The Eco-sensors4Health project in teacher training: Using sensors to raise awareness in environmental health

Maria João Silva, Ana Caseiro, Margarida Rodrigues, Bianor Valente, Nuno Melo, António Almeida, Clarisse Nunes
School of Education, Polytechnic Institute of Lisbon (ESELx, IPL)
Lisbon, Portugal
mjsilva@eselx.ipl.pt , anac@eselx.ipl.pt , margaridar@eselx.ipl.pt , bianorv@eselx.ipl.pt , nunom@eselx.ipl.pt , aalmeida@eselx.ipl.pt , clarisse@eselx.ipl.pt

***Abstract* — The Eco-sensors4Health research project proposes the use of everyday Information and Communication Technologies (ICT), such as sensors, in the creation of healthy and sustainable environments in school. Complementarily, the TEL@FTELab (*Technology Enhanced Learning@Future Teacher Education Lab*) research project investigates how a technology enriched training can improve teachers' education. The research presented in this article was developed in the context of both projects and created a set of multidisciplinary learning scenarios to raise awareness in environmental health, through the use of sensors in teacher training. The referred scenarios focus on various dimensions of environmental health in schools, such as sound and air quality (trough the study of carbon dioxide concentration in air). The assessment of the use of sensors to explore such dimensions of environmental health in school made it possible to validate learning scenarios and envision multidisciplinary practices of prospective teachers regarding the empowerment of children to eco-innovate in environmental health.**

Keywods — sensors; teacher training; environmental health; ICT

I. Introduction

Sensors are frequently used in daily life as an extension of human senses [1]. They are embedded in mobile devices that allow ubiquitous, formal and informal, learning and health promotion activities [2] [3]. Additionally, mobile technology allows the exploration of the environment, anytime and anywhere, along with research and problem solving collaborative activities, by acquiring environmental data (from sensors or introduced by the user), as well as processing and presenting such data in multiple representations [2] [4]. Notwithstanding all these potentialities and an increasing possession of mobile devices by teachers and students [5], teachers' training for this type of teaching-learning strategies is not sufficient yet [2] [6].

The research presented in this article aims the study of the use of sensors as tools for environmental health promotion in teachers' training, foreseeing future teaching practices that lead to children's awareness and empowerment in this domain.

The study was developed in the context of the Eco-sensors4Heatlh and TEL@FTELab (*Technology Enhanced Learning@Future Teacher Education Lab*) research projects. Both projects are linked to the present study, given that while the TEL@FTELab project researches how a technology enriched training can improve teachers' instruction, the Eco-sensors4Health project aims at promoting the use of everyday Information and Communication Technologies (ICT), such as sensors, in the creation of healthy and sustainable environments in school, thus preparing teaching practices that lead to children's empowerment in the use of sensors to intervene in the schools' environmental health.

In the context of both projects, the use of sensors and other mobile technologies is outlined by the following approaches: i) multidisciplinarity [7] [8], mobilizing different disciplinary areas, namely natural sciences, mathematics and technologies, for the implementation and reflection on environmental health mobile learning activities; ii) promotion of students' autonomy, namely about how to search what [2]; iii) development of authentic and situated activities, integrating the use of sensors and other ICT to approach real and proximity problems [9]; iv) promotion of technological pedagogical content knowledge, as intersection of technological knowledge, content knowledge, and pedagogical knowledge, in accordance with the TPACK model [10].

This article incorporates, apart from this introduction, the framework and work related to the undertaken research, the used methodology, data presentation and analysis, the work in progress and the conclusions.

II. Framework and Related Work

The use of sensors has been considered, since the beginning of the 21st century, a powerful strategy in science and mathematics education, contributing to better learning results [11] and teachers' positive experiences in science teaching [12].

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There are many projects that have been using sensors integrated in mobile devices to explore the environment in research activities. One of the pioneer projects was the Globe project, in which students from schools from around the world used sensors to obtain scientifically valid measurements, whose data were collected, treated and presented in global and local interpretations [13]. Many other projects followed this one, developing meaning making environmental activities with sensors (including GPS, photographic cameras, sound, temperature, and humidity sensors) and mobile devices (as PDA and smartphones), integrated in platforms, and used in real environments (an analysis of such projects can be accessed in [14]). More recently, with the development of more accessible sensors to any citizen, and with the increase of everyday use of smartphones with access to the Internet [5], sensor kits that detect and measure environmental and environmental health parameters have been spreading [15], to be used by networks of citizens, including schoolchildren. The CITI-SENSE project, for example, is a European project that aims to empower citizens in the participation and contribution to a healthier and more sustainable environment, influencing related priorities and decisions (www.citi-sense.eu). It provides sensors kits, among other resources, for people to monitor the environmental quality. In this project, there are 12 schools, in 4 countries, monitoring the indoor air.

