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# APPs in sound measurements to gain a school-work experience

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**Abstract.** To gain autonomy in studies and work competences, the Italian Ministry of Education introduced a mandatory school-work integration in upper secondary school curriculum. University is one of the possible work area for that students, offering lot of different proposals and experiences. University of Udine and Flaminio Liceum in Vittorio Veneto, in cooperation with University of Salento in Italy, planned to focus on innovation in using ICT for that aim. The research-based formative intervention module of the project phases are the following: choice of a topic (sound), exploration of some suggested mobile APPs for sound measurements, writing of technical reports on APPs by students and relative discussion, the use of City SoundScape APP to monitor landscape from city centre to natural reserve. Problems and learning needs of students have been monitored during the activities to find out the autonomy strategies, paying particular attention to the stimuli and motivational role of the APP use for measurements in developing study and work competences.

## 1. Introduction

In order to promote 16-18 years old students' working competencies, autonomy in study and orienting skills, the Italian ministry of education introduced a mandatory 200-hours integration between schools and employments realities in scholastic curricula, named "school-work integration" (SWI) [1]. Public institutions are possible contexts for these kind of activities, in particular Universities can offer different opportunities to students. Despite the SWI represents an opportunity for students to experience a real challenging working environment, supported by schools and tutors, a lack of formative finalization emerge when very often the offers for students consist in attending seminars, or managing passive activities in labs or libraries. The opportunity is thus misinterpreted and students are not asked to work on a common project or to produce something new. In order to transform in competences the potential power of the studies done by students and to produce formative orientation for students, active and creative stimuli are necessary in innovative perspective.

Within PLS-IDIFO6 Project [2] University of Udine, in particular our Physics Education Research Unit (PERU) offers to the schools of the territory for SWI a research-based intervention module promoting mobile APPs as a context to integrate new technologies in physics teaching/learning in secondary school, offering students, at the same time, an autonomy working experience for a product



useful in the school itself. Physics Education Research (PER) can contribute in designing activities, focusing on a specific disciplinary content and analyzing learning outcomes.

Referents for our proposal is the recent literature on implementation of mobile devices in school activities for physics [3-6] and in particular in the field of acoustic [7-14].

The main goals of our educational research-based approach are to: 1) promote individual technical analysis of different mobile APPs, 2) encourage the comparison of the performed analysis and test proposals in group work, 3) stimulate the process of finding out, planning and implementing experiments, documenting results achieved, 4) reflect on how to study school and social employ of the cluster of selected APPs, 5) engage students in planning and attending data collection campaigns to produce an official report. The operative proposal of the intervention module on sound and APPs was designed in collaboration with secondary school teachers and PERU, integrating curricular teaching activities and SWI work. The module integrates data collection campaigns with the aid of City SoundScape (CSS) APP, that allows measures of outdoor acoustic noise to be shared online on a cloud-based platform.

Activities are characterized by the presence of some peculiar aspects: (1) the use of content knowledge by students; (2) editing of technical reports on APPs' functionalities, design of significant experiments, reports on carried out activities; (3) tight cooperation between students and university in order to provide them constant feedback and discussion and (4) efforts in the analysis of socio-environmental problems. Different phases (formative, operative, analysis and discussion) characterize the project as well as individual or cooperative tasks carried out with the supervision of school and/or University. The activity involves not only scientific and digital competences, but also creativity, designing and soft skills thanks to the opportunity of working in group integrating in the curriculum an original working task.

Students' problems and learning needs have been monitored in order to highlight autonomous and cooperative strategies with particular emphasis to the stimuli and motivational role in the use of mobile APPs to develop studying and working competencies. For space reasons, only the characteristics of the research work done and main results are reported here.

## **2. Research questions**

The SWI intervention module implemented is not only a simple collaboration between school and university to offer students a work experience, but it has an important value from a research point of view, in the perspective of the following research questions:

- RQ1) How do students face the proposed task in order to analyze the APP?
- RQ2) How do students test different APPs suggesting significant measures and experiments?
- RQ3) How does informal lab work activate students' content knowledge and how does it play a role in linking cultural and technical skills?
- RQ4) How do students get involved in designing a booklet for school activities containing a technical manual on different mobile APPs?
- RQ5) How do students plan and perform the social task to contribute in reaching EU challenges on sound and noise?

