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Learning about UV radiation and sustainability with arduino and sensors

Ana Sousa [a] *, Pedro Rodrigues [a], Cláudia Maia-Lima [a,b], Alexandre Pinto [a,c], António Barbot [a,c]

[a] *School of Education, Polytechnic Institute of Porto, Rua Dr. Roberto Frias 602, Porto 4200-465, Portugal*
[b] *InED – Centre for Research and Innovation in Education, Rua Dr. Roberto Frias 602, Porto 4200-465, Portugal*
[c] *CIDTFF – Research Centre "Didactics and Technology in education of Trainers", Campus Universitário, Aveiro 3810-193, Portugal*

Abstract

The excessive exposure to ultraviolet radiation, natural or artificial, is a public health concern. For this reason, it is important that, from an early age, children and teenagers gain awareness of this problem. By not being visible to the human eye, ultraviolet radiation is an abstract concept and difficult to understand, although its short-term effects may be visible. In this project, we proposed the use of the Arduino platform to measure and verify the effect of various sunblocks, making it possible to materialize the concept of UV radiation. Thus, it was the aim of this project to study the influence of the Arduino platform use, associated with an ultraviolet radiation sensor, in the understanding of this type of radiation and in the awareness to the artificial sources of UV radiation used in the daily life of many people. This project was carried out with a group of students from the ninth grade, from a school in Porto, Portugal. The methodology used allowed the students to develop interdisciplinary skills, namely in the areas of natural sciences, programming, and mathematics, providing them with useful lifelong tools.

Keywords: Epistemic practices; UV protection; Sustainability

* Ana Isabel Silva Sousa. Tel.: +351912435640
E-mail address: anaisabelss@ese.ipp.pt

1. Introduction

The sun is a source of energy essential to life on Earth, emitting light, heat and ultraviolet (UV) radiation. However, excessive exposure to UV radiation, natural or artificial, is a public health concern.

Fashion trends to which children and teenagers are especially susceptible may suggest that a suntan is healthy, but skills-based health education can help them resist to peer pressure (World Health Organization, 2003). Sun protection education, according to World Health Organization (World Health Organization, 2003), can be integrated into a range of curriculum areas, such as science, mathematics, and the arts. Because of its recognized importance, this theme has been an integral part of the Portuguese curriculum since early grades, starting with a more preventive approach regarding the harmful effects of excessive sun exposure in the fourth grade, and later, in the third cycle of primary education, approaching the concepts of light and radiation.

By not being visible to the human eye, ultraviolet radiation is an abstract concept and difficult to understand, although its short-term effects may be visible. To facilitate the understanding of this concept the ideal is to materialize it, monitoring the UV radiation in real time. There are several sophisticated devices for this monitoring, but because of its high price and the complexity in use, it is impracticable to use them in the classroom. Thus, as a way of avoiding this, there is a low-cost and easy-to-use technological tool, that, in addition to allowing the monitoring of several variables, also allows the development of interdisciplinary skills. This tool is the Arduino platform (Figure 1).

Figure 1 - Arduino board.

This platform was first developed in 2005, in Italy, with the aim of supporting small automation projects, especially for people with low programming skills (Silva, Cavalcante, Camilo, Galindo, & Viana, 2014; Silveira, 2016). Arduino boards are equipped with many analog and digital IO pins, USB connection, ICSP capability and communication modules, that allow an easy interface with external components for data acquisition and control applications and the use of LEDs, LCDs, motors, buzzers, among others (El-Abd, 2007; Souza et al., 2011). The boards can be programmed from a specific software created by the Arduino community. The programming language available to the user is based on C/C++ and several ready-to-use codes for the many existing sensors and components are available online (Ferreira, 2015; Rocha & Marranghello, 2014).

The main motivation for the development of this project was, in parallel with the need to alert to the dangers of excessive exposure to UV radiation, the increasingly urgent need to approximate school reality to the technological world that surrounds children and with which they have been interacting almost since the beginning of their lives. This need has already been considered, as can be seen in Resolution of the Council of Ministers of Portugal no. 137/2007, which states that it is essential to enhance and modernize the school, create conditions that favor students' school success and consolidate ICT as a basic tool for learning and teaching in this new age. It was described as national objectives for the modernization of school, among others, content development and open source promotion and, as strategies, develop skills for knowledge society, make learning more attractive and strengthen links to the world of work.

