Eco-Sensors4Health Toolkit: Scaffolding Children Participation in Schools' Environmental Health

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***Abstract*— The research presented in this paper aims at improving health education in primary schools, supporting the use of environmental sensors in environmental health problem solving. A research based design approach was adopted to develop a toolkit, aiming at supporting teachers in scaffolding children's participation to improve their schools' environmental health. The toolkit will facilitate children's activities that make use of eco-sensors to identify and explore environmental health problems, as well as to suggest local solutions. Sound pollution, air pollution, and lack of thermal comfort are three central problems in Portuguese primary schools' environmental health. The data acquired by children through the use of sensors will inform and validate children's decisions to improve schools' environmental health and will be made available to other schools in a collaborative platform. The design of the toolkit was situated in Portuguese primary schools. It is an iterative design process, based on teaching and learning interventions with primary school children, in-service teachers, and students of a teacher education graduation, all in their natural and complex settings. Those interventions confirmed the practicality and effectiveness of the planned activities, and, together with the results of previous projects, informed the content and form of the designed toolkit that will be used in diverse schools to improve schools' environmental health.**

Keywords – environmental health; eco-sensors; children; participation.

I. INTRODUCTION

A. Thematic, research goals, and context

Primary schools' environmental health is a current and relevant subject in Portugal, since there are several identified problems that affect school communities' well-being, and that consequently can affect the learning processes [1] – [3]. Sound pollution, air pollution, and lack of thermal comfort are three central problems in Portuguese primary schools' environmental health [1] – [3]. These problems are three important dimensions of indoor environmental quality [2] that, together or separately, create concentration difficulties [1], and consequently affect students' and teachers' performance [2].

Eco-Sensors4Health is a research project whose main goal is to improve environmental health in Portuguese primary schools, through the use of eco-sensors by children. Eco-sensors are devices that detect and measure environmental factors and elements, such as temperature, sound, and carbon dioxide. Eco-sensors communicate those measurements to other electronic devices, which transform the sensors' signals into multiple representations, such as digits, tables, and graphs.

In the Eco-Sensors4Health project, children's participation to improve schools' environmental health includes: i) the use of eco-sensors to identify and explore problems; ii) the suggestion of local solutions that will also be validated with the use of eco-sensors. This way, children's participation in the Eco-Sensors4Health project will be developed in the context of primary school curricular activities, using techniques of the scientific inquiry strategy.

The data acquired by children with the eco-sensors will be made available on the Eco-Sensors4Health collaborative platform, allowing multiple queries and comparisons of environmental health conditions in different schools and circumstances.

The research presented in this paper is part of the Eco-Sensors4Health project. It aims at improving health education in primary schools, through the creation of a toolkit, using a research based design approach, to support primary school teachers in scaffolding children's participation in schools' environmental health.

B. Goals of the Eco-Sensors4Health toolkit

The Eco-Sensors4Health toolkit will support monitoring and intervention in environmental health, enabling children to eco-innovate to create healthier environments in schools. Since it is widely recognized that mediation, namely in what concerns scaffolding, is fundamental in problem solving and scientific inquiry activities [4] [5], this toolkit is targeted to primary school teachers, to facilitate the implementation of children's activities. It will offer support to teachers in

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scaffolding children in the use of eco-sensors to identify and understand school environmental health problems, allowing the suggestion of solutions to such problems.

The specific goals of the Eco-Sensors4Health toolkit are:

- To make eco-sensors and tablets available to teachers and children in order to support the acquisition of schools' environmental health data;
- To offer suggestions and support documents for problem solving and scientific inquiry activities. These suggestions and documents should also make it easier for teachers and children to enter data in the Eco-Sensors4Health platform;
- To make pre and posttests available to teachers (questionnaires to support learning assessment).

Following this introduction (Section 1), the theoretical background, and the related work are presented in Section 2. Then, in Section 3, the methodology, and toolkit design process are described. The subsequent sections are the systematization of the lessons learned and of the conclusions (Section 4).

II. THEORETICAL BACKGROUND AND RELATED WORK

The design and development of the Eco-Sensors4Health toolkit represent a development study, in the context of an educational design research, since it aims at developing research-based solutions for complex problems in educational practice [6]. This section reports the main dimensions of the first phase of this development study: the review of literature.

