Critical review of literature resources on the use of Arduino and smartphones in physics education: a first result of the ADELANTE project

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Abstract. The Next Generation program of the EU prioritizes digital transition to address educational inequalities. In Italy, the National Recovery and Resilience Plan highlights the importance of embracing the digital revolution. ADELANTE is a research project aimed at enhancing secondary school physics labs with smartphones and Arduino microprocessors. Despite the abundance of resources, the effectiveness of teaching with these technologies remains understudied. A systematized review was conducted to identify validated experiments in physics education literature. The review has revealed a significant gap in educational applications. These findings will guide the project in designing teaching-learning sequences and identifying areas for further research.

Background

Digital transition represents one of the key objectives in the Next Generation EU program, enhancing training activities and fostering greater gender, territorial and generational equity. This is particularly necessary in Italy, where many schools and universities are still reluctant to "seize the myriad of opportunities associated with the digital revolution" (Italian National Recovery and Resilience Plan – "Piano Nazionale di Ripresa e Resilienza" – PNRR).

Science laboratories represent an ideal environment for cultivating both scientific knowledge and abilities [1]; indeed, scientific practices and skills are the component that could best benefit from well-structured lab activities [2,3]. Even if in the past decade, there has been a renewed emphasis on the role of the laboratory in science education [4,5], several factors influence the utilization of science labs in school instructional practices, as for example lack of time, resources and staff, limited familiarity with laboratory-oriented teaching methodologies, and the necessity to comply with national standards [6].

This context has inspired the research project "Adopting Digitally-Enhanced Laboratories in a Network of Teachers" (ADELANTE), aimed to promote an innovative approach to secondary school physics labs enhanced by the use of smartphones and Arduino microprocessors. Specifically, the project will consist in two phases: (i) designing a set of teaching-learning sequences (TLSs) [7] featuring laboratory experiences with Arduino and/or smartphones and (ii) establishing a community of practice of physics teachers [8] interested in the integration of digital technologies in physics experiments.

Rationale and research question

The potential value of technologies such as Arduino and smartphone is manifold: from a technical and practical point of view, they can help overcome many of the typical challenges to the implementation of school labs, such as time-consuming data collection, limited lab resources, and low accuracy and precision of manual measurement; from the physics education

point of view, they can promote a deeper understanding of the measurement apparatus (a fundamental skill in experimental physics) and foster the development of student agency by facilitating small group and/or individual work as opposed to teacher-led classroom demonstrations. However, the integration of these technologies in teaching practice does not occur automatically. Additionally, despite an impressive number of proposals for Arduino or smartphone-based experiments found in books, websites, and physics education literature, their efficacy for the learning of physics has not been explored systematically. In order to understand the state of the art of their application in classroom, particularly in terms of their educational value, the first task of the ADELANTE project has consisted in a systematized review guided by the following research question: "What are the validated experiments in the scientific literature that can be performed using smartphones or Arduino, and how can they be categorized according to the research scope?"

Methods

To gain insights into this research question, we analyzed about 500 papers from the most important research databases (Scopus, Web of Science, Google scholar, ERIC), limiting our search to papers with keywords "Arduino" or "Smartphone" and "physics education" and "secondary school" or "high school" to align with the focus of our research question. We selected only peer-reviewed publications, regarding content suitable for integration into secondary school or undergraduate curricula.

In this work we describe the review process, analyze the criteria upon which the review has been based, as well as the choice of indicators used for the classification of the papers (as for example, school levels, time needed to perform the activities, topics, etc.).

Preliminary results

A preliminary analysis indicates that 95% of the papers focus on describing experimental apparatus, while only 2% discuss the educational application of these technologies. Roughly one-third of the papers features Arduino-based devices, while over half utilizes sensors for data acquisition embedded within smartphones.

This analysis will guide the development of the ADELANTE project, helping our community of practice in designing the TLSs and stimulating the integration of these technologies in educational settings.

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