## **3. Sample, contents, instruments and methods**

Two classes of 17-18 y.o. students from Vittorio Veneto (Treviso, Italy) Scientific Lyceum Flaminio were involved in the activity for a total of 42 students in the scholastic year 2016/17. The final steps of the activity were carried out at the beginning of the following scholastic year. CSS APP [15, 16] developed by University of Salento has been integrated with the aim of collecting environmental noise and to offer data to the city Mayor for 2020 EU challenge on sustainability environments. That APP allows to perform sound and noise measurements in outdoor areas using the built-in microphone of mobile devices.

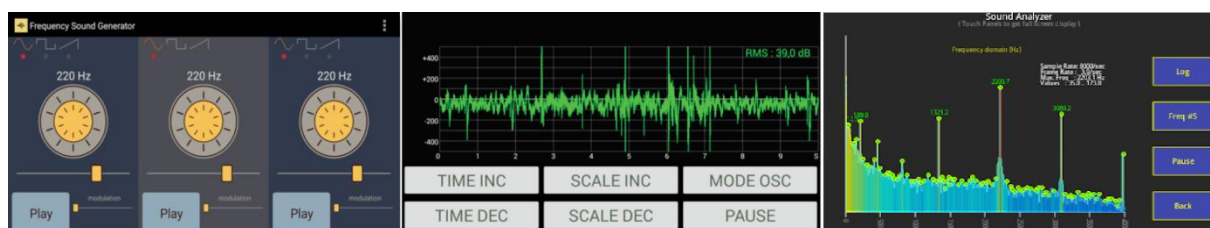
The whole activity has been planned since the beginning in several phases, hereafter described.

### 3.1. Curricular contents and activities

In the period December 2016-February 2017 students were introduced by their teachers in ordinary school activity to the theory of waves in order to analyze the phenomenology of sound, treating sound propagation, acoustic oscillation and involved quantities in measurements. Problem solving activities were conducted focusing on the usage of the Decibel scale. Lab activities concerning diffraction and interference of mechanical waves as well as production of sound with a diapason, resonance and interference of acoustic signals have been performed. On-line simulation software e.g. stationary waves on a string or perturbations in different mediums with visualization of the wave fronts [17] were used in order to consolidate the addressed concepts.

### 3.2. Assignment of the individual work

The task of an critical individual analysis and relative report, exploring the characteristics of three different commercial APPs on sound suggested by us (figure 1) was assigned to students in March 2017. The suggested APPs are: Sound Analyzer (SA), Sound Oscilloscope (SO) and Frequency Sound Generator (FSG). The SA APP allows to perform analysis both in time and in frequency domain, and shows in real-time the sonograms. The SO APP is an oscilloscope emulator for acoustic signals: it shows the intensity as a function of the time. The FSG APP allows to generate up to three acoustic signals at the same time varying amplitude and frequency.



**Figure 1.** Main user interfaces of the three suggested APPs: Frequency Sound Generator (FSG), Sound Oscilloscope (SO) and Sound Analyzer (SA).

### 3.3. Tutoring and feedback, first stage

In April 2017 individual reports were discussed in a plenary meeting with the students. Power and limits of each report were analyzed in the perspective of a product useful for teachers in school. Further indications were given to them, in order to produce a collaborative technical manual, whose contents are managed by different groups in parallel, compared later. During this phase emerge the need of discuss physics concepts, of stimuli for theoretical deepening on waves and sound (e.g. frequency analysis or mathematical model for the propagation of waves) and of suggestions for laboratory activities useful as a test and as a suggestion for the booklet for teachers to inspire educational experiments based on the studied APPs. Modalities of discussion were typical of a working environment: the University tutor acted as an employer, discussing the quality of each work done, asking for further work or clarifications. The projection on the screen of each work and of the comments help the whole class in growing. The APP CSS was presented as well as the goal to be achieved at the end of the SWI as a task to contribute to the social challenges in environmental sustainability. The provisional product of the SWI was agreed in a booklet containing the outcomes of the different stages of the activity, including several exploration paths on different aspects related to sound.