The use of technology in teaching and learning can expedite and enhance work production, offering more time for thinking, interpretation and discussion, increase the scope of relevant phenomena, support exploration and experimentation, by providing immediate visual feedback, foster self-regulated and collaborative learning and improve motivation and engagement (Osborne & Hennessy, 2003). Despite all the proven advantages of using classroom technologies, there are some constraints that prevent teachers from taking advantage of it, such as insufficient technical support or lack of resources and investments (Castro, 2014).

Thus, since the technologies are not used in the classroom due to difficulties in their use and the fact that most of the technologies involve excessive expenses, it is the general objective of this work to study the potentialities of the use of Arduino in science educations. The specific objectives of this work are to promote the discussion of scientific questions about ultraviolet radiation and to validate a model programmable prototype as a didactic purpose for the study of UV radiation that can be used in schools.

This paper will describe a study using the Arduino platform, in the understanding of ultraviolet radiation and the protections against them. The aim of this research is to understand the relevance of using Arduino to develop interdisciplinary skills and to promote meaningful learning and epistemic practices in students. These practices are related to the skill to deal with scientific knowledge, having as reference the activity of the scientists (Lopes et al., 2009) and emerged from students' attempts to solve a problem, mobilizing prior knowledge and using procedures as description, representation, production and so forth. It has been confirmed in several studies that teaching practices centered on students are more effective for students learning (Lopes, Branco, & Jimenez-Aleixandre, 2010).

The experimental work presupposes students to question, reflect, interact with peers and teacher, answer questions, plan ways to test previous ideas and confront opinions, to foster the intellectual challenge that will keep them interested in understanding phenomena, relation situations, develop interpretations and prepare forecasts (Martins, et al., 2007).

This project also seeks to achieve the link, described as inextricably by UNESCO (UNESCO, 2017; UNESCO,2006; Michelsen, & Wells, 2017), between education and sustainability. According to the same authors, education for sustainable development is a lifelong process that implies improve basic education, reorient existing education to address sustainable development, develop public understanding, awareness, and training.

This research intends to answer the following questions:

a) How can the use of Arduino develop students' epistemic practices and interdisciplinary skills?
b) How can the use of Arduino help in understanding the concept of UV radiation and prevent risk behaviors?

2. Method

This project was based on the characteristics of action research and started from a case study, which consists of detailed observation of a context or individual (Bogdan & Biklen, 1994). Thus, a small sample of eight students was selected. These students attend the ninth school year of a school in the district of Porto, Portugal. This school has the peculiarity of being covered by a project of the Portuguese government called "educational territories of priority intervention" because it is in an economically and socially disadvantaged zone, marked by poverty, social exclusion, violence, indiscipline and school dropout and failure. The students involved in the work were between 14 and 16 years of age, come from middle-class and lower-middle-class backgrounds and, in general, did not have great expectations about their academic and professional future.

To ensure the rigor of the investigation, it was carried out in the context of the classroom and counted with the collaboration of the teacher of Physics and Chemistry of these students, class in which the activities were developed. In addition to this contribution, other students from the school, some teachers and school employees participated in the study, albeit more indirectly.

The group of students who participated directly in the work were part of a project promoted by the local authority, entitled Society, School and Research, which aims to bring together public schools (basic and secondary) and higher education institutions for the promotion of culture and scientific literacy.

To answer the research questions already mentioned and to collect relevant data were used audio, photographic and video recordings, student productions, surveys and interviews applied to the school community, multimodal narrations, print screens and field notes.

Observation grids of the occurrence of epistemic practices were developed to gauge the student involvement index, which will serve as a criteria to evaluate the success of the teaching project.

All the activities carried out during the project were previously planned and structured considering the year of school and the previous knowledge of the students. These activities were implemented in six sessions with ninety minutes each. The following table summarizes these activities.

