INTED 2020

14th International Technology, Education and Development Conference

2-4 March, 2020 - Valencia (Spain)

CONFERENCE PROCEEDINGS

Sharing the Passion for Learning

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STRATEGIES TO TEACH ENERGY-RELATED CONCEPTS TO ELEMENTARY-SCHOOL STUDENTS THROUGH VISUAL ACTIVITIES AND LABORATORY EXPERIMENTS

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Abstract

A summer course was held during the first week of July 2019 for 30 youngsters (aged 8 to 12) to promote their (perhaps natural) curiosity for science through STEM experiences. The 5-day summer course was held at different facilities, including those described along this paper hosted by Universitat Politècnica de València (València, Spain). Several activities were developed to allow young students to discover concepts related to energy types and energy transfer processes through an active manipulation of laboratory assemblies. In this way, students' motivation is enhanced in an intuitive way and their attention and interest may be maintained. Finally, it is also reported some issues faced during these energy-related experiments and how they may be solved in the future.

Keywords: elementary school, active learning, energy, STEM, educational experience.

1 INTRODUCTION

It is broadly acknowledged that most students undergo difficulties when learning energy-related concepts because it is difficult to assume some abstract notions and phenomena related to them [1]. Most elementary-school students have presumably heard that "energy can be neither created nor destroyed (it can only be transformed from one form to another instead)". Nevertheless, learning it through a series of lessons and theoretical problems may be not sufficient to achieve a meaningful learning of the concept of energy [2], which is among central keywords for a common international framework in monitoring studies like the Program for International Student Assessment (PISA) [3]. On the other hand, according to international standard appraisals such as PISA, several children are able to succeed in our educational systems without a deep, integrative understanding of intangible terms, because of the poor alignment between learning aims and outcomes.

Students' conception of energy and how energy should be taught at different ages is a matter of debate in science education research [4]. Strategies to enhance teaching-learning process of these abstract notions at early stages of their education should be taken in consideration. In addition, discovery and inquiry-based learning approaches make students feel motivated and involved, which is essential to spark interest in scientific phenomena around them [5]. Interactive teaching techniques result in more significant learning rather than traditional strategies based on all-purpose "cookbook" experiences [6]. Moreover, collaborative interaction in small groups provides an opportunity for students to share their ideas and has also been found to be more effective for learning than individual approaches [6]. For this reason, the inclusion of STEM experiences and playthings can have a favourable impact on science education teaching.

Infrared cameras constitute a powerful example of this: they provide a pedagogical opportunity for students to learn thermal science, by making visible the invisible [7]. The idea of taking advantage of infrared technology is not new. In 2001, Vollmer et al. [8] used infrared imaging to visualize thermal phenomena in teaching. In the same way, other researchers have used this technology to inspire inquiry-based approaches in physics and chemistry education, creating even a suite of infrared experiments for educational application [9].

This paper discusses the development of a summer course for junior students to teach science through STEM experiments held in high-education facilities, which contributed to increase their excitement and motivation [10]. The summer school course was co-organized by the "Fundación QUAES", the ASCIRES-Biomedical Group and its Business Chair "Cátedra Fundación QUAES" at the Universitat Politècnica de València (Valencia, Spain). It aimed at promoting scientific vocations for children of 8-12 age along with the rise of their talents through close contact with everyday context of researchers in a scientific environment. Finally, some remarks on the course development and suggestions for future issues are reviewed.

2 METHODOLOGY

Several scientific experiments and phenomena were designed in the context of a STEM summer school, hosted by Universitat Politècnica de València (València, Spain). The experiences were divided among the five days of the course, distributed according to their scientific and technical nature, while all were based on the "predict-observe-explain" (POE) approach [11]. The first day was devoted to energy-related concepts and thus, ten critical-thinking activities were chosen regarding transitions between thermodynamic states (in pressure, volume or temperature), thermophysical properties of substances, types of energy and their transformations.

Students were divided into working teams (7-8 students each) to stimulate their participation and interaction. Each of the four teams was assigned to an assembly with a teacher in charge for conducting the session. Every 10 minutes, all groups shifted to the next spot and so forth until a full cycle was completed. Then, two recreational activities were performed outdoors (still related to science and technology) and a second round of new experiences took place.

For every experimental session, the teacher first raised a question about the assembly and asked the students to predict the resulting effect. Sometimes the introductory questions were presented as riddles or quests, along with some theoretical basis when needed. Then, they observed what occurred and, finally, the teacher encouraged the students to explain their observations and to discuss them. To avoid the pupils' theories to rely on instructor's premises, since teachers are authority figures, all explanations were considered as equally and presumably valid. However, further evidences defending every hypothesis were requested and only robust reasonings were inherently bolstered.

