA, 2017; TUNYAGI et al., 2018).

Thus, experimental activities in the teaching of Physics are viable alternatives for the development of scientific, critical and creative thinking by students, as they are methodologies with the potential to awaken their interest in the functioning of Science and its investigation methods, contributing to the construction of scientific concepts from data explored in the classroom (MOYA, 2017; SZMOSKI, et al., 2017).

It is not possible to wait for a new generation of scientists if students are not allowed to appropriate the scientific language and its methods. It is necessary to create opportunities for exploration in the field of science and the practical experience of scientific models that enable the development of creativity and curiosity of students, preferably in a friendly, constructive and technologically viable educational environment.

Experimental methodologies allow overcoming the encyclopedism of terms and concepts in Physics, in addition to being in line with the guidelines recommended by the Base National Common Curriculum (BNCC) as to the need to promote the scientific literacy of students.

According to the BNCC, the commitment to scientific literacy should start from elementary school. This is a process that "[...] involves the ability to understand and interpret the world (natural, social and technological), but also to transform it based on the theoretical and procedural contributions of science" (BRASIL, 2017, p. 273).

For the teaching of Physics to contribute to the consolidation of scientific literacy in public school students, investments in teaching laboratories are needed. However, considering the material constraints to which these schools are subjected and, given the high cost of specific commercial equipment that can exceed hundreds of dollars, a viable alternative is the development of low-cost electronic instrumentation, easily found on a daily basis. day and with the same quality and precision in obtaining the data. As examples of this equipment we can mention the Arduino Uno platform, the resistors, the potentiometers, the light emitting diode (*light-emitting diode* - LED), the 5V battery, the sensors, among others.

Arduino is a free software and hardware platform that allows the development of programmable electronic circuits via Universal Serial Bus (USB) in a quick and practical way, even by people without training or specific knowledge in electronics. The Arduino is relatively low cost (in the order of ten reais), it is open source, it is easy to transport, it is precise and versatile, it is easy to handle and access, in addition to the fact that several scientific communities make available assembly schematics and codes free of charge (SOUZA et al., 2011).

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Thus, this article aims to identify the literary production on the use of the Arduino platform, in order to verify its viability as a digital educational resource favorable to the teaching of Physics for the development of experimental activities in the classroom.

Methodology

The research was developed due to the need to identify studies on the use of the Arduino platform as a viable RED for the development of experimental activities in the teaching of Physics in high school. The methodology had a qualitative interpretive hermeneutic approach, using the strategy of document analysis with a focus on a Systematic Literature Review (SLR), which proposes to identify, select, evaluate and synthesize the relevant evidence available (GALVÃO; PEREIRA, 2014).

For Kitchenham (2004), the SLR must meet the following criteria: the creation of a review protocol, the selection of primary studies, the assessment of the quality of the available studies, and the extraction and synthesis of data. The creation of the review protocol establishes a process of greater reliability in the research, making it susceptible to reproduction.

For that, some guiding questions were elaborated that were adopted as exclusion and inclusion criteria of the studies on the subject: can Arduino be used as a tool in the teaching of Physics? Does the experimental activity with Arduino provide satisfactory results for the construction of knowledge by the student when compared to the results of theoretical classes?

In order to seek answers to these questions, three specific objectives were defined: to understand the methodology of experimental teaching with the Arduino platform, adopted in the selected study; identify experimental scripts with accessible values that can be replicated in public schools and identify the cases that were successful in applying this methodology.

The search for studies was carried out in the databases of national and foreign journals (in Portuguese, English and Spanish) specialized in the areas of teaching and Exact Sciences, published from 2010 until the month of July 2020, namely:Scielo (Scientific Electronic Library Online), ERIC (Educational Resources Information Center), REdAlyc (Red de Revistas Científicas da América Latina y el Caribe, España y Portugal), e ASP (Academic Search Premier).