The relevance of monitoring and intervention in schools' environmental health is highlighted by diverse authors, emphasizing that:

- The school's environment can affect the health of the school community [7], with children being particularly vulnerable to environmental health risks, such as air pollution [8];

- Environmental health in elementary schools is often inadequate, especially when financial resources are scarce, and the ventilation is insufficient with classroom temperatures reaching values out of the recommended range, and carbon dioxide levels exceeding the safety level [9] [10].

The design and development of the Eco-Sensors4Health toolkit are grounded in the recognition of the importance of the participation of children in schools' environmental health, since the participation of students in health promotion has demonstrated positive personal effects on students, as well as positive effects on the school [11].

The participation of children in schools' environmental health, using problem solving and scientific inquiry strategies, needs scaffolding, since children need support (guiding and resources [12]) to succeed in such activities [5]. In this context, scaffolding should integrate concreteness fading over time, and transfer of responsibility to students [13]. In concreteness fading, the concreteness of the representations successively decreases to allow students to understand abstract representations that are connected to the concrete situation that is represented [14]. Following this scaffolding guiding principles, in the Eco-Sensors4Health toolkit, activities are sequenced from sensory exploratory activities to data acquisition in inquiry and problem solving activities. Since observation tables and experiment plans can make scientific strategies visible and transfer responsibility to students, the Eco-Sensors4Health toolkit will include such tables and plans, together with sensors, as manipulable mediators [5] [12] – [15].

Electronic sensors, together with data-loggers, can be cognitive tools in scaffolding, facilitating the complex task of monitoring environmental variables, and improving the level of children's scientific reasoning [4]. Diverse related projects evidenced the practicality of the use of sensors by elementary school children in environmental and health sense making activities [16]. In the SchoolSenses@Internet project, children used mobile phones built-in sensors, to create multiple sensory views of environmental quality, portraying and assessing the schoolyard environment [17]. In the USense2Learn project, children used mobile phones built-in sensors together with external weather sensors to the mobile creation of georeferenced multisensory information, intertwining quantitative and qualitative visions of the schoolyard, and sharing such information with other classrooms, using Google Earth [18]. Also, with a context aware approach, the SENSE project engaged elementary school students in the use of environmental sensors to collect, analyse, reflect, and share authentic air pollution data [19].

In order to support elementary school teachers and children, the TEEMSS2 [20] and the POLLEN [21] projects created documentation that describes activities in which children use sensors to explore the environment and its multiple representations.

The scaffolding of the use of sensors by children, in the context of scientific inquiry and problem solving activities, should address the following requisites: i) an appropriate balance of automated technology and user control [22]; ii) contextualization of data acquisition [19]. Consequently, the Eco-Sensors4Health toolkit adopts: i) a manual approach to data acquisition (children will register sensors' data manually in registration forms and in the platform), following the affordances and challenges identified in previous studies and projects [18] [21]; ii) the manual registration of time and local data in the registration forms; iii) and the production of photos/audios/videos and captions to contextualize the acquired data [19].

III. THE TOOLKIT DESIGN PROCESS

The design process of the Eco-Sensors4Health toolkit is iterative, based on teaching and learning interventions, situated and implemented in real world contexts (Portuguese primary schools). The research team includes primary school teachers, together with experts in education, in environmental health, and in information and communication technologies.

The first version of the Eco-Sensors4Health toolkit is based on the conceptual framework, drafted in the previous section. To acquire empirical evidences of the practicality and effectiveness of this version, three case studies were developed with different participants: primary school children, pre-service teachers, and in-service teachers.

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A. *Structure of the first version of the toolkit*

Following the three central problems of the Portuguese schools' environmental health [1], the specific goals presented in the introduction, and the conceptual framework drafted in the previous section, the main components of the Eco-Sensors4Health toolkit are:

- A set of tablets, iOS or Android, with an app to allow the sensors data logging;
- A set of sensors: Sound sensor (tablets have in-built sound sensors); Carbon dioxide sensor (PASPORT Carbon Dioxide Gas Sensor - PS-2110); Temperature and humidity sensor (PASPORT Weather Anemometer Sensor - PS-2174);
- Guidelines for children's activities on schools' environmental health, with the following structure: i) introduction to main concepts; ii) exploring with the senses (research questions; tasks; questions for reflection); iii) measuring and interpreting (research questions; tasks; questions for reflection); iv) suggesting solutions;
- The registration forms and collaborative documents (experiment plans) to support children's activities on schools' environmental health;
- The children's pre and posttests (with questions in the following categories: Knowledge, Environmental and Health Awareness, Attitudes, Personal Investment and Responsibility, Perception of the Physical Environment).

