Empowering In-Service Teachers to Support Students in Using Sensors to Address Environmental Problems

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***Abstract*— Electronic sensors can be used by teachers and students as epistemic mediators in environmental knowledge creation. A workshop was designed and developed, on the basis of the Eco-SolvingS Model, in order to train in-service teachers in using electronic sensors with their students to identify and explore school environmental problems. In this paper, the authors describe that workshop, and analyze its results, presenting evidences of the significant use of sensors by students. This way, this paper make available a simple, brief and validated strategy to empower in-service teachers to support students in using sensors to address environmental problems.**

***Keywords*— sensors, environmental problems, teachers, students, workshop**

I. Introduction

Human senses are the primary interface of children with the environment. Consequently, embodiment is in everything children see, feel, think and do, and must be addressed in children's constructions of meanings, with these constructions being made in practice [1]. This way, any educational approach should privilege the knowledge and experimentation of body [2].

Sensors can measure or detect physical, chemical, and biological quantities [3], and nowadays they are integrated in ICT devices, such as smartphones, and tablets. Therefore, sensors are portable, affordable, wireless, connectible, and widely available [4] [5].

With teacher mediation, electronic sensors can be used by children, together with human senses, as epistemic mediators to collect and make sense of qualitative and/or quantitative environmental data [6] [7]. Sensors, as epistemic mediators, allow children to codify and make sense of unexpressed information, through manipulation of those external devices [8].

In this paper, the authors present a workshop that was designed and developed, on the basis of the Eco-SolvingS (Solving Environmental Problems, using Sensors) Model, in order to train in-service teachers to mediate the use of electronic sensors by students, to identify and explore school indoor and outdoor environmental problems. The Eco-SolvingS is an educational model developed to produce didactic sequences that empower in-service teachers to support students in using sensors to address environmental problems.

The next section will describe the theoretical framework, including: the context of indoor environmental problems in schools; and the presentation of the Eco-SolvingS Model. The methodology is explained in the succeeding section. In the fourth and fifth sections, the results of the implemented workshop are presented. The conclusion is the closing section.

II. Theorethical Framework

In the last two decades, sensors have been used in schools to sense the environment in diversified activities, namely in inquiry tasks, in which data are collected, analyzed and communicated [9] [10] [11]. Globe [12], TEEMS [13], POLLEN [14], and Eco-Sensors4Health [15] are four examples of projects that are developed through curricular activities to improve scientific inquires, and used sensors to acquire, analyze and make sense of environmental data.

The workshop, analyzed in this paper, was developed on the basis of the Eco-SolvingS Model, which facilitates the creation of didactic sequences that allows teachers to mediate the use of sensors by children to solve environmental school problems.

In this paper, the authors follow the framework of the Eco-Sensors4Health Project, in what concerns the focus on the main indoor environmental school problems [15]. According to the Portuguese National Plan for School Health, the main schools' environmental risks include air and water quality, noise, thermal (dis)comfort, solid wastes, and transportations [16]. The sound pollution and thermal (dis)confort are two specific problems, whose variables can be sensed by human senses, and which can be addressed by children, using affordable and robust sensors.

A. Sound Pollution and Thermal (dis)Confort in Schools

Sound pollution and termal disconfort are important environmental school problems, at a national but also at an international level [16] [17] [18] [19]. These problems can cause concentration difficulties [16] [20], with negative consequences in teaching and learning performance and well-being [19] [21].

Noise can cause hearing damage and has negative effects on speech, communication and learning [21], which are fundamental processes in schools. Noise affect children in a more significant way, since they are often exposed to noise for long periods in schools [21], and their cognitive functions are less automatized than the adults' ones [22].

The thermal conditions of classrooms can affect students' motivation, concentration and performance [20]. This way, learning results are influenced by the thermal conditions of the classroom, where teaching and learning take place [20].

Noise and thermal discomfort are perceived, in a sensorial way, by students in schools, and the assessment of such perceptions, together with students' opinions, can be used to identify the sources of the problems and to address significant solutions [19] [23].

