Exploring Acoustics in Middle and High Schools via BYOD and Inquiry-based Learning

Antonella Longo[1], Marco Zappatore[1] and Marisa Michelini[2]

[1]Dept. of Innovation Engineering, University of Salento
via Monteroni sn, 73100 Lecce (Italy)
{antonella.longo, marcosalvatore.zappatore}@unisalento.it

[2]Research Unit in Physics Education, University of Udine
via delle Scienze, 208, 33100 Udine (Italy)
marisa.michelini@uniud.it

Abstract. Mobile devices and novel information and communication technologies are paving the way to significant changes in learning perspectives, thanks to their daily intensive usage both by students and teachers. Emerging paradigms such as Bring-Your-Own-Device (BYOD), Mobile Crowd-Sensing (MCS) and Inquiry-Based Learning (IBL) can be fruitfully merged to engage students into scientific laboratorial experiences. In this paper we describe the learning context and methodology adopted for a didactic experience in acoustics exploiting the approaches mentioned above and involving 20 classes from seven middle and high-schools in Southern Italy.

1. Introduction

The capillary diffusion of ICT (Information and Communication Technologies) solutions and electronic portable devices (ITU, 2014)) represents nowadays an incredible opportunity and a potential risk in the educational scenario. Several studies assessed how the diffusion of such devices amongst youngsters should be taken into proper account when defining teaching activities, since students consider smartphones and tablets more and more as "*friendly and personal"* (Traxler, 2010). The first tentative of merging mobiles and educational activities is represented by the Mobile Learning (ML) paradigm (Brasher & Taylor, 2004), which has now been replaced by other approaches such as the interaction with teachers and collaborative learning experiences amongst peers (Pachler, Bachmeir, & Cook, 2010) and this trend is continuously growing.

Despite all these advancements, a relevant gap still exists between the technology-intensive activities that students perform outside their schools and the level of technology available within the educational offering they receive daily (Wu, et al., 2012). Therefore, mobile devices brought by students into their learning experiences, according to the Bring Your Own Device (BYOD) paradigm (Afreen, 2014) can offer a significant increase in learning effectiveness. The

DIDAMATICA 2016, ISBN: 9788898091447

benefits are clearly evident in specific areas such as the STEM (Science, Technology, Engineering and Math) disciplines, thanks to powerful computational and sensing capabilities within mobiles, which can act as easily-deployable, low-cost and large-scale sensing networks, as defined by the Mobile Crowd-Sensing (MCS) paradigm (Ganti, 2011). MCS can be also exploited in order to involve smartphone owners directly into scientific monitoring activities. It is well known that the traditional educational approach for dealing with scientific monitoring topics would require the usage of expensive laboratorial equipment and the involvement of skilled personnel to manage laboratory sessions during classes. Consequently, this represents a significant limitation in learning opportunities for students (e.g., few available laboratories for short time-periods) as well as for their learning outcomes. By introducing mobiles, instead, the opportunities of students' engagement into hands-on and laboratory activities can be broadened. In addition, the typical experiential dimension can be detached from traditional school laboratories in order to be merged seamlessly into students' daily life, thanks to the usage of smartphones as effective learning drivers. Moreover, the adoption of mobiles fosters another educational strategy, the so-called Inquiry-Based Learning (IBL) (Keselman, 2003), which promotes the active participation of learners in problem-solving activities. Mobiles can, therefore, represent the key enabler for activating the IBL strategies in a modern educational scenario.

For such reasons, in this research paper, we aim at easing and promoting the diffusion of laboratorial activities on sound and acoustics as daily learning experiences, even outside the school scenario, by engaging students from middle and high schools into IBL activities that exploit the and the BYOD paradigm.

Amongst all the possible environmental sensing opportunities disclosed by the presence of several built-in sensors within modern portable electronic devices, we selected the acoustics domain for two reasons. On the one hand, both in middle and in high schools, it can be addressed as a cross-disciplinary knowledge area, ranging from science, physics and technology to biology and music. On the other hand, noise is becoming one of the most concerning pollutants in urban contexts, mainly due to increasing vehicular traffic, thus requiring to make citizenship better aware about the effects of noise exposure.