### 3.4. Collaborative work

As decided in plenary during the discussion of individual contributions, the collaborative work was oriented in two directions: the revision of the individual technical report and the deepening of topics related to applicative areas as music, sound in natural environments and in social contexts and physical and mathematical aspects of wave propagation. In May 2017 groups of 4-5 students were formed,

according to the various interests/attitudes. In this way students' personal interests were given importance, strengthening decisional skills and developing in them autonomous decisional attitudes. Students also started to test the planned experiments both in physical lab and at home, having at their disposal their own mobile devices. A first environmental noise data collection was performed.

### 3.5. Tutoring and feedback, second stage

In June 2017 written productions of students concerning APPs technical analysis, proposed and performed experiments and the first campaign of environmental noise data collection were discussed in plenary. Critical points were focused and suggestions to improve the work were given. A second data collection campaign of environmental noise with CSS APP was planned.

### 3.6. The final booklet

In the period September 2017 the final booklet was completed. This result represents the main outcome of the school-work integration activity. Contents are divided in chapters, representing the different stages and dimensions of the whole research-based project. The chapters are: technical descriptions of the used APPs, physical aspects related to sound (production, propagation, detection, intensity, frequency, tone, beats and Doppler effects), applications (in music, in nature and in social contexts) and mathematical aspects (wave equation and modeling for the propagation).

## 4. Outcomes from students' work

Some significant examples of students' work and outcomes during the different phases of the school-work integration activity are described in the following.

### 4.1. Individual study of the APPs

With the goal of characterizing and describing from a technical point of view the three proposed APPs, students performed different tests and analysis. The APP SA (figure 2) is mainly used to visualize waveforms, perform frequency and time domain analysis of notes generated by different musical instruments and/or by the APP FSG. This APP is also used to generate beats analyzed with SA and compared with simulation set up with the aid of a spreadsheet (figure 2). The APP SO is used in order to study waveform in time domain using different sound sources: musical instruments, environmental noise, sounds produced with FSG. Students noticed the potentialities also in visualizing beats (figure 2).



**Figure 2.** From upper left, clockwise: frequency-domain analysis of a single note from a flute (SA); beats (SO), modelling of beats with a spreadsheet and generation of beats (FSG).

### 4.2. Analysis of the reports

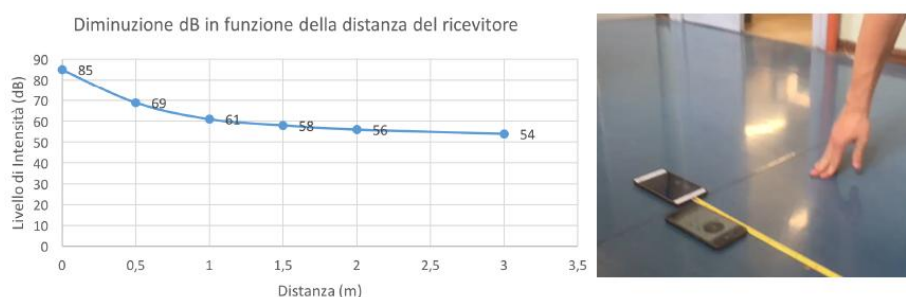
The main elements emerged by the analysis of the individual reports are: research concerning technical terms, an accurate description of the available instruments, an exploration of the

potentialities and suggestion for a significant use. The majority of the students highlights the intuitiveness of the interface. The main noticed limits are: the impossibility to download data (even in .csv format) in order to conduct further analysis and the need to add some tutorial or further explanations on some commands of the APPs.

#### 4.3. Explorations and deepening on various aspects related to sound

As said, the final product of the whole activity is a booklet containing, besides technical reports of the APPs and the description of data collection campaign with CSS, different works of deepening on the topic of sound, managed in groups set up on voluntary basis. In the following the main outcomes of those activities are described.