Table 1. Activities held in each session and procedures of action research

Session	Activities held in each session	Procedures of action research
1	Survey of students' knowledge about ultraviolet radiation and introduction to the subject.	Analysis of students' responses to questions regarding the topic of UV radiation
2	Preparation of the surveys to be applied to the remaining students of the school.	Analysis if the questions that the study group asked the remaining students at the school were pertinent
3	Analysis of survey answers.	Check the level of knowledge of the remaining school community regarding the topic of UV radiation
4	Interviews with students, staff and teachers.	
5	Assembly and programming of two ultraviolet radiation sensors; Taking the first measurements.	Verification of the level of student involvement during activities
6	Testing the effectiveness of different sunscreens.	
7	Reflection on the results obtained; Withdrawal of conclusions.	

The first session was developed to understanding students' previous knowledge about UV radiation, artificial sources of this type of radiation and the protections they use when exposed to the sun. Also, during this session were discussed some ways to control UV radiation, namely the UV index, a commonly accepted parameter for measuring UV intensity (Zhang, Huang, & Ren, 2013), designed to represent erythemally weighted Ultraviolet radiation in a simple form, as a single number (Fioletov & Fergusson, 2010). This index is available on the internet for daily control.

Also, during this session, it was suggested that a survey was carried out to understand the knowledge and behaviors of all students of the school regarding the subject under study. This survey was developed by the students, with the support of the teachers, during the second session.

Surveys were applied between sessions and the results were statistically analyzed by students in the third session. These surveys were applied to 198 students between the fifth and the ninth year of schooling, aged between ten and seventeen years.

As some doubts arose in the interpretation of the results, as some subjects were not addressed in the surveys and as it was considered important to also evaluate the knowledge of teachers and staff on this topic, in the fourth session individual interviews were held with nine students, one school official and two teachers to fill these gaps.

In the fifth session, the assembly and programming of the sensors using the Arduino platform were performed. Two different assemblies and programming codes were made so that one of the sensors measured the intensity of UV radiation and the other sensor measured the UV index (Figure 2). It was decided to measure the UV index so that it was possible to associate the correct protection for the index measured at that time. As the World Health Organization (WHO) states, the UV index is an important way to raise awareness to the risks of excessive exposure to UV radiation and for the preventive measures to be taken (World Health Organization, 2002).

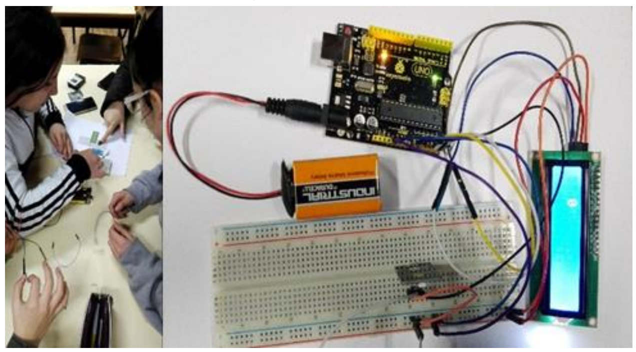

Figure 2. Assembly process and final result for the sensor that shows in real time the UV index.

This correlation between UV index and required sun protection was based on information from the WHO.

In the sixth session, the different sunscreens suggested by the students were tested with the sensors, in an outdoor activity (Figure 3).

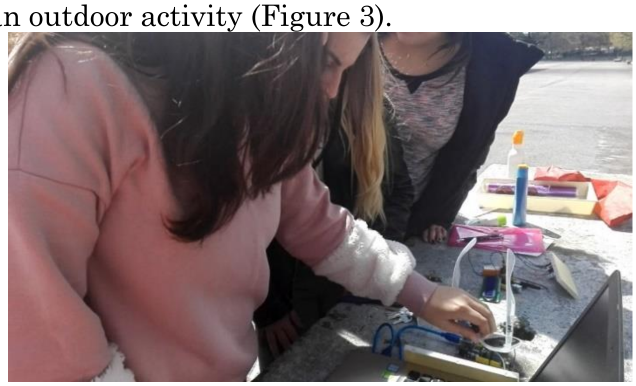

Figure 3. Testing the efficacy of sunglasses in the protection against UV radiation.

The results of this experimental activity were discussed in the last session along with the data collected during the project, such as those related to the surveys and the interviews and even the predictions of the students who participated actively in the project.

3. Results and discussion

Before presenting the findings, it is important to note that this presentation will have two strands. The first one related to the general knowledge of the students of the school on the theme and the second one related to the students participating in the project and its performance during the project.