The descriptors used to identify the studies were "Education of Physics", "Physics" and "Microprocessors". In the first searches of the databases, thirty-two articles with the potential to answer the research questions were identified. Then, the abstract of all

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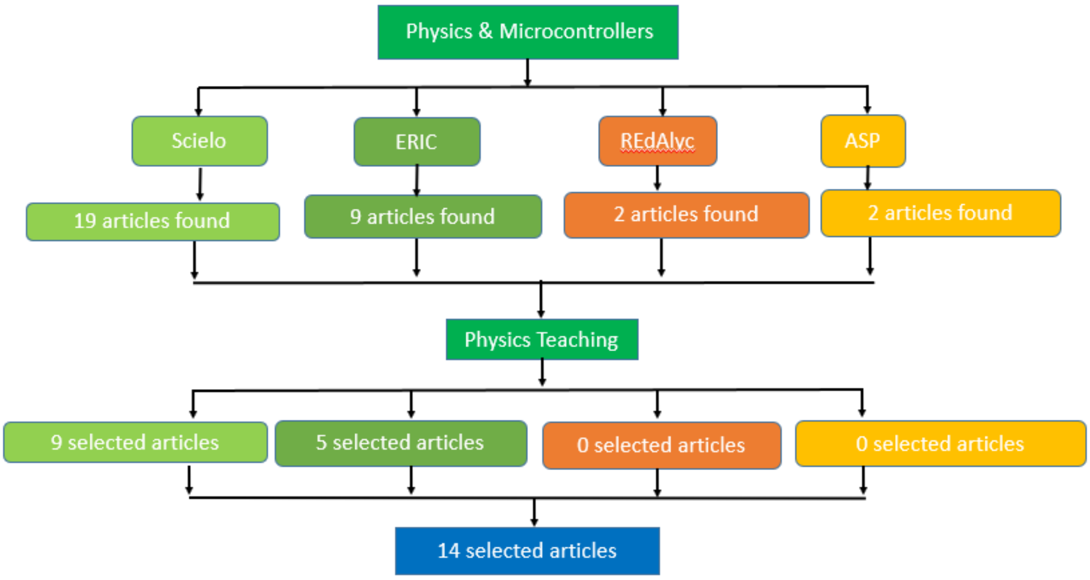
selected articles and the excerpts containing the descriptors used in the search were read, in order to assess the alignment of the article with the objectives of this research.

After this step, only the articles that explicitly addressed the use of the Arduino platform applied to the teaching of Physics were kept, considering the teaching methodology and the script of experimental activities with the platform. Following the selection criteria, eighteen articles were excluded and fourteen were selected for analysis, nine articles in the Scielo database and five in the Eric database.

Figure 1. Flowchart of articles selected for the study.



Source: Prepared by the authors (2020).

Results and discussions

Table 1 presents the identity of the analyzed articles and the relevant aspects of scientific productions with the theme of Physics teaching and the use of the Arduino platform. It was observed that the productions were concentrated in the period from 2011 to 2018, demonstrating that from 2017 there was an increase in publications by 65%.

All analyzed studies presented as main characteristics the low cost of acquiring the components used in the experiments and the easy access to informational materials (scripts) for the elaboration of the projects. In addition, there was a consensus among researchers that the Arduino platform can be used to support the teaching practices of physics teachers (CARVALHO; AMORIM, 2014; CARVALHO NETO et al, 2017; DWORAKOWSKI et al., 2016; MORAES; SILVA, 2015; PEREIRA; MOREIRA, 2017; TUNYAGI et al., 2018; SZMOSKI et al., 2017).

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Below, table 1 presents the comparison of selected and analyzed articles:

