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Ambient intelligence for smart classrooms: schools perception of the need to regulate environmental conditions

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Resumen
La inteligencia ambiental (AmI) utilizada en las aulas escolares implica la integración e interacción de *software*, *hardware* y redes de sensores para empoderar a estudiantes y profesorado a través de un entorno digitalizado sensible al contexto, adaptativo y responsivo. Una de las aplicaciones de la AmI es monitorear y regular las condiciones ambientales (iluminación, acústica y calidad del aire). Este trabajo tuvo como objetivo ofrecer una visión integral sobre la necesidad de regular tales condiciones en las aulas inteligentes mediante el uso de AmI y, especialmente, comprender cómo los equipos directivos de centros escolares aceptarían dicha innovación. Un cuestionario fue respondido por 138 directores/as de centros educativos de Cataluña. Los resultados muestran interés en la temática, pero en la mayoría de los casos falta voluntad para explorar tales nuevas tecnologías para la regulación de las condiciones ambientales en el aula, al menos hasta que la investigación brinde más evidencia del impacto en estudiantes y docentes, y el retorno de la inversión sea más claro.

Palabras clave: Inteligencia ambiental, aula inteligente, condiciones ambientales, entornos de aprendizaje.

Abstract
Ambient Intelligence (AmI) used in school classrooms implies the integration and interaction of software, hardware and sensor networks to empower students and teachers through a digitalised context-aware, sensitive, adaptive and responsive environment. One of the applications of AmI is to monitor and regulate environmental conditions (lighting, acoustics and air quality). This work aimed at offering a comprehensive view on the need to regulate such conditions in smart classrooms by using AmI, and specially to understand how school principals would accept such innovation. A questionnaire was responded by 138 school principals from Catalonia. Results show interest in the topic, but in most of the cases lack of willingness to explore new technologies to regulate environmental conditions in the classroom, at least until research provides further evidence of the impact on students and teachers, and the return of investment is clearer.

Key words: Ambient Intelligence, Smart Classroom, Environmental Conditions, Learning Environments.

1. Introduction

Ambient Intelligence (AmI) is a subfield of Artificial Intelligence that implies the integration and interaction of software, hardware and sensor networks. AmI proactively and seamlessly supports humans in their daily tasks by automated processes (Gams *et al.*, 2019). Initially related to the area of smart homes, AmI is gaining increasing attention in educational settings. With the development of learning technologies in the last decades, the education system has changed rapidly. As Ghavifekr and Rosdy (2015) argued, this is due to the capability of technology to provide a proactive, easy access and comprehensive teaching and learning environment.

Several initiatives have shown the use of AmI in education in the last years: AmI-RIA (Real-time Instructor Assistant) is a tool for monitoring classroom activities in real-time, being able to analyse and to identify potential difficulties from specific students or the whole group and notify the teacher accordingly (Mathioudakis *et al.*, 2014). LECTOR aims to help educators in understanding when students have stopped paying attention to the educational process and assists them using eye-trackers, microphones, cameras and pressure-sensitive sensors following a sense-think-act model (Korozi *et al.*, 2017).

The AmI concept-based smart classroom model has the goal of showing the impact of the right choice of a learning strategy on the student's success (Radosavljevic *et al.*, 2019). Thus, SaCI (Salón de Clase Inteligente) proposes a smart student-centered classroom considering AmI, including a recommender system of learning resources, and supports the learning process through collaborative devices and applications that facilitate self-training (Aguilar, Valdiviezo-Diaz *et al.*, 2018). AmI can also be used in online education contexts, as in the use of learning analytic techniques as services aiming both to analyse the learning process and to analyse the student behaviour, as shown by means of the AmICL middleware (Aguilar, Sánchez *et al.*, 2018).

There are still several challenges that must be considered to give response to educational demands (Saini & Goel, 2019). These include dealing with different students and teachers' profiles, implementing fully-controlled environments and adapting the physical environment to the comfort level that best suits the group or the activity being performed. The environmental parameters to monitor are related to lighting, acoustics and air quality. Hence, there is a need to interpret the environmental parameters in which AmI is used, whilst fusing data from the affected agents to propose meaningful applications for improvement of the physical context.