The present investigation designed and is now validating a set of learning scenarios for teacher initial training, mobilizing Curricular Units (CU) of Natural Sciences, Mathematics, and Technology areas to develop environmental health activities, using sensors. These activities addresses the need for teachers' familiarization with sensors, prior to their use in schools with children [16].

III. METHODOLOGY

In the context of a Degree in Basic Education (LEB), in Lisbon, a set of learning scenarios was implemented, in diverse Curricular Units, aiming at the analysis and significance of acquired data, using sensors and involving environmental health variables. The scenarios were assessed by participant observation, undertaken by teachers and by open items questionnaires to students. A content analysis of the answers to such questionnaires was carried out.

The scenarios design considered the Future Classroom Maturity Model [17], placing the considered dimensions (Table I) in different levels, according to that referential, concerning both the moment previous to the implementation of the scenario as well as the level the scenario intended to achieve.

The scenarios also aimed to develop the knowledge of prospective teachers in the three dimensions of the TPACK model (Fig. 1).

TABLE I. LEVELS OF FUTURE CLASSROOM MATURITY

Dimensions	***Maturity Levels***	
	Current	***Intended***
Student	2 - Enrich	3 - Enhance
Teacher	3 - Enhance	4 - Extend
Learning and assessment objectives	2 - Enrich	3 - Enhance
Institution's capacity to support innovation in the classroom	3 - Enhance	4 - Extend
Tools and resources	3 - Enhance	4 - Extend

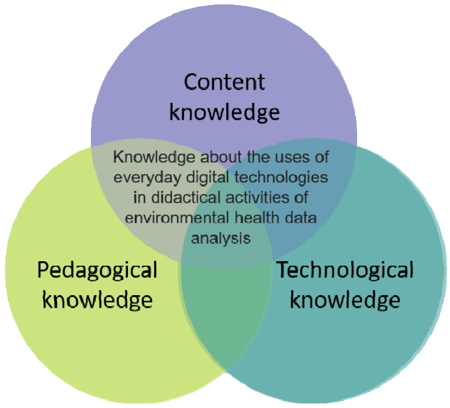

Fig. 1. TPACK model considered in the learning scenarios.

A. *Use of sound sensor in the Curricular Units "Data Analysis" and "ICT in Mathematics and Natural Sciences"*

Three diurnal 2nd year classes participated in the Data Analysis CU, in a total of 92 prospective teachers. In the elective CU of ICT in Mathematics and Natural Sciences (TICMC) the participant class was composed by 8 students of the evening 2nd year.

The learning scenario, used in both CU, aimed the gathering, organization, treatment, and analysis of the statistical data of sound level in different places inside the school. There was an initial moment dedicated to collect students' predictions gathering of such data. To this work students used: i) their smartphones with embedded sound sensors, using the SPARKvue application, to collect data; ii) e-mails to export collected data; and iii) Excel to data treatment, to calculate statistical measures, and to create and analyse graphic representations. To assess the didactic intervention, the works produced by the students were gathered and a survey by questionnaire was applied to each participant, in the Data Analysis CU, and to each pair of participants in the TICMC CU. The questionnaires had a common set of questions, with an added set in the questionnaire applied in the TICMC CU.

B. *Use of heart rate sensor in the Curricular Unit "ICT in Mathematics and Natural Sciences"*

In the heart rate sensor activity of the TICMC CU, there was a total of eight participants (all the students of the class). The scenario aimed the implementation of activities with the heart rate sensor, together with the Endomondo application, to monitor the changes of heart rate rhythm in the school's environment and during a dramatization of a debate in "Parliament" about the Almaraz Nuclear Power Plant. Graphical representations created by the software were exported to Google Earth and interpreted by the students. To assess the scenario, a new questionnaire was given to each pair of students.

C. *Use of carbon dioxide sensor in the Curricular Unit "ICT in Mathematics and Natural Sciences"*

Only half of the TICMC CU students participated in the carbon dioxide sensor activity. The scenario aimed the implementation of activities with the sensor of carbon dioxide to monitor its concentration changes in the air in several activities and places in the school. Data were collected with the SPARKvue application and, posteriorly, exported to Excel, where students made their treatment. The assessment of the scenario was based in participant observation and in the answers of two pairs of students to the questionnaire.