Table 1. Comparison of studies involving the teaching of Physics and Arduino

AUTHOR AND YEAR	ARTICLE	OBJECTIVE	CONTRIBUTIONS
Cavalcante et al. (2011)	Physics with Arduino for beginners.	Acquisition and automation of data in experimental Physics activities.	Didactic proposals for interaction with Arduino with tutorials that enable the reproduction of experiments.
Souza et al. (2011)	The Arduino Board: A Low-Cost Option for PC-Assisted Physics Experiences	Present the Arduino board, for data acquisition.	A low-cost option for acquiring data with a PC. And two applications that show the potential of this platform.
Galeriu et al. (2014)	An Arduino investigation of simple harmonic motion.	Investigate the simple harmonic motion of a mass in a spring.	Interdisciplinary activity integrates electronics, computer programming, physics and mathematics.
Cordova; Tort (2016)	Medida de g com a placa Arduino em um experimento simples de queda livre.	Measure g with the Arduino board in a simple free-fall experiment.	Experimental results with a relative error of 0.1% compared to the local measured g value by the National Observatory, Rio de Janeiro.
Dworakowski *et al.* (2016)	Use of Arduino platform and PLX-DAQ software to build real-time motion graphics.	Build an experimental apparatus suitable for teaching Kinematics graphics.	Identified better student performance in analyzing and interpreting motion graphics. real, from the experimental apparatus used.
Moya (2017)	Connection Time and Frequency in the RC Circuit.	Study the charge and discharge of a capacitor through a resistor.	Allows comparison of time constants.
Szmoski *et al.* (2017)	Development of a low-cost experimental apparatus for the study of falling objects: analysis of magnet motion in vertically oriented tubes.	Propose a low-cost experimental apparatus to study these behaviors in a quantitative way.	The results obtained corroborate the predicted theoretical results.
Carvalho Neto *et al.* (2017)	Six-channel analog photogate system for Physics didactic labs.	Describe and make available a complete optical switch system (photogates) (hardware + software) for use in Physics teaching laboratories.	In the structuring and autonomy of teaching laboratories by providing the development of robust projects with quality and versatility equal to or superior to commercial options.

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Nascimento *et al.* (2018)	Temporal description of collision forces: a didactic model for a physics laboratory assisted by an embedded system.	Modeling the collision force on a ball.	The laws of classical mechanics were verified with remarkable accuracy.
Silveira *et al.* (2018)	Experimental didactic proposal for the inclusive teaching of waves in high school.	Develop two experiments that present relationships between invisible and inaudible frequencies.	Inclusive activity, which allowed a sensory experience for blind and deaf students.
Cordova *et al.* (2018)	Audiothermometer: a thermometer for the inclusion of visually impaired students.	Reduce the difficulties presented and by students with visual impairments.	Allows to identify the values of temperatures, by sound.
Tunyagi *et al.* (2018)	Determination of friction coefficient by electrical resistance measurements.	Obtaining the coefficient of friction using a rubber cord and a force sensor.	The results obtained are in line with the results in the literature.
Espindola *et al.* (2018)	Use of an Arduino to study the buoyant force.	Measure apparent weight as a function of depth using two load cells connected to an Arduino.	He verified Archimedes' principle, Newton's third law, and calculated the density of the liquid.
Atkin (2018)	Investigating the Torricelli Law Using a Pressure Sensor with Arduino and MakerPlot.	Examine Torricelli's law for liquid flow from a small drainage hole in a container.	Better data acquisition with a technique replacement.

Source: Prepared by the authors (2020).

The authors of the evaluated articles do not explain a specific learning theory as a guide for pedagogical practice, however, it was observed that they all corroborate Ausubel's Theory of Meaningful Learning, which states that new information is anchored in relevant concepts or preconceptions, existing in the cognitive structure of students, assuming students' participation, dialogue and critical reflection (D`AUSILIO, 2011; MOREIRA; MASINI, 2002).

Cavalcante et al. (2011), presented different ways of operating the Arduino platform, one of which was the alternative interface for data acquisition and automation in experimental Physics activities via the computer's USB port.

In this work, the selected experiment was the study of the charge and discharge of a capacitor, in a Resistor Capacitor (RC) circuit. The steps of interaction with Arduino, circuit construction, collection and simultaneous graphic visualization were presented. For each step, all the source codes necessary for the interaction with the microprocessor were presented.

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Thereby, Cavalcante et al. (2011), showed how we can transition from an application in which Arduino behaved only as a real-time data acquisition interface with the help of the Processing software for reading the captured data and transforming it into graphics. The study demonstrated the potential that a microcontroller can offer and the range of possibilities for its exploitation, above all, because it is an open source resource, which greatly facilitates its use and dissemination.

Carvalho Neto et al. (2017) described and made available a system composed of free hardware and software for use in Physics teaching laboratories. Used for different approaches and with good response time (approximately 1ms) and accuracy in data collection, with analog-digital conversion of up to 10 bits.