B. *Teaching and learning interventions with primary school children*

The empirical testing was developed with primary school classes in the Ciência Viva School (CVS), a science museum school in Lisbon. Each class stays in CVS for a week to develop a technology enhanced experiential science learning program. This program is mediated by the CVS teachers/researchers, whereas the school teachers of the classes follow all the process. CVS was the context chosen by the Eco-Sensors4Health project to develop empirical testing, since it made it possible to develop teaching interventions with two visiting classes in each week (60 classes each year).

Two research questions were formulated: i) Do children perform epistemic practices in a scientific inquiry that makes use of the Eco-Sensors4Health toolkit? ii) Can the Eco-Sensors4Health toolkit be used in a scientific inquiry to support children in identifying school's environmental health problems and suggest solutions?

Using the toolkit, two different teaching and learning interventions were successfully implemented during the school year of 2017-2018: the "Sound Pollution", and the "Air Pollution" interventions. The implementation of the "Sound Pollution" intervention in two classes was observed and audio-recorded, while the "Air Pollution" intervention was observed and audio-recorded with another class.

Epistemic practices (EP) are practices that "construct scientific knowledge, having as reference the scientific practices in the context of scientific production" [23]. The audio-recordings allowed the identification of diverse types of EP, by project researchers with experience in such identification. Some examples of the EP, performed by children during the measurement and interpretation tasks, are presented in Table I. These EP were facilitated by teacher mediation (performed by teachers/researchers) [23], and guided by research questions, such as: "How does carbon dioxide concentration change when we change our location in the school environment?", "How does carbon dioxide concentration change when we open the door/window of the classroom?", "How does sound level change when we change classroom activities?", or "How does sound level change when we change our location in the school environment?" Likewise, it was possible to identify these same types of EP during the sensory exploration of sound and air tasks, which were also guided by teacher mediation, and research questions (e.g., "Can we observe the sound waves?" or "Can we catch the air?").

TABLE I. EXAMPLES OF EPISTEMIC PRACTICES

Epistemic practices	**Examples**
Describe	After opening the door of the classroom, children read the values of carbon dioxide concentrations displayed by the sensor and reported the decreasing in time (1650 ppm, 1480 ppm, 1223 ppm, 913 ppm, 580 ppm…)
Forecast	When asked if the values that the sound sensor will register will be higher while singing the Happy Birthday or while clapping, children gave different answers, justifying their estimations.
Use sensors	Children used the carbon dioxide sensor near the road, and measured at first a concentration of 450 ppm, and afterwards a concentration of 5000 ppm, after a car passed by.
Interpret	In the sequence of the carbon dioxide data acquisition near the road, a child verbalized that when a car passes by, the values increase.
Organize information	Children registered the data acquired with the sensor in the registration form.
Relate	When asked why were the measured values of carbon dioxide concentrations lower in the garden, a child answered that it was because there are more plants in the garden.

In both "Sound Pollution" and "Air Pollution" interventions, all children were able to fill the registration forms with the data acquired with sensors. Figure 1 shows the "Air Pollution" registration form, filled by a child. It is possible to observe the carbon dioxide concentrations in two days (columns), in the empty classroom, during the class, after opening the classroom door, and in the exhaled air (lines). It is also possible to observe the concentrations outdoors, at the Pavilion door, in the garden and near the road. In this context, after gathering the sensors' data in different conditions, the great majority of children were able to make sense of the data, suggesting ways of renewing the air in the classroom: opening the door or the window (last sentence completed on the form). In what concerns "Sound Pollution" intervention, children were also able to gather and register sensors' data in different conditions, during different activities. In one class of the "Sound Pollution" intervention, children suggested ways to improve hearing protection, but in the other class, children only repeated the sentence suggested by the teacher/researcher. This result will inform teachers/researchers to avoid this kind of influence.