We have developed a platform allowing students to learn more effectively foundational topics about acoustics. BYOD and IBL has been exploited in order to prepare young learners for the demands of the 21st Century in terms of an informed usage of novel technologies in their daily learning experiences. In order to provide both students and teachers with effective learning strategies and proper learning materials, the didactic experience has been rigorously defined according to the IBL phases. Our final aim is take science outside the school walls, challenging students in real-life activities.

The paper is organized as it follows: Section 2 overviews learning opportunities disclosed by BYOD and IBL approaches. The proposed platform is briefly described in Section 3. Section 4 presents our didactic experimentation, in terms of learning contexts and objectives, planned coursework, exploitation of the proposed platform. Conclusions are outlined in Section 5.

2. The BYOD and Inquiry-Based Learning Perspective

Youngsters perform every day several activities thanks to their smartphones (Nielsen, 2013), which can be leveraged also in learning scenarios. Mobiles, however, do not only offer learning support and new opportunities for teaching and learning but they also pose challenges for educators, since it has to be expected that learner will bring their mobiles into the classroom more and more frequently. This has drawn a lot of attention, on the Bring-Your-Own-Device (BYOD) approach, defined for the first time by Intel in an internal report, which refers to the practice of people bringing mobiles within working or learning environments. Thanks to BYOD, the teacher is not anymore the only one allocating and controlling technologies in the classroom. Several advantages can be brought by BYOD (Stavert, 2013): 1) easier teacher-to-learner interaction; 2) usage of mobile built-in sensors during scientific experiments; 3) ubiquitous access to networked technologies; 4) flipped learning; 5) increase of independent learning opportunities. There are, however, numerous open challenges (Gidda, 2014): 1) risk of uncontrolled access to the Internet by students (e.g., loss of attention, non-learning activities, etc.); 2) device misusage; 3) social gaps (i.e., some students may not afford expensive devices). However, BYOD practices are becoming widespread across several countries (Traxler, 2010), (Pachler, Bachmeir, & Cook, 2010), (Halliday-Wynes & Beddie, 2009), thus re-shaping the traditional educational landscape.

Similarly, the Inquiry-Based Learning (IBL) approach (Abd-El-Khalick, et al., 2004), represents a promising area where BYOD can be seamlessly integrated. According to IBL, students construct their knowledge by formulating hypotheses and testing them by making observations and performing experiments (Pedaste, Maeots, Leijen, & Sarapuu, 2012). Frequently, this means students are involved in self-directed, inductive-deductive learning processes where they perform simple experiments to investigate how dependent and independent variables are related (Wilhelm & Beishuizen, 2003), (Etkina, et al., 2010). The fruitful combination of novel technologies and mobile devices has been recently examined by several scientific studies (Pedaste, Maeots, Leijen, & Sarapuu, 2012), where the instructional approach of IBL experiences have been quantitatively analyzed (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011) and where the successful adoption of recent technological advancements has been confirmed (De Jong, Sotiriou, & Gillet, 2014). In IBL, students are involved in true scientific discovery process: this is achieved by following logically connected pedagogical units called inquiry phases – such as: Engagement-Exploration-Explanation-Elaboration-Evaluation (Bybee, Taylor, & Gardner, 2006) – where an initial inductive approach is followed by a deductive prosecution (Klahr & Dunbar, 1988). In this research activity, inquiry phases have been carefully and collaboratively defined according to a specific design process that has involved the teachers (Section 4). In this way, the didactic experience is shared and agreed by all the teachers and can be used as a common framework upon which experimentation results and students' learning outcomes can be compared in order to determine the effectiveness of the proposed approach.

3. The Proposed Platform

The proposed platform exhibits both sensing and pedagogical capabilities and it fulfills the requirements elicited by profiling students' activities and teachers' needs in several local middle and high schools. The platform consists of three main components (see Fig. 1): a mobile app for noise measurement collection, a Web app for visualization purposes and a Learning Management System (henceforth, LMS) for managing didactic materials.

From a metering point of view, students are allowed to either collecting sensor data automatically or deciding when/where to perform a measurement and then annotating it with optional comments and photos.

From an educational point of view, both students and teachers are provided with didactic materials about acoustics as it will be described in the next section. These contents are delivered via the LMS. In addition, students are supplied with supporting and context-aware materials (e.g., pop-ups, dialog boxes, dedicated pages) during their usage of the mobile app, in order to learn how to: 1) perform measurements correctly; 2) tackle inaccurate measuring sessions; 3) understand core acoustic phenomena; 4) interpret measurement outcomes.