On the students' knowledge about UV radiation and the protections to be used in relation to UV rays, it was possible to understand from their answers to the surveys that students, although they are aware that UV radiation can be harmful even on foggy days, do not take protective measures, as shown in figure 4.

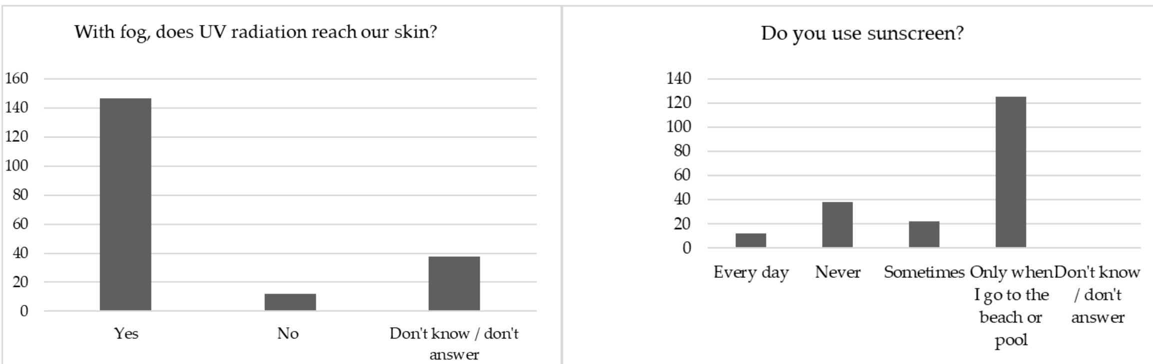

Figure 4. Analysis of students' responses to questions: "With fog, does UV radiation reach your skin?" and "Do you use sunscreen?"

It was found that most students don't know how to properly protect themselves from the sun, don't know the time at which direct sun exposure should be avoided and some have some risk behaviors when exposed to sun such as the using oils that don't have sunscreen, as shown in figure 5.

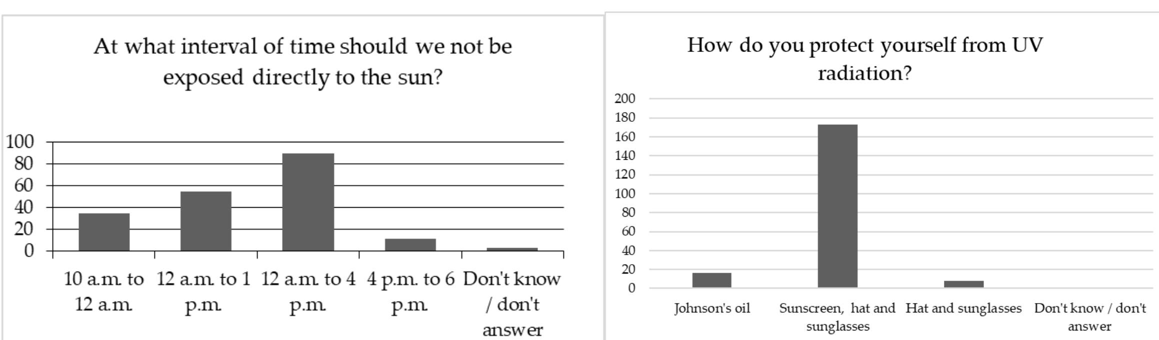

Figure 5. Analysis of students' responses to questions: "At what interval of time should we not be exposed directly to the sun?" and "How do you protect yourself from UV radiation?"

When questioned about artificial sources of UV radiation almost all students have exclusively indicated the solarium and most students consider it to be harmful to health.

Regarding excessive sun exposure, 85% of students admit that it can cause illnesses, the most mentioned being skin cancer (71% of students), although burns and scalds (7% and 4% respectively) were also mentioned, the other students (3%) admitted that they knew it could cause illness, but they didn’t say which.

As for students who participated actively in the project, it was possible to understand that their knowledge on the subject was common sense and that they had enough doubts. The students didn’t know, for example, that there is a way to quantify the intensity of UV radiation and didn’t know about the existence of this functionality on the internet. They also had some doubts about the variation of the intensity of the UV radiation throughout the day, the existence of worrying UV radiation on days of autumn or winter, and whether machines such as those used in solariums or to do gel manicures could emit this type of radiation.