B. *Eco-SolvingS Model*

The Eco-SolvingS Model resulted from the analysis of multiple case studies, based on the use of electronic sensors to solve environmental problems. It is a model to develop didactic sequences, and uses some of the components of the METILOST Model, Model for Effective Teaching of Intended Learning Outcomes in Science and Technology [24], namely: Tasks, Teacher Mediation, Epistemic practices, Resources, and Learning outcomes.

The METILOST model define that [24]: i) tasks are what students are asked to perform, are related to problems, ask for action, induce the development of competences, allow assessment, and can be exemplary for autonomous work; ii) teacher mediation includes the assignment of tasks, and a set of frequent interactions, during and after the performance of tasks; iii) epistemic practices are students' practices that produce knowledge, and have as reference the Science and Technology practices that produce Science and Technology knowledge; iv) resources can be diverse equipment, tools, and facilities, being important to assure that the intended activity take place; v) learning outcomes include knowledge learning, attitude change, and development of competences.

Nevertheless, the Eco-SolvingS Model is more specific than the METILOST Model. While the METILOST Model can be used with diverse teaching methods, the Sensors4Eco-Problems Model is linked to the Problem-based teaching mode. The Eco-SolvingS Model supports the creation of didactic sequences encompassing the following components: i) problem question/s that will inform the students' tasks; ii) the main concepts and processes related to the problem; iii) a set of sensorial tasks related to the main concepts and problems, which ask students to use their multiple senses, together with everyday resources, to explore, and understand such concepts and processes; iv) a set of students' tasks (epistemic practices) that makes use of students senses together with electronic sensors, and registration forms, to acquire and interpret data, fostering the identification and characterization of processes/problems related to the global problem question/s; v) a set of students' tasks to allow decision making to solve the identified problems; vi) teacher mediation; vii) resources, and viii) learning outcomes.

Problem questions are fundamental components of the model, since they guide the diverse set of tasks. Examples of problem questions are: "How does sound level change, when I change my location in school?", "How does sound level change, when I change the class activity?", "How does carbon concentration change, when I change my location in school?", "How does carbon concentration change, when I open the classroom door or window?"

Epistemic practices are "ways of proposing, communicating, evaluating, and legitimizing knowledge claims" [26], as for instance "to observe", "to describe", "to recognize phenomena in context", "to predict", "to acquire new data", "to represent", "to interpret", and "making decisions based on data" [26] [24].

The joint use of students' senses and sensors in sensorial and epistemic practices make it possible [6]: i) to improve students' awareness to sensors' affordances and environmental phenomena; ii) to complement sensory information with sensors' data, this ways improving sensorial observation; iii) to proceed from concrete sensory observation of reality towards more abstract representations, such as sensors' data, through concreteness fading; iv) to enhance observation and description, facilitating better interpretations, predictions, and decisions.

Teacher mediation is related to: i) providing the relevant information to the learning of the main concepts; ii) assigning the tasks, as challenges, making resources available, such as sensors, registration forms, scales… ; iii) perform the needed interactions to scaffold students' activities, such as contextualize the problem; ask questions, stimulating the sharing of ideas and valuing students' thoughts; respect and encourage students' autonomy; synthesize information; guide and support students in the development of tasks; make resources available; conduct formative evaluation [26] [27].

In the Eco-SolvingS Model, the resources include: everyday objects, as bottles or hangers to the sensory exploration of air and sound properties; electronic sensors that are usually linked to mobile devices, such as smartphones; registration forms that support the organization of the acquired data; information tools, such as sound or carbon dioxide scales, which support the interpretation of the acquired data; surveys to assess knowledge and attitudinal outcomes.

Resources, such sensors and registration forms, are epistemic mediators designed to support students in reifying, and making sense of environmental information in knowledge building (epistemic) practices.

III. Methodology

The study here presented adopts a qualitative methodology [28], and investigates the efficacy of a Workshop in supporting in-service teachers to scaffold students in using sensors to address school environmental problems.