We followed a Data Warehouse (DWH) approach (Golfarelli & Rizzi, 2009), according to which data are processed in an Extract-Transform-Load (ETL) pipeline. Firstly, measurements are gathered from sensors and then they are cleansed, transformed and stored in order to make them available to final users. The DWH approach is crucial since the proposed system must offer the students not only the possibility to examine (in real-time) the results of the noise measurements they perform on their own mobiles but also the opportunity (after ETL steps) to examine measurements coming from other students.

From an architectural point of view, our platform consists of a mobile sensing app and of a cloud-based system tasked to sensor data management and learning material organization. The app works on Android mobile devices and it emulates a professional Sound Level Meter (SLM): we aim at offering to unskilled users a way for learning how to manage such a kind of equipment as well as to understand which physical quantities are involved in noise monitoring. Noise quantifiers are collected in customizable temporal windows, as required by current national noise regulations and communitarian directives: we refer to the sound pressure level (SPL), which is an instantaneous measurement of the sound intensity, and to the equivalent continuous sound level $L_{EQ(\Delta T)}$, which is a time-averaged measurement for coping with time-varying sound sources. Both these quantities are expressed in dB(A).

The adopted LMS platform is a customized version of the well-known Moodle framework: it has been modified in order to offer in a suitable way learning resources for both teachers and learners from the schools involved in the didactic experimentation (see Section 4). As for the teachers, they will have access to a course syllabus that will guide them in performing laboratorial experiences and managing the correct usage of the apps throughout the didactic exploration. In addition, they can use the LMS to fill the forms required for collaboratively designing the initial phases of the inquiry cycle. The LMS also offers teachers a wiki and a forum for sharing opinions and comments on the didactic experimentation. Similarly, students can access the LMS for obtaining the learning materials designed and published by the teachers for each of the inquiry phases. Both teachers and students can also use the LMS to access noise surface maps, in order to visually examine the measurements outcomes achieved in a given time window by the noise monitoring campaigns performed according to the MCS paradigm.

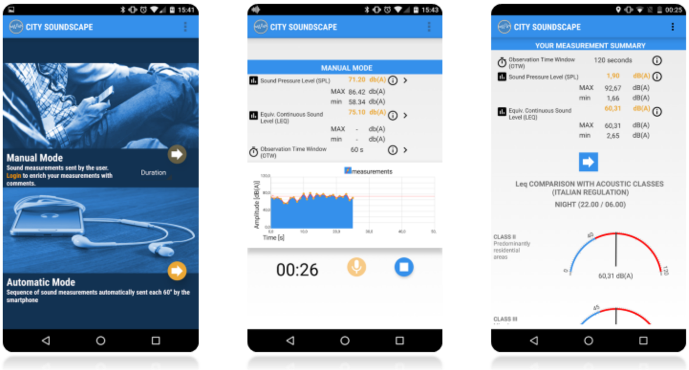

Fig.1 – The developed sound-sensing mobile app

4. The Didactic Experimentation

4.1 Learning Context and Strategy

This section examines overall aspects of the experimentation as well as selected learning objectives, methodologies and learning contents.

In order to involve profitably students and teachers, the learning context has been shaped starting from the analysis of the reference physical phenomena in acoustics (i.e., sound waves and sound propagation mechanisms) so that a structured experimental evaluation of noise pollution issues is possible. A set of ad-hoc mobile apps supporting the learning process have been defined. These apps cover the following sectors: 1) acoustic signal monitoring (both in time and frequency domain); 2) acoustic signal generation; 3) analysis of the sensing capabilities of a mobile device.

We selected 20 classrooms from seven (middle- and high-) schools in Southern Italy (administrative province of Brindisi) as the pilot cases for our experimentation. The experimentation has started at the same time in all the selected schools and it is currently under way. It will last 2-months. The experimentation consists of three sequential phases.

- Preparation: during this phase, teachers from the selected schools have been trained on how to use the platform and its featuring aspects. They have also received the supporting learning materials, in order to help them in managing both the theoretical and the laboratorial activities scheduled for the second phase.