A sample of three activities will be described in detail in the next section to illustrate the overall structure of the sessions and how it was adapted to the different scientific principles at issue.

3 RESULTS

Figure 1 shows the layout and assemblies for the three aforementioned experiments of those performed in the day dedicated to energy-related concepts, summarizing the studied physical principles, the structure of the experiments and their development.

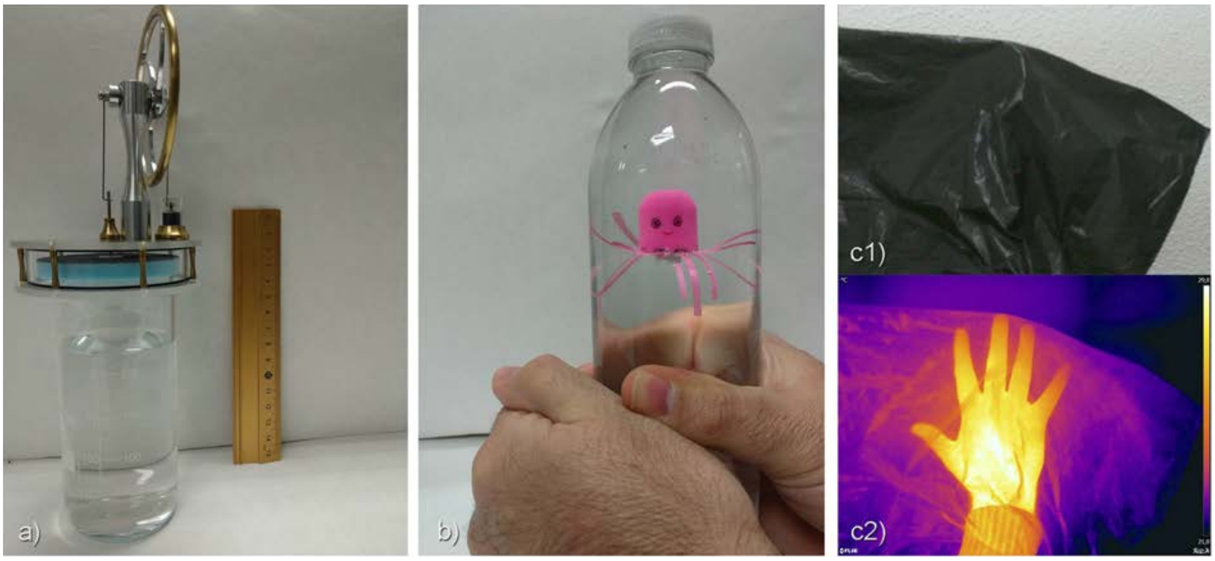

Figure 1. Images of assemblies for three energy-related experiments: a) The Stirling Engine. b) Diving with jellyfishes. c) A hand covered with a trash bag: c1) Visible light image; c2) Infrared thermal image.

3.1 Heat to create motion: The Stirling Engine

The Stirling Engine is a mechanism from which thermal energy is converted into mechanical energy (*i.e.*, rotation of a wheel). The principle of operation is as follows: a fluid at a temperature different from room temperature (higher or lower) is brought into thermal contact with a face of a closed piston containing a gas (lower part of the Stirling Engine in Figure 1a). The gas on the lower part of the piston modifies its temperature by heat transfer, so its density changes: if the gas is heated, it expands and vice versa. The aforementioned volume change causes the piston to longitudinally move due to the existence of different pressures between the two faces of the piston, lower and upper, resulting in a mechanical imbalance that finally moves the piston. Whether the upper face of the piston is eccentrically connected to a wheel by means of a rod, a rotational movement is then obtained.

At the beginning of this experience, kids found the Stirling Engine (commercialized by Ventus Ciencia Experimental, S.L., Alcalá de Henares, Madrid, Spain) at room temperature (*i.e.* in equilibrium and without motion) and tested its operation by moving their parts delicately using their hands. Besides, two vessels with hot and cold water were prepared. Next, the Stirling Engine was placed first on the vessel with cold water and the resulting motion of the wheel was observed. Afterwards, the experiment was repeated but using hot water instead, observing that the wheel turns in a direction opposite to that of cold water. Furthermore, it was also observed that the wheel rotation is normally faster with the hot water vessel. These behaviours gave rise to some questions regarding the capacity to transform thermal into mechanical energy.