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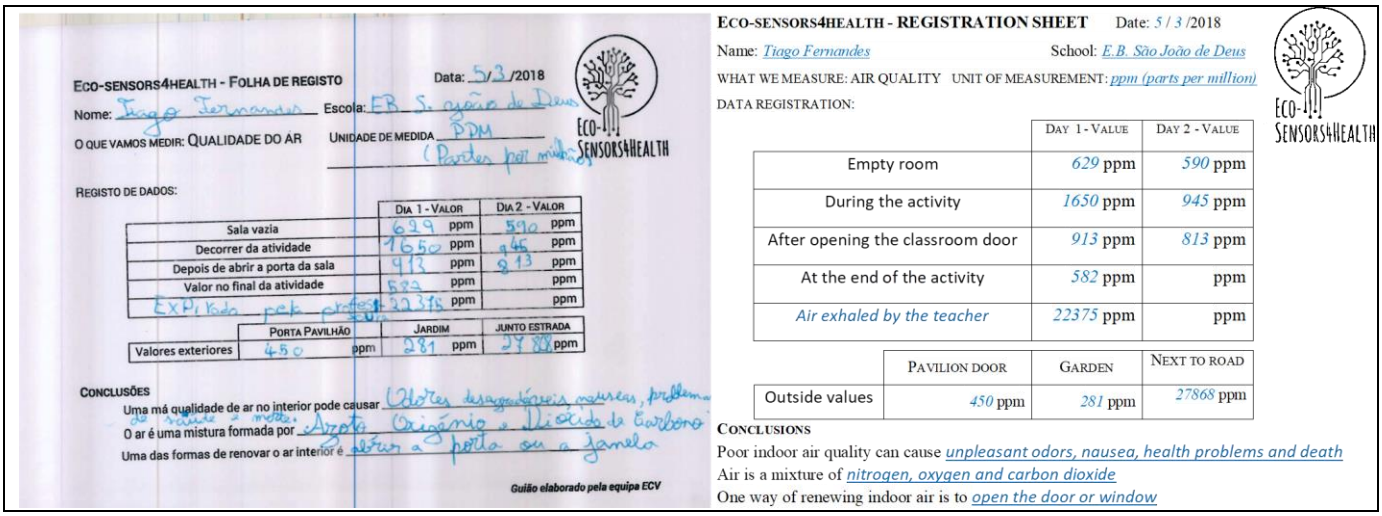

ECO-SENSORS4HEALTH - FOLHA DE REGISTO Data: 5/3/2018
Nome: Tiago Fernandes Escola: EB S. João de Deus
O QUE VAMOS MEDIR: QUALIDADE DO AR UNIDADE DE MEDIDA: PPM (Partes por milhão)
REGISTO DE DADOS:

	Dia 1 - Valor	Dia 2 - Valor
Sala vazia	629 ppm	590 ppm
Decorrer da atividade	1650 ppm	945 ppm
Depois de abrir a porta da sala	913 ppm	813 ppm
Valor no final da atividade	582 ppm	ppm
Expirada pela professora	22375 ppm	ppm

	Porta Pavilhão	Jardim	Junto estrada
Valores exteriores	450 ppm	281 ppm	27880 ppm

CONCLUSÕES
Uma má qualidade de ar no interior pode causar Odores desagradáveis, naúseas, problemas de saúde e morte
O ar é uma mistura formada por Azoto, Oxigénio e Dióxido de Carbono
Uma das formas de renovar o ar interior é abrir a porta ou a janela
Guião elaborado pela equipa ECV

ECO-SENSORS4HEALTH - REGISTRATION SHEET Date: 5 / 3 /2018
Name: Tiago Fernandes School: E.B. São João de Deus
WHAT WE MEASURE: AIR QUALITY UNIT OF MEASUREMENT: ppm (parts per million)
DATA REGISTRATION:

	Day 1 - Value	Day 2 - Value
Empty room	629 ppm	590 ppm
During the activity	1650 ppm	945 ppm
After opening the classroom door	913 ppm	813 ppm
At the end of the activity	582 ppm	ppm
Air exhaled by the teacher	22375 ppm	ppm

	Pavilion door	Garden	Next to road
Outside values	450 ppm	281 ppm	27868 ppm

CONCLUSIONS
Poor indoor air quality can cause unpleasant odors, nausea, health problems and death
Air is a mixture of nitrogen, oxygen and carbon dioxide
One way of renewing indoor air is to open the door or window

Figure 1. Close view of an "Air Pollution" registration form filled out by a child (on the left, the original filled registration form; on the right, the translation into English)

In spite of the efforts of the teachers/researchers to avoid the influence of the school teachers of the classes in children's answers, these classes' teachers helped some of the children in answering some of the questions, especially in the pretest. This influence was noticed but could not be quantified.