The RED was used in the test phase in three experiments: inclined plane, viscometer and simple pendulum. The authors reported that the students set up the experimental apparatus without difficulties and the program code was informed by the professors/authors to obtain the data. They also highlighted that it is essential to observe the processes underlying data acquisition devices for a correct evaluation and experimental limitations (CARVALHO NETO et al., 2017).

The study found that experimental activities in teaching enable students to have contact with physical quantities based on procedures of the scientific method. The work proposal of these authors enabled the development of a project with reasonably sophisticated resources, requiring basic knowledge of electronics and programming to implement the algorithm. The proposal was based on the concept of shared projects with free access to programming codes. The examples illustrated the Arduino's versatility and the quality of the results obtained, confirming its viability for the practice of experimental activities that would require the use of Physics teaching laboratories (CARVALHO NETO et al, 2017).

Dworakowski et al. (2016) described the construction of an experimental apparatus to facilitate data acquisition to sketch kinematics graphics. The experimental apparatus used the PLX-DAQ software, in addition to an ultrasound sonar sensor coupled to an Arduino platform in order to record the positions and distances of objects. The instrumental apparatus was developed for classes in the first year of high school, as an educational product, developed and applied during graduate studies at the professional master's level.

The practical activity consisted of watching a demonstration on how the equipment worked, and then the students tested its functionality. The room was divided into five groups and each group received an experimental kit. When starting the experiment by moving the object, space and time data were generated in real time to obtain the graph.

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Thus, students compared the graph produced with the graph received for analysis, identifying the movement situation through the graphs.

Authors' motivation Dworakowski et al. (2016) to develop this activity took place when students had difficulties in collecting and tabulating time and distance data in experimental activities and in sketching Kinematics graphs.

Aiming at overcoming the difficulties reported by the students, the activities described in the work helped students become familiar with obtaining and using data in real time, something they had never experienced before. With this, the students had the opportunity to interpret qualitative results and reproduce motion graphics, in real time, from the Arduino platform and the Parallax Inc software. The authors found, throughout the set of activities, the progressive development of the students, assessed as fully satisfactory in relation to the expected learning objectives.

Souza et al. (2011) presented didactic experiments in the classroom using the Arduino platform to study damped oscillations. For this purpose, the damped movement of a plastic ruler with a small flat mirror fixed at one end and the other end of the ruler, which was fixed with the aid of a small pedestal, was recorded. Then, the free end of the ruler was touched, making it vibrate in the vertical direction. Using a laser pointer, a mirror to reflect light and an LDR (Light Dependent Resistor), he formed the experimental apparatus that, with few adjustments, could also be used to study radiative exchanges. All programs, details of the experimental assembly and locations where the national version of the Arduino board (Freeduino-BR) can be obtained directly, via e-mail, from the corresponding author.

The Arduino board in this experiment was used for data collection, however, the application possibilities go far beyond that. The authors pointed out applications in which small electronic components such as resistors, thermistors and LDR can be used with low-cost transducers (a device used in energy conversion from one nature to another) as simple complements to the Arduino board. The entire system of this RED for data acquisition has high portability being convenient for field experiments, when used with a laptop (SOUZA et al. 2011).

Galeriu et al. (2014) realized the advantages of using the Arduino platform for teaching laboratory experiments in high schools, as this experimental equipment has a lower cost than commercial alternatives.

The experimental activities developed were simple harmonic motion (MHS) mass and spring. In this activity, only an ultrasonic distance sensor and an Arduino microcontroller were used. The obtained data were graphically represented and analyzed using the Origin 9 program. The programming codes used were relatively simple and did

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not require in-depth knowledge of programming, making it easier for the teacher to explore the countless potentialities that a microcontroller can offer.

The authors described the low cost of components for the construction of RED, the ease of assembly and the accuracy of the data obtained by it, when compared with the data provided in the theoretical model. During the activity, fundamental connections between Physics, electronics, computer programming and Mathematics were revealed, which enables interdisciplinarity between the areas of knowledge. It was also observed that students were motivated during the experimental activities as they had the opportunity to build knowledge in an autonomous and pleasurable way (GALERIU et al., 2014).