Previous studies conclude that using cameras, sensors and tools to measure environmental parameters and others like teachers' voice and hands movement is a reliable strategy for recognizing students' satisfaction with the lecture quality (Uzelac *et al.*, 2018). AmI systems contain devices and sensors integrated into the user's working environment: sensors for lighting, temperature, noise, pressure, object position, face and speech recognition, bio-signal reading, GPS and RFID (Radosavljevic *et al.*, 2019).

It is necessary to maintain the right environmental conditions inside the classrooms, which is required for effective learning and to help learner's progress, mood, comfort and concentration capacity (Cebrián *et al.*, 2020). But there is the doubt whether schools are willing to adopt such changes, if they are interested in this topic. This research aimed at providing more information to have a comprehensive view of the situation in Catalonia.

2. Objectives

1. Analyse how school principals approach the possibilities of AmI to monitor environmental conditions and make decisions accordingly.
2. Explore how school principals perceive the possibility of tracking air quality and their willingness to act in this sense.

3. Method

This study used a qualitative questionnaire developed to gather concrete data in an exploratory approach. Qualitative disquisition is a method of investigation centred on acquiring a deep comprehension of social cautions (Creswell, 2007). The schools participating in this study were chosen via a purposeful sample with the aim of exploring the phenomena from diverse points of view.

An online questionnaire was designed and spread throughout a number of schools using their corporate email. The addresses were extracted from the public directory of education centers published by the Catalan government within the open data initiative (Departament d'Educació, 2021). In the call, the research was explained, and we required the questionnaire to be answered by someone from the school management team. A total of 138 school principals participated: 88 representing public schools (63,8 %), 46 partially funded (33,3 %) and four private schools (2,9 %). This sample reflects the Catalan distribution, as from the 5469 education centers in Catalonia, 3816 are public (69,78 %) and 1653 are private (mostly partially funded) (30,22 %) (Departament d'Educació, 2021). As this research intended to provide an exploratory qualitative approach, the sample was considered enough to ground a general view. Representation of schools is heterogeneous as they are located in both urban and rural environments and include pupils from diverse socioeconomic statuses. In terms of number of students enrolled, 106 are small schools with less than 500 students (76,8 %), 26 have between 500 and 1000 students (18,8 %) and six have more than 1000 students (4,3 %).

Data analysis consisted of comparing frequencies of responses.

4. Results

Principals were asked whether they have placed in any space of the school a device to measure environmental conditions. Most schools have a device to measure temperature (n = 95; 68,8 %) and to a lesser extent a device to measure humidity (n = 34; 24,6 %). A minority somehow measure the acoustic values (n = 21; 15,2 %) and air quality (n = 19; 13,8 %). Five schools own a device to measure lighting (3,6 %).

Participants who have confirmed to own a device were then asked what kind of use they make of it, either if punctual or sustained. Answers in this segment show that the majority only make informative or anecdotal use of them (n = 59; 57,8 %), and a certain extent use them to make decisions (n = 29; 28,4 %) such as measuring the amount of CO2 to make a ventilation protocol. The rest of respondents refer to pedagogical uses: to create graphs, to do comparisons by seasons, to extract statistics from the measures along several weeks and years, to reflect on energy saving, and to complement mathematical projects.

When asked about their perception of the importance of environmental factors improving the comfort, motivation, and academic performance of students and the working conditions of teachers, answers show a positive trend as shown in figure 1.