4.3.1. *Physics beyond sound.* This deepening regards physical aspects related to sound, in particular production, propagation and detection. Students conducted researches on theoretical aspects on books different from the scholastic one and on the internet. This activity was supported by experiences performed with the aid of the various suggested APPs. Significant measures were, as example, the quantitative dependence of the sound intensity from the source-detector distance (figure 3) and the qualitative analysis of the propagation of sound in different mediums, using a vacuum pump.

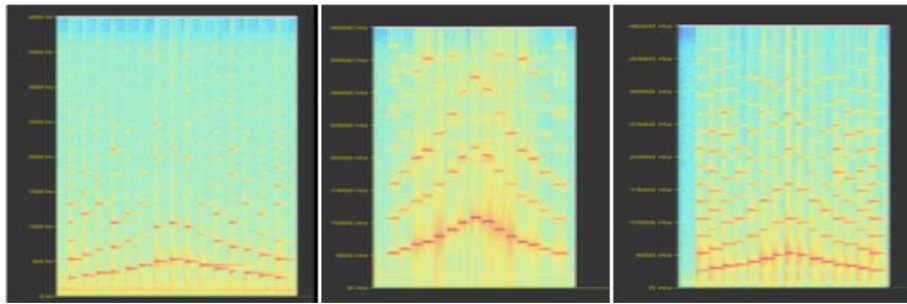


**Figure 3.** Intensity of sound VS distance from the source.

4.3.2. *Physical quantities.* The definition of the various quantities involved in acoustic analysis, i.e. frequency, intensity and tone, was at the centre of the work of this group. Students chose different sources, as bottles, pipes, a xylophone and their voice in order to analyze the produced sound with SA and SO to highlight qualitative characteristics, measurable with the APPs.

4.3.3. *Music and sonograms.* Realization and analysis of sonograms of notes and musical scales performed with different musical instruments (flute, piano, guitar) served in order to highlight common features and differences, as for example the presence of harmonics, in particular production of different notes with the same instrument highlighted the relationships between notes and frequencies; scales performed with different instruments enriched the analysis. Students designed and realized a setup to visualize spectrograms in a dynamical way in order to make the physical aspects more comprehensible and addictive (figure 4).





**Figure 4.** Sonograms of musical scales performed with a piano, a guitar and a flute. In spectrograms it is possible to see, as a function of the time, the presence of harmonics and their amplitude.

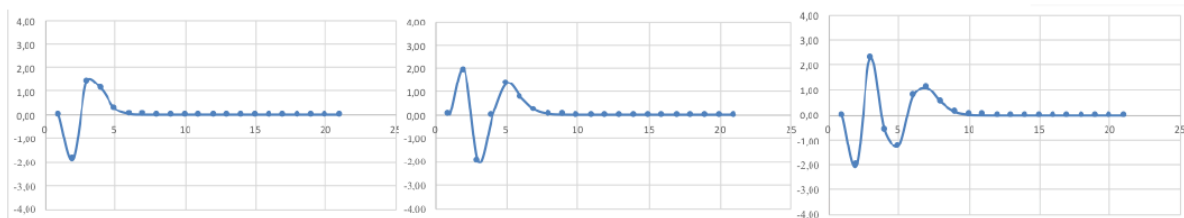
*4.3.4. Important effects: beats and Doppler.* Contents addressed in class were deepened with particular attention to formal aspects, deriving the formal laws. Students proposed different activities in order to highlight the physical aspects involved: beats were studied using FSG to generate sounds, SA to collect data and SO to visualize the signal, Doppler effect was studied made mobile devices spinning in order to quantify the effects due to the motion of the source toward or away with respect to the detector.

*4.3.5. Sounds in natural environments.* Consulting on-line documentations, students located several areas of natural interests on the territory. Each area is characterized in terms of acoustic level, in particular the maximum level of sound admitted (expressed in dB) both during day and during night. Campaigns of data collection allowed to compare measured values with the limit ones admitted.

*4.3.6. Sound in social contexts.* In order to highlight noise pollution in different social contexts, students collected data of sound levels in outdoor environments i.e. in crowded places, in discos, on public transportation. A research concerning health effects of noise pollution, architectural sound barriers, technical aspects and reference standards was conducted by students themselves.