3.2 Diving with jellyfishes

A Cartesian diver (Figure 1b) is a simple device composed of a container that can entrap a variable amount of air inside of it. When filled and placed in water, the container should be heavy enough to submerge, but it must remain afloat when part of the volume is filled with air. In other words, the density of the whole device can be tuned by adjusting the amount of trapped air. A typical example for this is an eye dropper, that can be partially filled with water, remaining vertical even when diving because of the air chamber on top.

Some plastic toys (like the so-called *hydrodynamic jellyfishes*, an alternative name for Cartesian divers) can reproduce this effect, by retaining some air bubbles because of the low surface energy of the material. This can be achieved through small cavities or just by increasing the surface in contact with the environment. When placed on a bottle filled with water and sealed, the average density of the toy and the air combined is less than water, hence causing the hydrodynamic jellyfish to float on top. Since water is virtually incompressible, applying pressure or an external force to the bottle results in a compression of the air. This leads to a reduction in the volumetric fraction of entrapped air, thereby increasing the density of the “bubbly” jellyfish. When it exceeds the density of water, the jellyfish starts falling down (Figure 1b), and it can be surfaced back quickly by releasing the pressure.

At the beginning of the experiment, the teacher held tightly the bottle and suggested the children to ask the jellyfish gently to dive down, even if it was clearly floating, no matter the position of the bottle. When the proper words were said, the teacher pressed the bottle without the participants noticing it. A harsh sound or yell happened, the jellyfish could be easily forced to go up back again. The children scepticism made them reject the explanation that was exposed by the teacher and soon after provided some alternative causes that could have been responsible for the motion of the jellyfish. Through a Socratic set of questions, they linked the force applied with the shrinkage of the air bubbles. They were provided with more bottles afterwards, to experience the effect by themselves.

3.3 Invisible… visible!

The “make the invisible visible” experience focuses on learning dissipative processes such as friction, conduction and the behaviour of different materials using thermal cameras. In the current experiences handheld infrared (IR) cameras (S640 and T1020 models by FLIR Systems, Wilsonville, OR) were used, working with length waves (LW) from 8 to 14 μm.

An important field for IR imaging in physics education concerns the visualization of mechanical phenomena such as friction. Whenever exists a force acting along a given direction for a given distance, work is done, which is finally converted into thermal energy [8]. A straightforward but eye-catching experience is using the fingers to write on the wall or the feet to draw on the floor. Since the work against sliding frictional forces results in a surface’s temperature increase, all the marks made on the surfaces can be detected using the IR cameras. To improve the visualization, surfaces’ conductivity should be not too large (in metals the thermal energy diffuses away very quickly) and depending on speed and contact pressure, one can achieve greater temperature differences.

Another experience carried out employing the IR cameras was based on the radiation behaviour and the optical properties of different materials and objects (Figures 1c and 1d). Materials' transmission varies depending on the spectral range (some of them are transparent in the visible range but opaque in the IR and vice versa). Taking advantage of this, some of the students were told to cover their hands with a garbage bag (made of polyethylene) and to do signs or to show some fingers while the others should predict what was going on. Without using the IR camera, since this kind of plastic is opaque in the visible range, nobody can guess what is happening inside. However, polyethylene has certain transmission in the LW range, so any IR camera operating at this range can see through it, knowing therefore whatever was happening. Regular window glass stands at the opposite: it shows no transmission above 3 μm. Consequently, it is not possible to look through glasses with the IR camera. For this reason, people wearing regular glasses will appear in IR images as if they were wearing sunglasses.

4 CONCLUSIONS

Throughout a summer course held in July 2019 at the Universitat Politècnica de València (Spain), it was possible to present some scientific concepts related to energy types and energy transfer processes to youngsters of 8-12 years old. To do so, different experiments were performed with the aim of promoting their inherent (hopefully scientific) curiosity and motivation. The following challenges were encountered by the instructors: i) the age range was too wide: students had different levels of knowledge and concentration, and ii) the number of students was also too large with working teams of 7-8 students per spot, which meant that some of them were not involved in the expected grade. Possible solutions for future calls of this summer course may be, on the one hand a less amount of students per group (i.e. either a higher quantity of working teams or less teenagers enrolled), and on the other hand to reduce the age range of the students. Notwithstanding the aforementioned concerns, we are aware of their overall satisfaction with this summer course thanks to the feedback received from them and their parents.

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