Cordova e Tort (2016) developed a RED for the development of an experimental activity to measure the local gravity acceleration (g), using an Arduino platform. Two meetings were held with students, the first, to present the theoretical foundations and the experimental arrangement, and the second, for students to collect and analyze data. The experimental results obtained in the classroom in this experiment showed a relative error of less than 0.1%, when compared with the local value of g measured at the National Observatory of Rio de Janeiro.

The authors provided the source codes, apparatus assembly scheme and also observed that there is no need for deep knowledge in electronics to assemble the circuit. The authors also highlight the low cost of assembling the experimental apparatus and its efficiency in calculating the free fall time of a body, with time precision in milliseconds.

Moya (2017) carried out an experimental study of charging and discharging a capacitor, in a simple electrical circuit with a source, a resistor and a capacitor, to introduce the concepts of exponential variation of electric current and voltage as a function of the time constant. Determining the time constant of the RC circuit can be used to measure unknown values of resistance or capacitance. The author has developed an Arduino platform that demonstrates how the time constant of the RC circuit can be easily determined.

The study revealed the ability to apply the experiment to the physics laboratory in several undergraduate courses such as chemistry, engineering, information technology and electronics courses. The values obtained during data collection proved to be in excellent agreement with the theoretical values expected in the literature. This activity allowed the students to use experimental techniques, the comparison of the obtained time constants and the correlation of the time and frequency domains.

Szmoski et al. (2017) compared two distinct theoretical approaches for determining the terminal velocity of a magnet inside metallic tubes. The purpose of this work was to

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develop a low-cost experimental apparatus using the Arduino to quantitatively and qualitatively study the motion described by falling magnets inside a metallic tube, aiming to explore the laws of falling bodies and induction attributed to Faraday and Lenz.

The apparatus had an ultrasonic sensor, coupled to the Arduino microcontroller, which made it possible to monitor the magnet's displacement in short time intervals (1ms) to, finally, calculate the magnet's velocity and acceleration. The results obtained were in agreement with the results predicted by the theory. The study showed that the Arduino platform allows a multitude of experimental activities for the teaching of Physics and that its use in the classroom in a well-oriented way represents an important step towards the construction of knowledge by students with the support of a technological resource (SZMOSKI et al., 2017).

Nascimento et al. (2018) modeled an experiment to temporally describe the collision forces on a ball. For this activity, the authors developed a programmable circuit with an Arduino and a piezoelectric sensor connected to a computer, where a certain ball with mass m was dropped at a height y vertically on top of this sensor. The programming was done in Wiring language (similar to C++ language) to read the sensor signal and calculate the force intensity. Immediately after the collision, the program provided data for the elaboration of a force x time table with a resolution of 120 μs, proving the laws of conservation of momentum and energy.

The authors of this work presented the assembly scheme and source codes to be reproduced and tested, in addition to teaching how to calibrate the experimental apparatus after its construction to find the proportionality constant (λ), as the Piezoelectric Sensor sends an electrical signal (V) to the Arduino and this electrical signal is proportional to the force (F) applied times the proportionality constant $V = \lambda F$.

The total cost of the experimental apparatus was close to R$ 160.00, except for the computer, obtaining results very close to those compared to the literature. The performance tests of the experimental apparatus allowed the detailed exploration of the force during the collision. In addition, it also demonstrated that the apparatus has the potential to be used for the experimental exploration of other phenomena, requiring only the change of sensors and adjustments in the program (MASCIMENTO et al., 2018).

Tunyagi et al. (2018) presented a simple and low-cost experiment, using the Arduino to measure the coefficient of friction between wood and other surfaces, using a conductive rubber cord as a force sensor. This activity was developed for high school and college students.

Pedagogically, the study confirmed that combining theory with practical activities helps in the teaching and learning processes, as the student is no longer a mere spectator of lectures and, when challenged to solve the proposed problems, accessed prior knowledge, reflected on the possible results, defined paths to reach the results, accessed theoretical knowledge to solve practical activities, building and giving meaning to the assimilated knowledge.