#### 4.4. Mathematical model for wave propagation

The formal study for wave propagation was based on the model of the 1-dimensional discrete string in which every point moves as the previous one at the previous instant of time [18]. Students implemented in recursive terms in a spreadsheet the algorithm, considering different boundary conditions and source signals. Approximate solutions were founded, realizing a simulation of the movement of points along a string in temporal succession (figure 5).

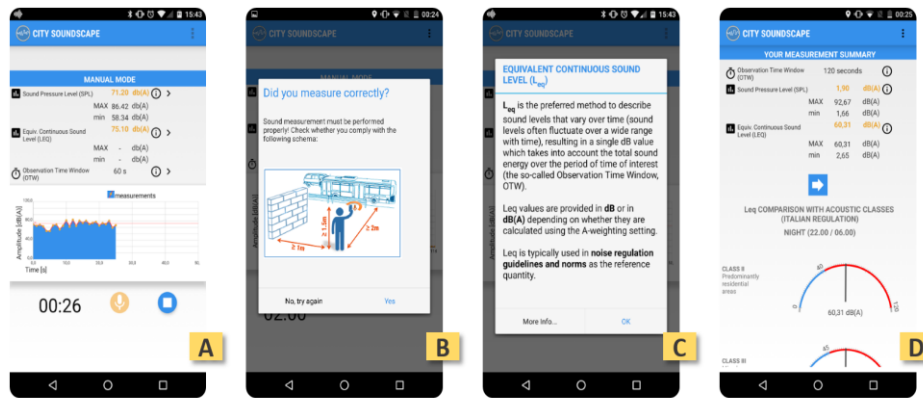


**Figure 5.** Simulation of wave propagation along a string with a spreadsheet.

#### 4.5. Data collection with City SoundScape

The APP CSS [15, 16] monitors two widely used indicators of noise exposure in time-domain: Sound Pressure Level, SPL and Equivalent Continuous Sound Level, LEQ in order to evaluate the loudness and nuisance of urban environments both instantaneous and averaged. In order to engage effectively students in learning-by-doing activities, the user interface of the APP offers a series of controls and interaction options that can be also found in a professional Sound Level Meter (SLM). It is possible to

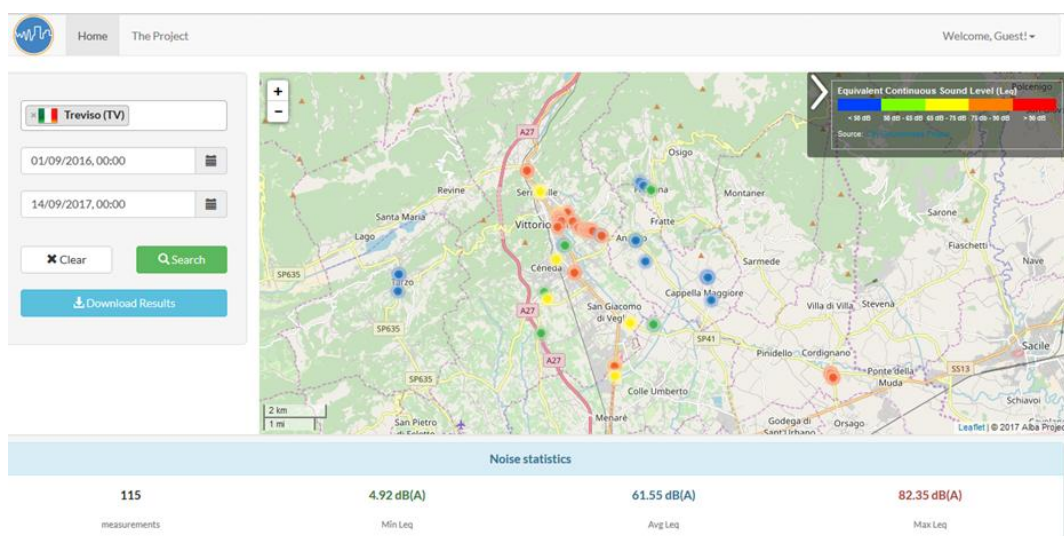
insert comments concerning the quality and settings of the measure, moreover the APP provides didactical support concerning the description of the involved quantities and suggestion to collect accurate measurements (figure 6). By using the APP, it is possible to participate in extensive and collaborative measurements campaigns, whose data are shared on an on-line platform. Users are allowed to examine measurements results as heat maps displayed on a geographical layer in Google Maps (figure 7).