It is noteworthy that in both interventions, and in both pre and posttests, children's answers to 'Environmental and Health Awareness' questions were very positive. Children's answers to 'Knowledge' questions related to the topic of each intervention improved after the respective intervention (see Table II). For instance, in the "Sound pollution" intervention, children's answers to the question "A strong sound level is harmful to health?" had a significant difference (improvement) between the pre and posttest (Wilcoxon= - 2.639, $p<.05$). However, in the "Air pollution" intervention, children's answers to the same question did not have a significant difference (Wilcoxon= -0.312, $p>.05$). Furthermore, in the "Air pollution" intervention, children's answers to the question "To ventilate the classroom is important for health?" had a significant difference (improvement) between the pre and posttest (Wilcoxon= - 2.627, $p<.05$). However, in the "Sound pollution" intervention, children's answers to the same question did not have a significant difference (Wilcoxon= -0.550, $p>.05$).

TABLE II. STATISTIC DATA OF 'KNOWLEDGE' QUESTIONS RELATED TO THE TOPIC OF EACH INTERVENTION

"Sound pollution" intervention			
Question	**Average**		**Wilcoxon**
	Pre	**Post**	
"A strong sound level is harmful to health?"	3.34	4.29	-2.639 $p<.05$
"Air pollution" intervention			
Question	**Average**		**Wilcoxon**
	Pre	**Post**	
"To ventilate the classroom is important for health?"	4.15	4.67	-2.627 $p<.05$

Unexpectedly, the children of the classes that participated in the "Sound Pollution" intervention did not improve the answers to the question "When we are silent, we do not hear sounds in the classroom?", from pre to posttests. It will be relevant to verify if those results are due to the negative formulation of the sentence, since children answered correctly to equivalent questions in debates during the intervention.

Several teachers of the participating classes continued to support children in monitoring and solving noise problems in their own school. Some teachers asked for support in implementing that intervention to the whole school.

C. *Teaching and learning interventions with students of a teacher education graduation*

To assess the perceived utility of sensors to study schools' environmental health problems, teaching and learning interventions were performed in a Statistics course and in a Biology course of a teacher education graduation school. The selection of these courses was based on two criteria: i) adequate course syllabus; ii) large number of participating students.

The intervention in the Statistics course aimed at understanding the perceived pertinence of the use of the sensors of mobile phones to acquire sound level data in diverse locations of the school, and of the use of Excel to organize and process the data. The 92 (100%) participants showed no technical difficulties in using the app of the mobile phones to acquire sound level data, nor in making sense of the acquired data. 82% of the participants found the activity pertinent, mainly (36%) because of the topic (sound), and also because of the opportunity to consolidate statistics knowledge (20%).

The intervention in the Biology course was developed with the same participants working in groups and aimed at understanding the perceived pertinence of the use of the carbon dioxide sensor to study the exchanges of that gas between the atmosphere and living beings.

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The content analysis of the groups' reports allowed the formative assessment of the perceived pertinence of the intervention. 84% of the groups reported that the intervention contributed to their knowledge of scientific concepts and phenomena, while 34% mentioned that the intervention was pertinent because it contributed to the development of didactic competences (use of the sensors with their future students). 84% of the groups wrote about the pertinence of the use of sensors with children, emphasizing the enhancement of the learning process, namely in what concerns knowledge acquisition (69%), and the increase of motivation (28%). Nonetheless, the analysis of the reports showed students' difficulties in learning complex phenomena, such as carbon dioxide exchanges, respiration and photosynthesis.