Espindola et al. (2018) studied the apparent weight of bodies, proposing an experimental apparatus that measures the resulting force exerted by the fluid on a body, as a function of the depth inside a cylinder with water. In this experiment, we chose to use the Arduino microcontroller for automatic data collection. The programming was done by the teachers themselves with little experience in programming languages, in an easy and intuitive way compared to other languages.

According to the research, the experiment provided the student with a better understanding of Archimedes' principle, Newton's third law and the density of a liquid. It also demonstrated that the experimental apparatus can be used in physics laboratories replacing commercial kits, as the limitations regarding accuracy are irrelevant when compared to the countless possibilities of student learning (ESPINDOLA et al., 2018).

Atkin (2018) studied the flow of liquid inside a container with a drainage hole under the action of gravity, based on Torricelli's theorem. There are two ways to model this system: using a traditional calculus-based approach or a computational method without calculus, the second option being more appropriate for high school students.

Based on this, an experiment was developed using the Arduino platform for pressure sensing, which allowed measuring the fluid flow at a rate proportional to the square root of the height of the liquid above the orifice. The author provided the assembly scheme, the materials used in the experiment and the codes for programming, enabling the reproduction of the experimental apparatus. This work proved to be able to demonstrate both in theory and in practice Torricelli's theorem.

Cordova et al. (2018) developed inclusive experimental activities in the light of the National Guidelines for Special Education in Basic Education. The authors developed a thermometer using the Arduino platform capable of emitting audible beeps when temperature is measured. The range of temperatures ranged from –10 °C to 110 °C, broken down from 0.5 to 0.5 °C.

The experimental activity proved to be an assistive technology capable of ensuring the right to learning for students with visual impairments in Physics classes, not only for the practical study of thermometry, but also, it proved to be efficient for measuring other magnitudes of physics, such as voltage (audio-voltmeter) and electrical current (audio-ammeter) (CORDOVA et al., 2018).

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Silveira et al. (2018) developed two experiments that present relationships between inaudible and visible frequencies, through wave processing with the Arduino platform, converted into frequencies that sensitize the senses.

Regardless of the nature of electromagnetic or mechanical waves, human beings are able to identify some tracks through our senses, however, people with hearing impairments are restricted to audible frequencies, but can perceive visible waves. Thus, the experiments aimed to provide students with visual or hearing impairments the same opportunity to interact with the content explored in the practical activities of Physics classes (SILVEIRA et al., 2018).

The authors emphasize that one of the greatest difficulties of students with visual impairments in learning Physics is related to the absence of elements that help them to understand the scientific concepts worked on in the classroom. Because of this, these teachers developed two assistive experiments with the Arduino platform that will be able to help these students in the apprehension of this content, allowing deaf students to "see" the sound in the form of light and the blind students "hear" the light in form of sound (SILVEIRA et al., 2018).

Final considerations

The selected articles presented proposals that can be easily reproduced and applied in the classroom, favoring the realization of experimental activities. The studies showed that the Arduino platform is an efficient RED in the reproduction and simulation of physical phenomena, as it is a low-cost equipment, especially when compared to commercial options, easy to operate, with the capacity for accurate and efficient measurements.

The Arduino platform has a versatile graphical interface for data acquisition and automation, easily adapted to control several didactic experiments, since its programming is accessible even for people who are not familiar with the programming language. With few modifications to the code, the teacher can adapt the experimental proposals to meet the specific didactic needs of the students.

Another advantage of this equipment is that the Arduino's graphical interface is available for desktops and mobile devices, such as smartphones, which allows it to be accessed remotely. Its use is easy and attractive for high school students, who can be encouraged to carry out experiments outside the school environment, just having an Internet connection. Therefore, it constitutes an adequate and versatile pedagogical resource to carry out experiments and demonstrations inside or outside the classroom.

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The authors of the selected works were unanimous in using the concepts of low-cost materials in experimental activities. The Arduino platform presents itself as an efficient RED and a viable alternative in view of the lack of equipment and didactic laboratories in Physics, even for studies in Modern Physics, as the acquisition of electronic components is accessible when compared to experimentais kits and traditional equipment disseminated and sold on the market.