**Figure 6.** User interfaces of the APP CSS: real time data and settings (A), suggestions on how to better perform the measure (B), technical and theoretical support (C) and output of the measure (D).

Data collection campaign allowed the active participation of students in the role of aware citizens in a responsible development of the "smart cities" in which new technologies are integrated in the social life in order to reach a better quality of it.

The design of data collection campaign implied the detection of suitable days, time slots and significant areas, aspects discussed with tutors. Measures were performed in the city centre, in the suburb and in areas of natural interest. Very important for students the gain of awareness of the modalities according to which a data collection campaign has to be performed in order to collect significant data.



**Figure 7.** 2-dimensional map of the acoustic surveys performed by students in the territory around their school.



## 5. Conclusion

Mobile APPs related to sound production and analysis allowing significant measurements and are a fertile context for a school-work integration activity (SWI). It represents a working opportunity for students on different plans: analysis of software and hardware characteristics, testing activities, editing of a technical manual, study of their use in measures and significant experiments.

In the research-based SWI experimented, every student was given the possibility of working individually and in a group, in order to realize a common project, which is a booklet describing the different dimensions of the experience. Students appealed to their responsibility and collaboration skills, indispensable aspects in a real working environment (RQ1). The study of the contents was a characterizing element of modalities and organizational aspects of the proposed activity. Students' efforts was not reduced to the simple reproduction of experiments or rituals, but the work was renewed and reinvented by students themselves (RQ1), contributing in this way their formative orientation. Creative and innovative elements were embedded in students' formation and they apply them in a context in which they have a productive goal.

The starting phase saw students engaged in the individual analysis of three mobile APPs able to perform qualitative and quantitative measures on the topic of sound. Student designed and produced a technical report containing the description of the APPs, highlighting potentialities and limits and pointing out operative difficulties encountered. Students shown good critical skills and in some cases they enriched the work with examples of measures and applications. The analysis of students' individual reports shows that they are mainly focused on proposing experiments in order to test the potentialities of the APPs in order to characterize them, rather than quantitatively characterize the measures the APPs can perform: SA and SO APPS have been used to analyze single notes or musical scales in order to highlight the characteristic frequencies of sound from different musical instruments. Experiments results are compared with theoretical previsions: this aspect emerges in every individual report. Few students specify the way in which a time-domain graph, a frequency-domain graph and a sonogram are related. Graphs shown by SA and SO APPs are quantitatively characterized by about two thirds of the students in terms of represented quantities and only in few cases units of measures (dB, s, Hz) have been specified. Difficulties emerged in specifying the shown quantities on the y-axes of the different graphs, which are sound intensities, while students do not show difficulties in noticing the quantities on the x-axes, frequencies and time respectively. Few students point out the specific potentialities of the SA APP as the meaning of a color scale, the possibility to change from a linear scale to a logarithmic one, or the possibility to change the visualization modalities of the frequency-domain graph. FSG APP is used by all students in order to produce beats and compare the frequency of the beats with the expected one. A minority of students specify the relation between frequency and period. Every student points out the possibility to save recorded data in order to perform further analysis. This highlight the dominant students' point of view of characterizing an APP by the allowed measures rather than the quantitative characterization of its instruments (RQ2).

The comparison with the cooperative work did not produced richer outcomes, pointing out a poor ability in using the individually-produced resources, in particular, in the case of SA APP analysis, in specifying minor settings as choice of the scale, the meaning of a color scale or the connection between time-domain analysis, frequency-domain analysis and the information in a sonogram. Very rich, on the other hand, was the collaborative operative work on data collection during experimental activities (RQ1 and RQ2).