The workshop was developed with in-service teachers, supporting them to implement a set of activities in classroom, aiming to identify, explore, and solve school indoor environmental problems. A fundamental resource in the workshop was the Eco-Sensors4Health Toolkit (Eco-Sensors4Health, 2019) – a teacher guide to develop activities that follow the Eco-SolvingS Model. The goals of the workshop were to: (i) recognize the importance of sensors to participation in environmental health; (ii) reflect on the potential of using sensors in science education; (iii) characterize environmental health problems in schools in Portugal; (iv) use sensors to identify environmental health problems at school and in the school environment; (v) reflect critically on case studies, centred on the use of sensors in the 2nd and 3rd cycle of basic education (CBE) to identify and solve environmental health problems; and (vi) conceive, implement and reflect on didactic activities that use sensors in the 2nd and 3rd CBE, to identify and solve environmental health problems in schools, which can be addressed within the scope of the Portuguese Curricular Autonomy and Flexibility Project.

TABLE I. WORKSHOP STRUCTURE AND SCHEDULE

Sessions	Activities
1st session	Information and debate on case studies presented by the trainer. Experimentation of sensors by the teachers.
2nd session	Design of didactic sequences to be implemented with students. Structuring and planning work related to these didactic sequences.
3rd session	Investigative reflection on implemented activities with students focusing on the treatment and interpretation of the collected data.
4th session	Communication and discussion of the results of the implemented didactic sequences.

A. *Workshop Structure and Content*

The workshop was developed along four presential sessions (see Table 1), lasting three hours each. The workshop also involved autonomous work, in which the participants developed and implemented the didactic sequences with the students, scaffolding them in identifying environmental problems, and in proposing solutions.

The presential sessions were designed in order to establish a strong connection between the theoretical ideas and the teachers' practices, using case studies, based on the Eco-SolvingS Model that was reified in the Eco-Sensors4Health Toolkit. This Toolkit offer structured and illustrated examples of problem question/s, main concepts and processes related to the problem, resources, sensorial tasks, epistemic practices, and learning outcomes, in what concerns sound pollution, air pollution, and thermal discomfort proble.

The diverse sensors were explored, and the in course didactic sequences were shared, with the support of the three trainers (two of them are the authors of this paper).

B. *Data Collection and Analysis*

Data collection used the techniques of participant observation and documents collection (group reports and individual reflections). The participant observation of the presential sessions was driven by the authors and was complemented by field notes. The activities were described, interpreted and reflected by in-service teachers in written reports (WR). A content analysis [29] of these reports and reflections was carried out.

IV. WORKSHOP RESULTS

At the beginning of the workshop, there were 11 participants, 11 in-service teachers of several schools that were teaching different disciplines of different grades. However, one of the participants gave up, due to difficulties of scheduling the didactic sequence with the students. The 10 participants organised themselves collaboratively in four according to the school they belonged (Table II).

TABLE II. GROUPS OF IN-SERVICE TEACHERS

Group	Women	Men
1	2	0
2	2	0
3	3	0
4	1	2

A. *Groups' Activities*

Three of the four groups selected the sound pollution problem. This option relates to their sensibility to the problem in the sense that "didactic-pedagogical processes depend on ideal sound conditions to be able to be exercised with minimal quality" (WR, Group 2, p. 1). The students of grades 5, 6 and 8 measured the sound level in several school locations, using Decibel X app (Fig. 1). Group 4 chose thermal (dis)comfort problem to work with 6th graders who measured the temperature using sensors (probes), in several days of January, hours and school locations. The students also answered a survey on thermal comfort sensations.

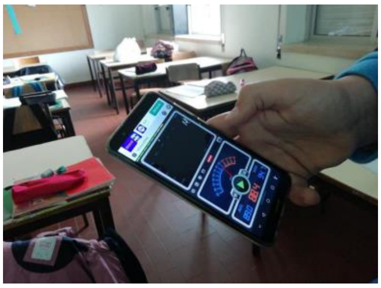

Fig. 1. Collecting data with the smartphone Decibel X app (WR, Group 1, p. 7).

Afterwards, all students analyzed and interpreted data collected, using registration forms, adapted from the Eco-Sensord4Health Toolkit. Table III presents groups' activities.