IV. DATA PRESENTATION AND ANALYSIS

A. *Use of sound sensor in the Curricular Units "Data Analysis" and "ICT in Mathematics and Natural Sciences"*

In the Data Analysis CU, students showed their motivation throughout the execution of the activity, especially at the moment where predictions were made about the sound level in diverse places of the school and at the moment of data collection (Fig. 2). Collection places and time differed in each class, with noise levels results being situated between 27.2 dBC e 70.0 dBC (Table II).

The analysis of the answers of the prospective teachers to the questionnaires allowed to verify that the majority (82%) considered the task relevant, with justifications referring, especially, the task's relevance in what concerns the subject of study (the sound) and the use/consolidation of statistical contents previously worked on in the CU.

In this learning scenario, the students were favourable to the use of ICT, with 90% stating that the use of the smartphone is relevant to undertake the proposed task, and 95% stating the relevance of the use of Excel. Despite such high values, it should be stressed that 10% of the prospective teachers considered that the use of the smartphone, and 5% the use of Excel, are strategies with no relevance for learning.

Fig. 2. Collecting data with the smartphone and the *SPARKvue* app.

TABLE II. NOISE LEVELS IN THE SCHOOL (CU DATA ANALYSIS)

	Snack Bar	***Cafeteria***	***Classroom***	***Outdoor garden***	***Library***	***Area of study I***	***Area of study II***	***Noble hall***
Minimum (dBC)	56.1	57.1	54.0	51.4	31.0	38.7	36.1	27.2
Maximum (dBC)	70.0	68.9	67.7	60.0	41.6	54.3	56.1	58.8

TABLE III. NOISE LEVELS IN THE SCHOOL (CU ICTMNS)

	Parking lot	***Cafeteria***	***Empty classroom***	***Entry hall***	***Area of study***	***Corridor***
Minimum (dBC)	38,7	55,4	47	66,8	44,2	57,6
Maximum (dBC)	65	90,7	53,7	80,6	72,1	67,9

In the TICMC CU, students predicted values that ranged from 20 dBC in the library and 80 dBC in the entry hall of the school. Concerning collected data, the noise level ranged from 38,7 dBC, in the parking lot, which can be felt as relaxing, and 90,7 dBC in the cafeteria, an extremely high and fatiguing value (Table III).

There was unanimity regarding the relevance of the use of smartphones and Excel in the proposed activity. Also 100% of the answers justify the utility of the use of a sound sensor in future teaching practices, namely for its practical and experimental dimension in children's learning, and for the importance of multisensoriality in the treatment of the subject of noise pollution. One of the pairs stated the isomorphism of the practices, pointing the future utility of their experience to implement the activity with children.

One of the answers, referring the use of the smartphone, called attention to the teacher's need of "always be aware of the economic and social differences among students, preventing the creation of any disadvantage among them". On the other hand, in the end of the activity, 3 of the 4 pairs referred to have appreciated the activity for being able to evaluate a dimension of environmental quality by solely using their smartphone.

The subject and the results were considered significant, since the students confronted the measurements made to their daily experiences and perceptions, thus attesting that the cafeteria and the snack-bar are areas with a high sound level, the library is the quietest place and that study areas do not always maintain the appropriate sound level. The measured values varied with the measurement moment, for instance there were no activities in the Noble Hall and there was a group of people socializing in the entry hall, in the measurement moments.

As expected, since TICMC is an elective CU, centred on ICT, the students' assessment regarding the relevance of the smartphone and Excel's use was unanimous and more positive when compared to the Data Analysis CU. It was highlighted that the BYOD (Bring Your Own Device) strategy must consider the students' diversity as well as the diversity of their mobile devices.

B. Use of heart rate sensor in the Curricular Unit "ICT in Mathematics and Natural Sciences"

In the TICMC CU, two students (one at a time) collected data of their cardiac rhythm, while walking outside the school (different pathways), accompanied by their colleagues that took notes of the places and the events, making it possible to subsequently interpret the variations in the graphic.

In the analysis of the heart rate sensor data, exported by the Endomondo app and presented in Google Earth (Fig. 3), the students recognised that the cardiac rhythm, in addition to being different from person to person (the first student had a higher average heart rate than the second one), had also changed according to the physical effort made throughout the journey (going up a hill, path irregularities and different terrain elevations, in the case of the second student) and in moments of increased stress, while crossing a less safe area, like the parking lot (first student).

During the simulation of a parliamentary debate about the environmental impact of the Almaraz Nuclear Power Plant, one student used the heart rate sensor. In Fig. 4, it is possible to observe that the heart rate began to rise, remaining relatively low, while the colleagues were discussing, up until the moment the student was called by the teacher to take part in the discussion, having her heart rate increased then.