D. Teaching and learning interventions with in-service teachers

A b-learning workshop with in-service teachers was developed by the research team to assess the utility and practicality of the Eco-Sensors4Health toolkit. The following research questions were formulated: Can teachers use the Eco-Sensors4Health toolkit to develop teaching and learning interventions, in which children: i) identify school's environmental health problems? ii) Suggest solutions to the identified problems?

Nine teachers participated in the workshop. Five teachers implemented the interventions individually and four worked in two groups. However, only six interventions were presented by eight teachers: four interventions were centered on temperature, while two were centered on noise.

Teachers showed evidences that in all the implemented interventions, children (from 2nd to 5th grade): i) started by the sensory exploration of temperature/sound; ii) used sensors to measure temperature/sound in the schools' environment; iii) identified noise and thermal discomfort problems in specific locations and activities; iv) suggest solutions to the identified problems.

Using the sensors and temperature/sound scales provided in the toolkit, the children recognized harmful sound levels (e.g., 83 dB in the canteen at lunch time) and non-comfort temperatures (e.g., 26.4ºC in the classroom). They were able to suggest solutions, such as "keep the classroom open and ventilated", "use light shutters", "use the sound sensor to be aware of the sound level", and "play 'silence games' in the canteen".

All the teachers expressed the will to continue the interventions in their classes.

IV. LESSONS LEARNED AND CONCLUSIONS

The Eco-Sensors4Health toolkit aims at supporting teachers in scaffolding elementary school children participation in schools' environmental health. It was developed using a research based design approach and, specifically, a development study [6]. The first version of the toolkit was based on the review of the literature, and included: tablets, sensors, guidelines for environmental health scientific inquiry activities, registration forms and experiment plans, pre and posttests. The empirical testing [6] was carried out in three case studies that were focused on the formative assessment of teaching and learning interventions, guided by the toolkit first version.

Both children and teacher participants of all the three cases showed no technical difficulties in using the sensors and tablets to perform the toolkit activities, making sense of the acquired data, while performing the tasks. In all the three cases, all the participants implemented the toolkit activities in an engaged way, and showed motivation to future similar activities, namely in what concerns monitoring and solving environmental problems in their schools.

In the case study developed with primary school children, the practicality and effectiveness of the toolkit were illustrated by children's epistemic practices, by suggestions to solve the identified problems, and by the answers to the tests. Some results were highlighted, in line with previous research: i) the importance of the research questions included in the toolkit guidelines in eliciting epistemic practices [13]; ii) the effectiveness of the registration forms in scaffolding the sense making in the use of sensors [15]; iii) the role of the reflection questions of the toolkit guidelines in scaffolding children's solutions to the identified problems; iv) the need to improve some questions of the pre and posttests, and to prevent the influence of classes' teachers in children's answers to such tests.

In the second case study, the students of the teacher education school acknowledged the pertinence of the activities (suggested in the toolkit), not only to their own content learning, but also as strategies to use with their future students.

In the third case study, the in-service teachers used the guidelines and tools of the toolkit to successfully scaffold primary school children in identifying, exploring, and suggesting solutions to some schools' environmental health problems.

Following the validation of the guidelines and tools of the toolkit first version, future work will include a refinement of the Eco-Sensors4Health toolkit, based on the lessons learned in the empirical testing, and its use, together with the collaborative platform, to improve health education in diverse elementary schools. The final version of the Eco-Sensors4Health toolkit will be made available on the project's website and will be used to support teacher mediation in environmental health scientific inquiry processes, which will allow children to identify, explore and solve problems in their schools.

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REFERENCES

[1] G. von Amann (Coord.), School health program 2015. [Programa de saúde escolar 2015]. Lisboa: DGS, 2015.

[2] L. D. Pereira, D. Raimondo, S. P. Corgnati, and M. Gameiro da Silva, "Assessment of indoor air quality and thermal

comfort in Portuguese secondary classrooms: methodology and results," Building and Environment, pp. 69-80, 2014.

[3] J. Madureira, et al., "Children's health and indoor air quality in primary schools and homes in Portugal: Study design," Journal of Toxicology and Environmental Health, Part A, vol. 78, pp. 915–930, 2015.

[4] B. J. Reiser, "Scaffolding complex learning: the mechanisms of structuring and problematizing student work," Journal of the Learning Sciences, vol. 13, n. 3, pp. 273-304, 2004.