From a didactic point of view, Arduino is a RED that helps in the scientific literacy of students, because from clear, well-defined and structured scripts, students are encouraged to undertake scientific initiation based on the experience and resolution of problems that require formulation hypotheses, data collection, analysis and discussion of the results obtained and, finally, the understanding of the studied phenomena.

All studies analyzed present partial or total proposals for the construction of experimental apparatus, in some cases the authors highlighted the possibility of new approaches with numerous opportunities for contextualization, adapting the materials and instruments available by teachers and students. It is important to highlight that the use of the Arduino platform in more than 50% of the works was to obtain data, as this feature allows obtaining measurements of physical quantities quickly and accurately through sensors. The most used sensors by the authors were: pressure sensor, light sensor, temperature receiver, optical and ultrasonic.

Arduino proved to be an efficient RED for the teaching of Physics as it allows the realization of experimental activities regardless of the existence of didactic Physics laboratories. Furthermore, the use of technologies in the classroom enables the creation of a stimulating, pleasant and participative environment, which favors learning.

The achievements of these practices arouse students' interest and curiosity in Physics, develop students' investigative spirit, awaken their interest and curiosity in science and ensure their involvement in the construction of knowledge in a meaningful way.

However, despite these advantages, this resource is still little known and little used in public schools and in physics classes, despite being disseminated in several academic researches. This is a problem that may be related to the teachers' lack of knowledge about the countless possibilities that the use of this RED brings to the teaching of Physics and how its use in experimental activities in the classroom could favor student learning.

This finding indicates the need for continuing education for teachers who work in basic education, both in terms of the diversity of DER that can be used in the classroom, as well as in its operationalization and in the development of methodological strategies suitable for its use.

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Therefore, considering the use of the Arduino platform in the teaching of Physics can be an interesting and efficient option for the development of experimental activities, as it is a low-cost technology, which, for the context of Brazilian public schools, is an economically sustainable alternative, socially fair and technologically viable.

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RESUMO:
Este estudo teve por objetivo identificar a produção literária sobre o uso da plataforma Arduino como um recurso tecnológico digital (RED) para o ensino de conceitos da Física no ensino médio. Trata-se de um estudo exploratório realizado em bases de dados de periódicos científicos reconhecidos nas áreas de ensino e ciências exatas. A partir do levantamento de 32 trabalhos que se caracterizavam ao escopo deste estudo, destacaram-se quatorze artigos que traziam os resultados de projetos experimentais desenvolvidos para o ensino de conceitos científicos com o auxílio do Arduino. Os resultados desses estudos indicaram que o uso deste RED no desenvolvimento de atividades experimentais em sala de aula, além de propiciar a autonomia e o desenvolvimento do pensamento científico, crítico e criativo do estudante, também se revelou como um recurso tecnologicamente viável e economicamente sustentável por ser de baixo custo, mas com qualidade e versatilidade iguais ou superiores às opções comerciais.

PALAVRAS-CHAVES: Ensino de Física. Recursos Educacionais Digitais. Arduino. Atividades Experimentais.

RESUMEN:
Este estudio tuvo como objetivo identificar la producción literaria sobre el uso de la plataforma Arduino como recurso tecnológico digital (RED) para la enseñanza de conceptos de física en la escuela secundaria. Se trata de un estudio exploratorio realizado en bases de datos de reconocidas revistas científicas en las áreas de docencia y ciencias exactas. Del relevamiento de 32 trabajos que se caracterizaron por el alcance de este estudio, se destacaron catorce artículos que trajeron los resultados de proyectos experimentales desarrollados para la enseñanza de conceptos científicos con la ayuda de Arduino. Los resultados de estos estudios indicaron que el uso de esta RED en el desarrollo de actividades experimentales en el aula, además de brindar autonomía y el desarrollo del pensamiento científico, crítico y creativo del estudiante, también resultó ser un recurso tecnológicamente viable y económicamente sostenible. recurso a bajo costo, pero con calidad y versatilidad igual o superior a las opciones comerciales.

PALABRAS-CLAVES: Enseñanza de la física. Recursos educativos digitales. Arduino. Actividades experimentales.