By the end of the activity, the students acknowledged the relation between heart rate changes and the environmental (dis)comfort. The students also highlighted that the use of the heart rate sensor would be of great usability in the study of the circulatory system in the sixth grade.

In the questionnaires' answers, 100% of the students stated having never used a heart rate sensor and considered the importance of its use together with Google Earth, making references to the possibility of "observing different variables in the same graphic area", therefore allowing "a better interpretation of the obtained results", by envisioning "the connection among all the variables and their joint evolution". All the pairs of students considered that the use of the heart rate sensor will be useful in future teaching practices, supporting this opinion with i) the mobilization of diverse curricular areas (Portuguese, Mathematics, Environmental Studies), and ii) the significance of the subject and the experimentation.

Fig. 3. Altitude graphic (upper line) and heart rate of two students (lower line), and Google Earth showing the pathway.

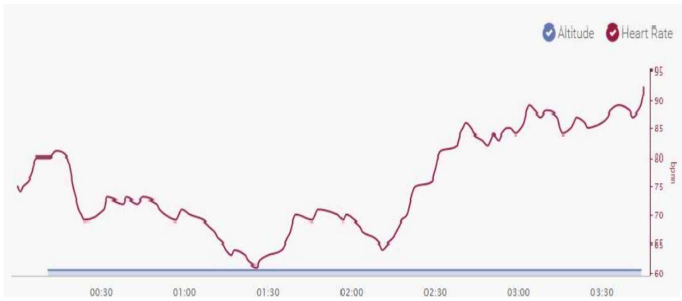

Fig. 4. Heart rate graphic of a student during the debate.

C. Use of carbon dioxide sensor in the Curricular Unit "ICT in Mathematics and Natural Sciences"

In the TICMC CU, the data collection took place in diverse moments. In a first moment, the sensor started to obtain data in the classroom's air, and then it was put in a bottle to which a student had breathed into (see Table IV, exhaled air). Therefore, the students recognized that the highest measured value was the concentration of carbon dioxide in the air within the bottle (exhaled air from a student that was mixed with the air from the classroom already inside the bottle).

In a second moment, a recently extinguished match was put inside the bottle with air from the classroom. In this way, it was also acknowledged that the maximum measured value (see Table IV, smoke from a match) corresponded to the value of carbon dioxide concentration in the air inside the bottle (air from the classroom already inside the bottle mixed with the smoke from the match),

TABLE IV. CONCENTRATION OF CO_2 IN DIVERSE ACTIVITIES AND SPACES.

	Exhaled air	*Smoke from a match*	*Garden, close to the IC19 freeway*	*Working car*
Maximum (ppm)	25868	2616	2837	13045

In a third moment, the carbon dioxide sensor was kept in the school's garden, close to the IC19 freeway, being noticed that, whenever a car passed by, the carbon dioxide concentration increased, when a truck passed by the rise was higher, and that when cars passed close to the garden the rise was also higher. In another moment of data collection, the carbon dioxide sensor was kept close to a car, before, during, and after the engine started to work (see Table IV, data from working car).

In this context, the students understood that: i) exhaled air has a high concentration of carbon dioxide, meaning that the classrooms' air quality should be monitored and cared; ii) combustions are sources of carbon dioxide to the air, contributing to the decrease of the indoor and outdoor air quality; iii) although its concentration can rise, carbon dioxide is always a minor component of the air. From questionnaires' answers of the two pairs, it is possible to highlight: i) the novelty factor related to the carbon dioxide sensor, its units and ease of use; ii) the acknowledgement of the utility of such sensor to study environmental health contents in higher education, but also in basic education.

D. Maturity model and TPACK model in the implemented learning scenarios

In the implemented learning scenarios, it was recognized some evolution regarding maturity levels in some of the addressed dimensions: i) Students (from 2 to 3), since students expanded their digital competence using previously unknown technologies (information confirmed by survey) in the research of environmental questions; ii) Teacher (from 3 to 4), since activities were autonomously developed by students in places outside of the classroom, and were planned with a clear focus on learning; iii) School's capacity to support classroom innovation (from 3 to 4), since there was an investment in the acquisition of new technologies such as sensors, and in technical training, in addition to the encouragement of the collaboration among teachers in the design of the learning activities, using multiple resources; and iv) Tools and resources (from 3 to 4, in the TICMC CU), as new uses or new technologies were successfully adopted in class, inside and outside the classroom, to support learning.

Other dimensions maintained the starting level: i) Learning and assessment objectives (2), since the short timeframe in which the activities took place did not allow the evolution from the learning objectives defined by teachers to a bigger involvement of the students in this definition nor a better customization of the objectives; and ii) Tools and resources (3, in the Data Analysis CU), since the adoption of new technologies and the collection of data occupied a reduced percentage of the classes.