- Didactic modules: teachers and external practitioners (from municipalities, healthcare sector, environmental protection agencies, etc.) will provide students with the learning contents. Students will also perform collaborative measurement sessions on environmental noise and they will discuss and critically analyze measurement outcomes. The acquired knowledge will be evaluated through specific assessment questionnaires during the modules and at their completion.
- Learning effectiveness analysis: conclusive meetings will be held with teachers, in order to evaluate the achieved results in terms of learning outcomes, students' levels of engagement and benefits for STEM education.

Since our proposal deals with laboratorial experiences on acoustics, we referred to well-defined educational approaches fostering active learning and collaboration, which have proven to be very effective in several STEM disciplines. Firstly, the experimentation has been designed in compliance with the IBL strategy as recalled in Section 2, these strategies stimulate both practical and conceptual efficiency in students. The inquiry cycle is activated by complying with the so-called Prevision-Experiment-Comparison approach (or PEC cycle) (Martongelli, Michelini, Santi, & Stefanel, 2001), (Theodorakakos, Hatzikraniotis, & Psillos, 2010). The PEC cycle has been designed and thoroughly validated by the CIRD (Inter-Department Center on Didactic Research) of the University of Udine, especially in the Physics domain.

During phase one (Prevision) of the PEC cycle, students start with phenomenological observations, which stimulate them to interpret the observed event and to provide quantitative estimations about physical phenomena (e.g., "how do you think the annoyance of a given noise source could be quantified?"). In phase two (Experiment), students are engaged into experimentations, in order to perform analyses about the phenomena under observation (e.g., "observe the real-time graphical representation of the given sound source directly on your smartphone display"). Finally, in phase three (Comparison), students validate their initial assumptions and hypotheses, by comparing them with the experimental evidences so that theoretical conclusions can be derived (e.g., "enforce your assumptions by examining quantitatively the graph from the experiment and by comparing it with your initial hypotheses").

4.2 Learning Objectives and Methodology

A series of primary learning objectives has been identified by examining the requirements elicited from the teachers.

- From an overall perspective, we aim at disseminating scientific and laboratory-oriented culture across schools thanks to novel ICT technologies and models (BYOD), thus improving the overall didactic quality in STEM disciplines.

- From a learning perspective, we aim at leading students towards the core concepts in acoustics both in a descriptive and in an interpretative way. In order to do so, the addressed topics are: sound sources; sound amplitude and intensity; sound propagation; sound velocity; sound detectors; the human earing system; sound pressure; sound waves and their features.
- From a pedagogical perspective, we aim at a progressive approach of students to the above mentioned topics by following a rigorous experimental approach and by fostering in them the formulation of hypotheses on the observed phenomena as well as the comparison of the achieved results against the expected ones.

Our didactic proposal starts with the identification of sound sources: objects can produce sounds if properly stimulated by oscillating or vibrating but not all the vibrational phenomena can produce sounds. This allows to address two core features of sound, amplitude and intensity, which are inherently related to sound sources since they vary depending on the specific object under examination. After that, the sound propagation aspects are examined, by highlighting the fundamental role played by the propagation medium. Subsequently, sound detectors are presented as those devices capable of sensing vibrations (e.g., daily-life objects, diapasons, etc.). Finally, other topics such as sound pressure and sound waves are addressed with an experiential approach.

The didactic experience has been designed by defining a set of operational documents structured as enlisted below:

- description of the experiment by text and pictures;
- multiple-choice questionnaires stimulating the definition of hypotheses and estimations;
- questions to be answered after the experiment, aiming at synthesizing observed results and interpreting them;
- conclusions drawn individually and collaboratively by students

4.4 Learning Contents

Five learning sections on acoustics have been identified. For each of them several Learning Experiences (LE) can be proposed, each having a set of Learning Objectives (LO) and involving a set of experiments (Exp). In the following list, an example of the tuple LE, LO, Exp is presented for each section.