TABLE III. ACTIVITIES OF THE FOUR GROUPS OF IN-SERVICE TEACHERS

Group	Problem	Sensor	Sampling Locations	School Discipline
1	Sound pollution	Decibel X app with mobile phone	Classroom Courtyard Mini Golf Course Gym Refectory Library Playroom Students room	Mathematics Natural Sciences
2	Sound pollution	Decibel X app with mobile phone	Classroom Bar Courtyard	Mathematics Physics Chemistry
3	Sound pollution	Decibel X app with mobile phone	Classroom Refectory Lobby/garden Hallway Bar Ping pong table	Mathematics Physico-Chemistry Natural Sciences Citizenship and Development

Group	Problem	Sensor	Sampling Locations	School Discipline
4	Thermal (dis) comfort	Temperature probes	Courtyard Hallway Bar Refectory Classroom Teachers Room Tap water Library Students room Girls WC Concierge	Mathematics Natural Sciences

B. Exploration and Solution of the Identified Problems

Concerning the sound pollution problem, the students identified some locations as presenting harmful sound levels (mean superior to 80 dB) such as the refectory (Fig. 2), the library, the hallway and the classroom (lesson final), being that these locations registered maximum values considered as dangerous (superior to 100 dB) (WR, Group 1; WR, Group 2; WR, Group 3).

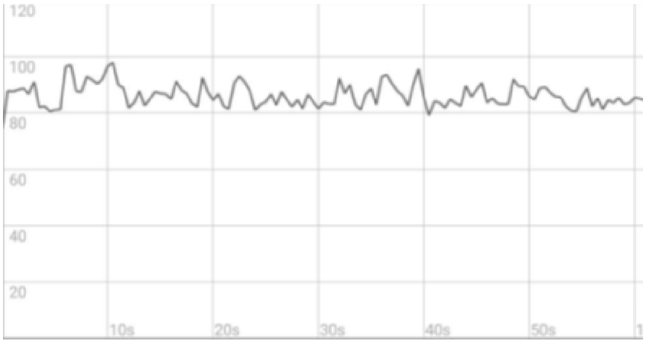

Fig. 2. Sound level graphic in the refectory (WR, Group 2).

The students proposed several solutions to the sound pollution problem, which are related to: (i) behavior changes, such as "speak quietly", "don't shout when leaving" (WR, Group 3, p. 18), "put up posters in refectory to alert to sound level" (WR, Group 1); "create relaxation sessions at school" (WR, Group 1), "avoid using music speakers at a high volume" (WR, Group 2); and (ii) intervention measures, such as "line the walls with insulator materials", "in the library we could put cork on the walls and ceiling and put giant origami hanging from the ceiling", "hang more exhibition work this to muffle the sound", "to have cork sculptures and decorate the walls and ceiling with egg cartons" (WR, Group 3).

With regard to thermal (dis)comfort problem, according to data from the survey, "it was found that more than 50% of students felt uncomfortable and symptomatically cold" (WR, Group 4). The temperature measured in the school's outdoor space and in the classrooms varied between 13ºC and 20ºC. The mean temperature was 16.8ºC (WR, Group 4).

About half of the students proposed solutions to thermal (dis)comfort problem, such as to install conditioned air or to use oil heaters in classrooms, hallways and bar. The energy consumption of these solutions were not discussed. Two students reported that simple glasses and PVC blinds are not very good for keeping warm. Other students suggested insulation of walls with cork (WR, Group 4) or "I think we could arrange lamps of various colors, to give us a feeling of hot or cold" (WR, Group 4).

C. Constraints and Facilitators

In the first session of the workshop, all the teachers shared that they had no prior knowledge or experience regarding the use of electronic sensors for educational purposes. Thus, it was required a high commitment and dedication from them to achieve the workshop's objectives. On one hand, the small number of sessions in the workshop required the in-service teachers to concentrate highly on the work developed in the sessions, taking advantage, efficiently and effectively, of all sessions' time and trainers' support. On the other hand, the workshop's autonomous work schedule coincided with the interval between semesters in the schools of some teachers; so the pressure on the fulfilment of the curricular programs at the end of the semester made it difficult to deepen the didactic intervention. Group 2 (WR) referred the difficulty of students performing the pretended work, due to lack of active learning habits. All of these challenges were overcome by the participants in the workshop. The teachers decided to return to the project intervention in the following semester. Group 3 also decided to involve the school Direction and extend the project to elementary classes, in the scope of an ongoing project called "To do Science", contributing to the awareness of the sound pollution problem to a wider school community.