The observation of the work implemented in classes as well as the analysis of the questionnaires' answers allow to verify that the students developed knowledge concerning the three dimensions of the TPACK model. Regarding content knowledge, they acquired knowledge about the meaning making of i) different variables and their relation to the school's environmental quality, ii) graphical representations involving different variables, and iii) statistical concepts. Regarding technological knowledge, the students acquired new knowledge about everyday digital technologies, as sensors, and deepened their knowledge about the use of the spreadsheet in statistical studies, focused on the identification and monitoring of environmental health problems. The students also identified potentialities of the use of Google Earth. Concerning pedagogical knowledge, the students developed knowledge about the didactic use of sensors and spreadsheets in activities of environmental health data analysis, experiencing the importance of multisensoriality and the experimental component of learning, being also able to bridge such experiences to future teaching scenarios in preschool and basic education. The development of the pedagogical knowledge of the students may have been favoured by a didactic approach that respected the phases of a statistical research and that invited students to research the environmental questions in study. Therefore, it was made possible the occurrence of practices' isomorphism, even though CU contents have a scientific nature and not a didactic one. Furthermore, in the TICMC CU, the reading of scientific articles that described and analysed the use of sensors by children, may have contributed to students' acknowledgment of the utility of the developed activities to future teaching.

V. WORK IN PROGRESS

In the previous sections, a set of already implemented scenarios was presented. Those scenarios used sensors to raise awareness in environmental health and to prepare prospective teachers for future innovating practices.

At the moment it is still being developed another learning scenario, "Carbon Dioxide and Oxygen exchanges between Plants and the Atmosphere", in the The Living World CU, with the same central goal of previous scenarios, but centred on the influence of plants in the indoor and outdoor air quality in schools. In this scenario, the students used carbon dioxide and oxygen in the air sensors, together with the SPARKvue app, installed in their own smartphones. In a first session, students familiarized themselves with the use of sensors, while empirically recognizing: the release of carbon dioxide in breathing (study of the outdoor air, classroom air, exhaled air, and fermentation produced by yeasts); and the consumption of oxygen in breathing (study of the outdoor air, classroom air, and exhaled air). In a second lesson, students explored, with the same resources (sensors and app), the carbon dioxide and oxygen exchanges by plants in the presence and absence of light, relating those exchanges with respiration and photosynthesis. By the end of the scenario's implementation, it was possible to reflect on the influence of people and plants in the indoor and outdoor air quality in school. The reports are being developed by the students. It is to be highlighted that the four classes of the 2nd year of the LEB are participating in these activities (around 110 students).

A future scenario will be focused on the measurement of carbon dioxide in natural and semi-natural environments, using sensors in field trips to areas with the referred characteristics. In this context, it was developed an exploratory study in the Mathematics in Environmental Themes CU with 15 students, using the carbon dioxide sensor and the abovementioned SPARKvue app. The obtained results ranged from 157 ppm to 1390 ppm in a lagoon protected area. Such limit values were measured in open field and in observatories for bird-watching at its full capacity. Those results envision diverse educational potentialities, from which it is important to highlight: i) comparison between the global average value of carbon dioxide in the atmosphere and the verified values in natural environments; ii) discussion of data variations, relating such variations to space characteristics; and iii) a more effective perception of the carbon dioxide percentage in the atmosphere when compared with the percentage of other gases.

VI. Conclusion

The present research created a set of multidisciplinary learning scenarios to raise environmental health awareness, through the use of sensors in teacher training. The mentioned scenarios were focused on diverse dimensions of the schools' environmental health, such as sound level and air quality (through the concentration of carbon dioxide in the air). The assessment of implemented scenarios, including the assessment of the use of sensors to explore the dimensions of school's environmental health, used the TPACK model [10] and the future classroom maturity levels [17]. Therefore, it was possible to validate such learning scenarios and foresee multidisciplinary practices of prospective teachers to empower children in environmental health.

Two other scenarios are being planned and implemented. These two scenarios use carbon dioxide and oxygen concentration sensors to complement the validated scenarios in this research, in what concerns: i) the influence of people and plants in the indoor and outdoor air quality in school; ii) the indoor and outdoor air quality differences in urban and natural areas.

Considering that the inclusion of children with Special Educational Needs in regular teaching contexts is a design of the Portuguese educational system, it is important to emphasize that the improvement of the implemented learning scenarios will consider the need to prepare LEB students to an inclusive use of sensors, making it possible the engagement and active participation of all children in the activities. This may require specific supports and strategies.

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