1) Sound sources
   a. LE: combined usage of rubber band, ring bell, diapason;
   b. LO_1: the vibration of properly-stimulated objects produces sounds; LO_2: objects differing in shapes and composing materials produce different sounds;
   c. Exp_1: the rubber band; Exp_2: the diapason; Exp_3: the ring bell.
2) Sound propagation
   a. LE: sounds do not propagate in free space;
   b. LO: sounds propagation requires a propagation medium;
   c. Exp: using a ring bell in a vacuum-sealed condition.
3) Sound detectors

   a. LE: identify devices capable of detecting sounds;
   b. LO: some objects are capable of sensing vibrations;
   c. Exp: using two diapasons at the same time.
4) Pressure
   a. LE: determine the effects of a force distributed over a surface;
   b. LO_1: the pressure is a force distributed over a surface; LO_2: pressure and surface are inversely proportional;
   c. Exp: using a solid objects over a modelling material (e.g., a brick on top of a packet of salt dough).
5) Sound Waves
   a. LE: identifying how sounds propagate;
   b. LO: sounds propagate as waves;
   c. Exp: usage of the Kundt's tube

As for the mobile apps supporting the didactic experience, we have proposed the following ones, partitioned into three different categories:

1) Acoustic signal monitoring
   a. City Soundscape[1]: the mobile app described in Section 3);
   b. Sound Analyzer[2]: it offers time and frequency analysis of the input sound signal as well as a spectrogram-creation function;
   c. Spectrum Analyzer[3]: spectrum analyzer emulator
2) Acoustic signal generation
   a. Frequency Sound Generator[4]: it allows generating sounds by tuning waveforms, volume, modulation, frequency;
3) Analysis of mobile devices' sensing capabilities
   a. Sensor Box for Android[5]: it allows testing all the sensing capabilities of the Android device where it has been installed.

These apps can be used together, in order to increase the effectiveness of the learning experience. For instance, Sound Analyzer app and Frequency Sound Generator app can be used for analyzing and generating several sound waves respectively during the same experiment.

4.5 Validation Strategy

Classes will be involved pairwise: students from the first one will use our platform as the supporting experimental learning environment; students from the second one will be addressed with a traditional teaching approach, based upon frontal lessons and without any experiential activity. By doing so, at the end of the experimentation it will be possible to compare the learning outcomes from the two different approaches, thus highlighting advantages and drawbacks of our proposal. This experimentation, therefore, represents an essential step towards

[1] https://play.google.com/store/apps/details?id=processing.test.soundanalyzer&hl=it

[2] https://play.google.com/store/apps/details?id=processing.test.soundanalyzer&hl=it

[3] https://play.google.com/store/apps/details?id=com.keuwl.spectrumanalyzer&hl=it

[4] https://play.google.com/store/apps/details?id=com.finestandroid.soundgenerator&hl=it

[5] https://play.google.com/store/apps/details?id=imoblife.androidsensorbox&hl=it

the evaluation of the effectiveness of the proposed approach before scaling it up to the MOOL dimension. More specifically, during the whole experimentation, we will monitor the following aspects: 1) progressive acquisition of scientific topics on acoustic and sound; 2) progressive acquisition of a sectorial language; 3) progressive acquisition of usage experience for the provided app; 4) level of motivation and personal engagement in data gathering activities.

5. Conclusions

Mobile device pervasiveness can be nowadays exploited in several ways, even in the educational domain. Novel usage models are emerging, such as the Mobile Crowd Sensing (MCS) paradigm, according to which mobile-embedded sensors can turn a smartphone into a powerful sensing platform, and the Bring Your Own Device (BYOD) approach, which promises to allow students using their own devices for learning activities. We believe that these opportunities can be adopted for improving the learning quality in STEM disciplines (Science, Technology, Engineering, and Mathematics). In this paper we have presented a proposal for a didactic experimentation on acoustics and noise monitoring designed according the most recent pedagogical trends (e.g., Bring-Your-Own-Device, BYOD, and Inquiry-Based Learning, IBL). The pedagogical perspective, the learning contexts, strategy and methodology have been thoroughly described. The experimentation involves 20 classrooms from seven different middle and high-schools in Southern Italy.

Acknowledgment

This research activity has been developed and financed by the EU-funded project SP4UM (Grant agreement n. 632853, sub-grant agreement n. 021), within the “frontierCities” FIWARE accelerator, and by the EDOC@WORK3.0 project.

References

Abd-El-Khalick, F., BouJaoude, S., Duschl, R., Lederman, N., Mamlok-Naaman, R., Hofstein, A., Tuan, H. (2004). Inquiry in Science Education: International Perspectives. *Science Education, 88*(3), 397-419.