Considering that this is a subject that, although it is spoken in the media mainly in summer campaigns, isn’t considered mainly by young people for lack of interest and for not being something easily measurable, such as temperature, students took the initiative to study if the other students of the school also had doubts about the issues already mentioned.

In the analysis and interpretation of data, it was possible for the students to be aware that a lot of ignorance on this subject and that is necessary to have a greater dissemination about it. In addition, it was possible for students to develop skills related to mathematics, namely the collection and processing of data.

At the assembly of the sensors, all the students revealed autonomy during this process and solved all the small problems that have arisen. In relation to programming, this process was also easily carried out and the students proved to be critical regarding verification.

During the experimental procedure, students were able to understand and, above all, observe the effect of sunscreens on our skin and eyes.

Figure 4 is a print screen of the real-time graph that students have access to using the “Arduino” program, which is also used for programming the sensor. As it is visible in the figure it was possible for the students to instantly verify the cause-effect relationship between the placement of the sunscreen and the intensity of the measured UV radiation. As can be seen, in the case of sunglasses, as also happened with the other forms of protection, as they are placed in front of the sensor, they block the UV rays and their intensity becomes zero.

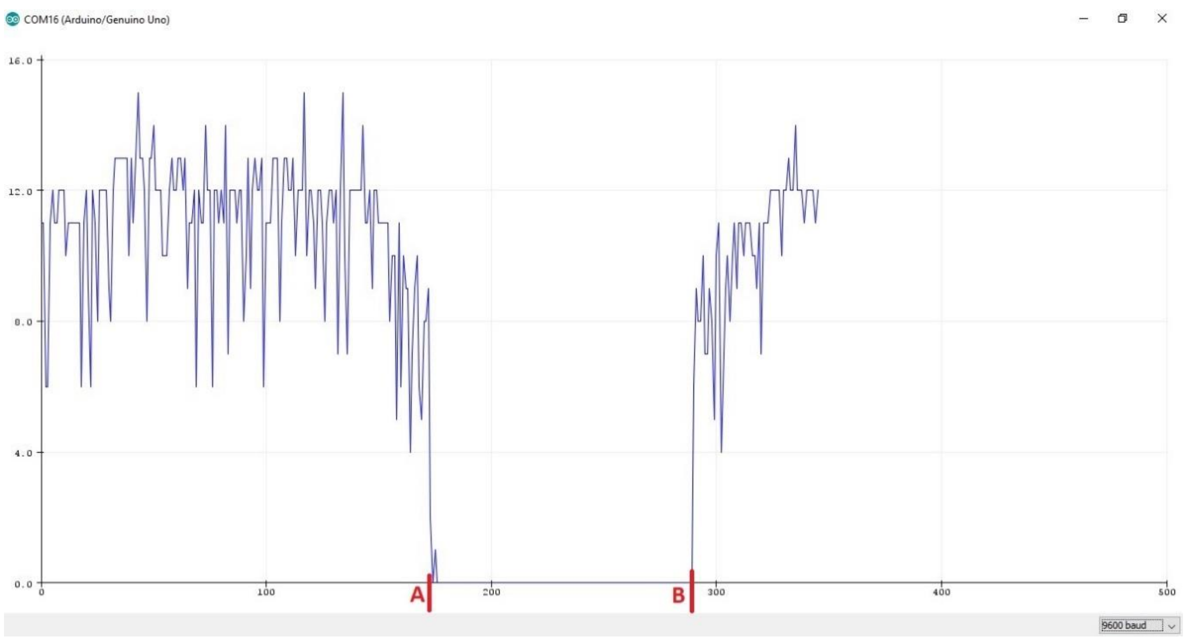

Figure 6. Graph representing the intensity of the UV radiation over time, with point A being the moment when the sunglasses were placed in front of the sensor and point B the moment when sunglasses were removed.

The following sunscreens were tested by students: sunscreens with different sun protection factor, different sunglasses and parasol.