There are multiple factors that facilitated the achievement of the workshop's objectives. One of them was the collaborative work between the teachers and also between students.

> As trainees, we feel that the collaborative and participatory work of everyone, both students and teachers, or others is an aspect of great relevance. Since we are from such different areas of knowledge, we used the different perspectives to, in a participatory way, conceive a project that is in everyone's interest, that concerns everyone and, with everyone's contribution, it can grow even more. (WR, Group 3)

Another facilitator was the interdisciplinary approach (WR, Group 1) that contributes to citizenship education, being coherent with the recent curriculum guidelines consigned in the Curricular Autonomy and Flexibility Project, as referred by Group 3:

> The articulation of several disciplines/knowledge, generally considered isolated, gives students a global view of knowledge and allows them to give meaning and intention to knowledge and to conceive more meaningful learning. They were active and non-passive agents in the process of building their own learning, allowing learning for life. (WR, Group 3)

The use of the mobile phone in a didactic situation was a facilitator to the achievement of the workshop's goals (WR, Groups 2 and 3). Nowadays, the mobile phone is a device owned by all students. Despite its recurring use to communicate, it can be explored with an educational proposal. Decibel X is a free and interactive app which is easy to access and read/interpret, allowing students to be aware of a problem that affects their health and, in an informed, creative and conscious way to adopt behaviours and attitudes that promote their health and the environment". Through the use of this application, "it is possible to motivate students and involve them in the construction of learning" (WR, Group 3), promoting their responsibility, autonomy and the possibility of working collaboratively.

All workshop's participants did a very positive global evaluation of the implemented activities, as illustrated in the following transcript:

> Overall, this project was considered very interesting, taking students (at the same time that they experience and develop contextualized essential curricular learning), to be agents in their school environment, identifying problems and being part of the solution. (WR, Group 2)

V. Conclusion

This paper described a workshop designed and developed to empower in-service teachers to scaffold students in using senses and sensors to identify, explore, and solve school environmental problems.

The workshop is structured in four presential sessions (4x3h) with intercalated autonomous work (12h). The first session includes: i) the discussion of a set of case studies on the use of senses and sensors to address and solve school environmental problems; ii) the exploration, by in-service teachers, of the electronic sensors to acquire environmental data. In the second session, the four groups of the in-service teachers, supervised by a trainer, designed the didactic sequences to be implemented with the teachers. The problem chosen by three groups was sound pollution, while another group chose thermal (dis)comfort.

The designed didactic sequences were based in the Eco-SolvingS Model, reified in the Eco-Sensors4Health Toolkit, and included: i) tasks to familiarize students with the main concepts and processes related to the problem; ii) the use of senses and sensors by students to acquire, analyse, and interpret environmental data, in knowledge creation (epistemic) practices, with teacher mediation; iii) the students suggestions to solve the identified and analysed school environmental problems. The electronic sensors, and the Eco-Sensors4Health Toolkit's registration forms, and scales, were used by students as epistemic mediators that supported the acquisition, signification, and application of environmental information.

During the didactic sequences, students were able to characterize each environmental problem, creating knowledge in what concerns the values of sound level/temperature in different school locations, and the harmful and dangerous situations. The students suggested solutions to such situations. Some of the suggested solutions were valuable and easy to implement, while others were too energy consuming. Future didactic sequences should scaffold students in finding more sustainable solutions.

In the third session, the focus was on the treatment and interpretation of the data collected by students in the implemented activities, making possible an investigative reflection, supervised by the trainer. In the fourth session, the implemented didactic sequences were presented and discussed.

In their Working Reports, the in-service teachers emphasized, as success factors: i) the collaboration between teachers; ii) the collaboration between students; iii) the interdisciplinary approach with students, with a focus on Mathematics and on Physical and Natural Sciences; iv) the use of an app and of mobile phones as educational resources; and v) the active role of students as environmental agents.

The trainers positively highlighted the developed competences of the in-service teachers and their students, the hard-autonomous work of the in-service teachers, and the efficacy of the 12 presential workshop hours in attaining the defined objectives.

This way, the workshop was successfully implemented with ten in-service teachers, validating this simple, and short strategy to empower in-service teachers to support students in using sensors to address environmental problems.

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