Afreen, R. (2014). Bring Your Own Device (BYOD) in Higher Education. *Int. Journal of Emerging Trends & Technology in Computer Science, 3*(1), 233-236.

Alfieri, L., Brooks, P., Aldrich, N., & Tenenbaum, H. (2011). Does Discovery-Based Instruction Enhance Learning? *Journal of Educational Psychology, 103*, 1-18.

Brasher, A., & Taylor, J. (2004). Development of a Research Plan for Use of Ambient Technology to Test Mobile Learning Theories. In J. Attewell, & C. Savill-Smith (A cura di), *Mobile Learning Anytime Everywhere: A Book of Papers from MLEARN 2004* (p. 33-37).

Bybee, R., Taylor, J., & Gardner, A. (2006). *The BSCS 5E Instructional Model: Origins and Effectiveness.* NIH Full Report.

De Jong, T., Sotiriou, S., & Gillet, D. (2014). Innovations in STEM Education: the Go-Lab Federation of Online Labs. *Smart Learning Environments, 1*, 1-3.

Etkina, E., Karelina, A., Ruibal-Villasenor, M., Rosengrant, D., Jordan, R., & Hmelo-Silver, C. (2010). Design and Reflection Help Students Develop Scientific Abilities: Learning in Introductory Physics Laboratories. *J. of the Learning Sciences, 19*, 54-98.

Ganti, R. (2011). Mobile Crowdsensing: Current State and Future Challenges. *IEEE Commun. Mag., 49*(11), 32-39.

Gidda, M. (2014, April 11). Students: Bring Your Own Technology to Uni. *The Guardian*.

Golfarelli, M., & Rizzi, S. (2009). *Data Warehouse Design: Modern Principles and Methodologies* (1st ed.). McGraw-Hill.

Halliday-Wynes, S., & Beddie, F. (2009). *Informal Learning. At a Glance.* Research Report, National Centre for Vocational Education Research Ltd., Adelaide, Australia.

Keselman, A. (2003). Supporting Inquiry Learning by Promoting Normative Understanding of Multivariable Causality. *J. of Res. in Science Teaching, 40*, 898-921.

Klahr, D., & Dunbar, K. (1988). Dual Space Search During Scientific Reasoning. *Cognitive Science, 12*, 1-55.

Martongelli, R., Michelini, M., Santi, S., & Stefanel, A. (2001). Educational Proposals Using new Technologies and Telematic Net for Physics. In R. Pinto, & S. Santiago (A cura di), *Physics Teacher Education Beyond 2000* (p. 615-620). Paris, France: Elsevier.

Nielsen. (2013). *The Mobile Consumer - A Global Snapshot.* Report.

Pachler, N., Bachmeir, B., & Cook, J. (2010). *Mobile Learning: Structures, Agencies, Practices.* New York, USA: Springer.

Pedaste, M., Maeots, M., Leijen, A., & Sarapuu, S. (2012). Improving Students' Skills Through Reflection and Self-Regulation Scaffolds. *Technology, Instruction, Cognition and Learning, 9*, 81-95.

Stavert, B. (2013). *Bring Your Own Device (BYOD) in Schools: 2013 Literature Review.* Eversleigh, New South Wales, AUS: NSW Dept. of Education and Communities.

The International Telecommunication Union. (2014). *Estimated Key Global Telecom Indicators for the World Telecom Service Sector in 2014.* Ericsson Mobility Report.

Theodorakakos, A., Hatzikraniotis, E., & Psillos, D. (2010). PEC Task Explorer: a Tool for ICT Supported Learning in Science. *Int. Conf on Computer-Based Learning in Science (CBLIS 2010)*, (p. 75-83). Oelizk, Warsaw, Poland.

Traxler, J. (2010). Distance Education and Mobile Learning: Catching Up, Taking Stock. *Distance Education, 31*(2), 129-138.

Wilhelm, P., & Beishuizen, J. (2003). Content Effects in Self-Directed Inductive Learning. *Learning and Instruction, 13*, 381-402.

Wu, W., Wu, Y., Chen, C., Kao, H., Lin, C., & Huang, S. (2012). Review of Trends from Mobile Learning Studies: a Meta-Analysis. *Computers in Education, 59*(2), 817-827.