In the majority of the cases students used their knowledge on the chosen topic designing experiments integrated in their curriculum; in other cases exploration were performed on the internet in order to find original experiments (RQ3).

Specific requests of building simple experimental devices and analyzing different APPs from a technical point of view guided students in revisiting studied concepts and in designing experiments to be shared with their peers in order to enrich scholastic knowledge as well as to give them information on how to produce a technical manual. Those tasks allowed students to focus on the important and

essential elements to be considered in deciding how to perform the analysis. Discussions concerning which elements insert in a technical report and on how to structure them turned out to be fertile (RQ4). Difficulties emerged in planning the measure campaign: a sort of local way of thinking to measurements require two revision and a long discussion on how to produce a global coherent framework of measurements (RQ5).

The way in which students interpret each task and the discussions on the work they are doing give us the opportunity to learn the power and limit of the SWI implemented and to explore the way of thinking of students, power in their engagement and the needs both in terms of e formative elements and in terms of opportunity to get involved, responsibility they can sustain. Last but not least a perspective of significant SWI was individuated.

## References

- [1] Law 107/2015 <https://labuonascuola.gov.it/>
- [2] IDIFO project <http://www.fisica.uniud.it/URDF/laurea/idifo6.htm>
- [3] Hammond E C and Assefa M 2007 Cell phones in the classroom *Phys. Teach.* **45** 312
- [4] Vogt P, Kuhn J and Müller S 2011 Experiments Using Cell Phones in Physics Classroom Education: The Computer Aided g-Determination *Phys. Teach.* **49** 383
- [5] Kuhn J, Vogt P and Müller S 2011 Cellphones and Smartphones Capabilities and Examples of Experiments in Physics Classroom Education *PdN-PhiS* **7** 5
- [6] Kuhn J and Vogt P (Eds.) 2012 iPhysicsLabs *Phys. Teach.* **50f** [Column starting on February 2012]
- [7] Gomez-Tejedor A, Castro-Palacio J C and Monsoriu J A 2014 The acoustic Doppler effect applied to the study of linear motions *Eur. J. Phys.* **35**
- [8] Hirth M, Kuhn J and Müller A 2015 Measurement of sound velocity made easy using harmonic resonant frequencies with everyday mobile technology *Phys. Teach.* **53** 120
- [9] Kasper L, Vogt P and Strohmeyer C 2015 Stationary waves in tubes and the speed of sound *Phys. Teach.* **53** 523
- [10] Kuhn J, Vogt P and Hirth M 2014 Analyzing the acoustic beat with mobile devices *Phys. Teach.* **52** 248
- [11] Parolin S O and Pezzi G 2013 Smartphone-aided measurements of the speed of sound in different gaseous mixtures *Phys. Teach.* **51** 508
- [12] Parolin S O and Pezzi G 2015 Kundt's tube experiment using smartphones *Phys. Ed.* **50** 443
- [13] Schwarz O, Vogt P and Kuhn J. 2013 Acoustic measurements of bouncing balls and the determination of gravitational acceleration *Phys. Teach.* **51** 312
- [14] Yavuz A 2015 Measuring the speed of sound in air using smartphone applications *Phys. Ed.* **50** 3
- [15] Longo A, Zappatore M and Bochicchio M 2026 Mobile Crowd -Sensing: a novel Technological Enabler for Teaching Acoustics <http://didamatica2016.uniud.it/proceedings/dati/articoli.html> DIDAMATICA 2016 ISBN: 9788898091447
- [16] Longo A, Zappatore M and Michelini M 2016 Exploring Acoustics in Middle and High Schools via BYOD and Inquiry based Learning <http://didamatica2016.uniud.it/proceedings/dati/articoli.html> DIDAMATICA 2016 ISBN: 9788898091447
- [17] PHET Homepage <https://phet.colorado.edu/it/>
- [18] Mazzega E and Michelini M 1993 SEQU: sistema per la modellizzazione dinamica delle onde meccaniche *La Fisica nella Scuola XXVI 1suppl.* **Q1** 30