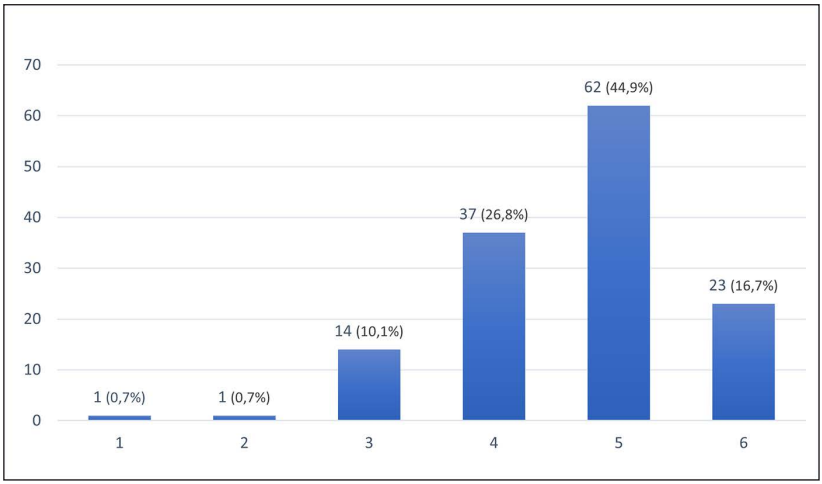

Figure 1. Perception of the importance of regulating parameters of environmental factors in classroom Settings.

Due to the health crisis caused by COVID-19, principals were asked about what decisions they made in relation to air quality. The unanimous response was to improve ventilation following the Procicat guidelines: doors and windows open at different times of the day, cross-ventilation, open windows while heating is open, ventilate spaces and spend more time outdoors, reduce the number of students per classroom. In addition to natural ventilation, six answers complemented the approach informing the acquisition of air purifiers with HEPA filters. Six schools report not having taken any action, because they live in a healthy environment or because the school building guarantees by itself health security.

Finally, two questions were added seeking to understand the predisposition of management teams to adopt new technological solutions to improve the environmental conditions of their classrooms. Responding to «what attitude would you have in your school if you were presented a system that allows you to monitor environmental conditions and offers recommendations to improve learning spaces with the consequent benefit for students and teachers?», principals showed interest to learn more about it rather than confirming interest. Concretely, 32 principals (23,2 %) responded they would be interested to know more about the service and perhaps to purchase it. 78 principals (56,5 %) responded they would be interested to know the service better just to be informed, probably without purchasing it. 23 of them (16,7 %) were not interested to consider this option for their schools, from which 9 convey not having curiosity; 8 inform that are not able to take such decisions, mainly because of the nature of public schools; 6 could be interested but regret on the funding, they wouldn't invest on such technology and would only adopt the system if no cost is associated. Five principals (3,6 %) were not interested at all.

Focusing on the COVID-19 pandemic, principals were then asked their willingness of acceptance of a system specialized in air quality. 62 of them (44,9 %) showed more interest than if the system was global, expressing interest in getting more information to adopt the system. On the contrary, 43 principals declined the possibility to learn more about such a system (31,2 %). The remaining 33 principals (23,9 %) would like to be informed but they saw it difficult to make a purchase, being the main reasons

lack of budget (n = 12), not finding it useful (n = 8), inability to take such decisions for their schools (n = 7), and other reasons like hesitating how complex would it be to introduce the devices and take profit of them (n = 6).

5. Discussion and conclusions

From a sample of 138 principals responding to an exploratory questionnaire, in this research we first analysed how schools approach the possibilities of Ambient Intelligence (AmI) technologies to track environmental conditions and make decisions accordingly. Our results show that not much interest is placed in adopting new technologies to control the environment in school classrooms, but a large number of principals would be interested to get more information. Literature is increasingly pointing at the benefits to count on systems related to AmI for smart classrooms (Uzelac *et al.*, 2018), but there are still challenges to give response to educational demands (Saini & Goel, 2019). More advances and concrete proposals are required to step forward.

Among the environmental conditions, air quality is a main concern due to COVID-19 pandemic. We confirmed this initial hypothesis and verified the need some school principals perceive to track air quality parameters and their willingness to adopt new technologies to complement elementary requirements. Not all principals would, though.

As a general conclusion we can state that controlling environmental conditions in smart classrooms using AmI receives more attention in the scientific literature than in real classrooms, but this could be explained because (1) Research must provide further evidence of the impact on students and teachers. And (2) due to the lack of knowledge transfer and the need to better develop concrete proposals for the market.

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