Now will be now presented some affirmations of the students after the accomplishment of this activity:

Student 1: "I thought the parasol protected us from the sun, and after all it protects, but not completely"

Student 2: "I thought sunscreens did not protect us and after doing the experiment I discovered that they protect more than I thought"

Student 3: "In my opinion, I thought the sunglasses protected less from radiation and I have found that sunglasses protect more than I thought"

Student 4: "There are companies that have several sophisticated UV radiation meters and with simple and basic things we were able to measure the intensity of UV radiation"

Student 5: "I think that it is important to measure the intensity of UV rays because, so we can know how and when to use the sunscreen, the parasol…"

By analyzing the students' discourse, it was possible to verify that they understood the scientific questions, adopting a correct and appropriate language.

During the experimental procedure, the following epistemic practices, described by Lopes et al. (2009), occurred: description of physical phenomena or events; formulation of questions, problems and hypotheses; manipulation of technological objects dexterously; collection, processing and organization of relevant information; troubleshooting; evaluation of the solution and resolution process; measurement of physical quantities; field of experimental techniques; experiment planning; identification and control of variables; comparison of forecasts with results; transformation of one language into another; communication of results and ideas using means appropriate to the message and adapted to the recipient. In the table below (table 2) are presented some examples of epistemic practices performed in each session.

Table 2. Epistemic practices performed in each session

Epistemic practice	Session	Examples of student practices
Description of physical phenomena or events	6	Description of the correlation between the values read with the sensor and the time of the day or the relative position to the sun
Formulation of questions, problems and hypotheses	1	The students asked some questions about the theme such as "Do the different sunscreens protect us equally from UV radiation?" or "Are there other sources of UV radiation rather than the sun?"
Manipulation of technological objects dexterously	5, 6	Assembly of sensors and measurements
Collection, processing and organization of relevant information	6, 7	Selection of relevant values to be collected, collection and organize them in a clear way
Troubleshooting	5, 6	Troubleshooting installation and programming (wire connection and sensor sensitivity adjustment)
Evaluation of the solution and resolution process	5, 6	Test the sensors to verify that the assembly and programming has been done correctly
Measurement of physical quantities	6	Measurements of the intensity of UV radiation and UV index
Field of experimental techniques	6	Measurements using sensors
Experiment planning	1, 5	Planning the experimental activity, defining the materials to use, what to measure and how to record the data
Identification and control of variables	5, 6	Identification of dependent (intensity of UV radiation) and independent (sun protection) variables
Comparison of forecasts with results	7	Comparison of the intensity recorded with each sunscreen with the respective forecasts
Transformation of one language into another	5	Use of programming language: transposition of the intensity of UV radiation to numerical values
Communication of results and ideas using	7	Presentation of the results of the project in

means appropriate to the message and adapted to the recipient	the city library

It can be said that the student involvement rate in the project was satisfactory because all the epistemic practices foreseen during the various sessions occurred.

4. Conclusions

This project focused essentially on the use of the Arduino platform to promote epistemic practices and interdisciplinary skills and to aid in the understanding of the concept of UV radiation and in the alert and prevention for risk behaviors.

It is possible to conclude that the Arduino platform has the potential of developing interdisciplinary skills ins students, studying the environment with sensors and, as a low-cost tool, allows the introduction of technologies and programming in the classroom.

It was promoted the discussion of scientific issues, resulting in a video, carried out autonomously by the students involved in the project, whose objective is to sensitize the community to the importance of measuring UV radiation and preventing its effects.

As for the developed prototype, it was possible to verify that this is a didactic purpose capable of promoting significant interdisciplinary learning regarding UV radiation.

With the results obtained, it was possible to conclude that the use of the Arduino platform is perfectly suited to this age group and that the work carried out allowed to develop technological, mathematical, scientific and communication skills essential for the future of these students.

Regarding the subject of this study, UV radiation, it was possible to verify that, in the beginning, the students didn't have great knowledge and didn't adopt the best behaviors in relation to solar protection. With the development of the project and through the students' speech it was possible to infer that with the use of the Arduino they understood the concept of UV radiation, the effect of sun protection and that there is UV radiation in devices used in the daily life of many people, like gel nail machine.

The students participating in the project developed an education for sustainable development, with the improvement of environmental education and with the experience and knowledge that the practical work provides.

Due to time constraints it wasn't possible to further develop the project, but it would be interesting, from an investigative point of view, to extend this project to other classes and to its implementation in other schools. A good way to promote students' interdisciplinary development would be to distribute kits of Arduino material in schools so that they could experience the advantages that this platform provides to students and teachers.

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