[5] C. Quintana, et al., "A scaffolding design framework for software to support science inquiry," The Journal of the Learning Sciences, vol. 13, n. 3, pp. 337-386, 2004.

[6] T. Plomp, "Educational design research: an introduction," in. Educational design research - part a: an introduction, Plomp, T. and Nieveen, N. , Eds. Enschede, the Netherlands: Netherlands Institute for Curriculum Development (SLO), pp. 10 – 51, 2013.

[7] J. Wargo, The physical school environment: an essential component of a health-promoting school, Geneva, Switzerland: World Health Organization, pp. 1–51, 2004.

[8] World Health Organization (WHO) Children's environmental health, 2018. Available at http://www.who.int/ceh/en/ [retrieved July, 2018].

[9] P. Wargocki and N. A. Da Silva, "Use of visual CO2 feedback as a retrofit solution for improving classroom air quality," Indoor Air, vol. 25, n. 1, 105-14, 2015.

[10] A. M. C. Ferreira, Schools' indoor air quality and children's health. [Qualidade do ar interior em escolas e saúde das crianças]. PhD Dissertation. Coimbra: Universidade de Coimbra, 2014.

[11] U. Griebler, D. Rojatz, V. Simovska, and R. Forster, "Effects of student participation in school health promotion: a systematic review," Health Promotion International, vol. 32, pp.195–206, 2017.

[12] B. R. Belland, C. M. Kim, and M. J. Hannafin, "A framework for designing scaffolds that improve motivation and cognition," Educational Psychologist, vol. 48, n. 4, pp.243–270, 2013.

[13] J. Van de Pol, M. Volman, and J. Beishuizen, "Scaffolding in teacher–student interaction: a decade of research," Educational Psychology Review, vol. 22, n. 3, pp. 271–296, 2010.

[14] R. Goldstone and J. Son, "The transfer of scientific principles using concrete and idealized simulations," Journal of the Learning Sciences, vol. 14, n. 1, pp. 69-110, 2005.

[15] M. J. Silva, J.B. Lopes, and A. A. Silva, "Using senses and sensors in the environment to develop abstract thinking – a theoretical and instrumental framework," Problems of Education in the 21st century, vol. 53, pp. 99-119, 2013.

[16] Y. Rogers, K. Connelly, W. Hazlewood, and L. Tedesco, "Enhancing learning: a study of how mobile devices can facilitate sense making," Personal and Ubiquitous Computing, vol. 14, n.2, pp.111-124, 2010.

[17] M. J. Silva, et al., "Adding space and senses to mobile world exploration," in Mobile Technology for Children, A. Druin (ed.), pp. 147-170. Boston: Morgan Kaufmann, 2009.

[18] M. J. Silva, J. C. Lopes, P. M. Silva, and M. J. Marcelino, "Sensing the schoolyard: using senses and sensors to assess georeferenced environmental dimensions," ACM 1st International Conference and Exhibition on Computing for Geospatial Research & Application, ACM, 2010.

[19] D. S. Fraser, et al.. "The SENSE project: a context-inclusive approach to studying environmental science within and across schools," Proceeding of CSCL'05, edited by International Society of the Learning Sciences, pp.155–9. Taiwan: Taipei, 2005.

[20] A. Zucker, R. Tinker, C. Staudt, A. Mansfield and S. Metcalf, "Increasing science learning in grades 3-8 using computers and probes: findings from the TEEMSS II project," Proceedings of the NARST 2007 Annual Meeting, 2007.

[21] E. van den Berg, F. Schweickert, and R. van den Berg, "Science, sensors and graphs in primary schools", Proceedings of the GIREP Conference 2010, pp. 1-9, 2010.

[22] S. Ananthanarayan, K. Siek, and M. Eisenberg "A craft approach to health awareness in children," Proceedings of the 2016 ACM Conference on Designing Interactive Systems, pp. 724-735, 2016.

[23] J. B. Lopes, J. P. Cravino, M. Branco, E. Saraiva, and A. A. Silva, "Mediation of student learning: dimensions and evidences in science teaching," PEC 2008—Problems of Education in the 21st Century, vol. 9, n. 9, pp.42–52, 2008.

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