International Journal of Enhanced Research in Educational Development (IJERED), ISSN: 2320-8708
Vol. 2, Issue 4, July-August, 2014, pp: (84-91), Impact Factor: 1.125, Available online at: www.erpublications.com

A Novel Approach for Education Indoor Air Quality Management using Wireless Sensor Networks

O. Abroun[1], A. Tahiri[2], N. Aknin[3], K. E. El. Kadiri[4]
[1234]Computer Science, Operations Research and Applied Statistics Laboratory Abdelmalek Essaadi University, Tetouan, Morocco

Abstract: Learning environments are a very important component in the educational system, and have a major role in improving learners' performance. However changes in Indoor Environment Quality (IEQ) factors such as temperature, CO2 level, and noise in addition to the number of students per class can harm learners' health and decrease their knowledge acquisition capacities. Due to the number of studies that showed how IEQ improvement leads to students' performance increase, this paper present the implementation, design and results of a WSN based IEQ monitoring system for the sake of students' performance improvement and decision making accuracy increase.

Keywords: E-Learning, WSN, Indoor Air Quality, Presence Detection, Information Technology, Learning Environment.

Introduction

Studies such as those conducted in [12], [4] and [3] showed the strong relationship that exist between Learning Environments Indoor Quality and students' performance. Learning environment such as classrooms are considered an important element in the educational process. Consequently, having poor quality environments, implies to have low students' knowledge acquisition, which is a problem that needs to be solved. To see the importance of this issue, assuming to have a class with 20 students and with the following conditions:

- Before every class begins, teachers need to count the number of attending students, which takes a significant amount of time that can be used more wisely.
- Often, loud construction work take place near the school. Due to its noise it influences negatively students' ability to concentrate.
- A small classroom, and a large number of students, lead to CO_2 level increase, which creates an unhealthy environment.
- Therefore, the need for a system that can tell when learning environments are not convenient for a positive knowledge acquisition is noticed. To satisfy this requirement, the aim of this work is to make learning environments more autonomous and intelligent using a rapid growing technology such as WSN. This system, which was implemented as a web application and tested in a simulated environment, aims to make factors such as the number of students per class, CO_2, noise and temperature levels easily monitored and allows to:
- Count automatically the number of students per class at every desired moment. (section 5 C-1)
- Alert when environment quality is decreasing due to high CO_2 and/or noise levels or temperature. (sections 5 C-2, 5 C-3 and 5 C-4)
- Have statistics about the history of learning environment physical measurements for every class independently. (section 4)
- Find with high accuracy the best environment conditions that maximizes students' performance (optimal students per class, CO_2, noise and temperature levels).
- Improve classes scheduling by managing classrooms availability in real time.(section 4)

Background

To give an overview of the context of this paper, the relationship between learning environments quality, or Indoor Air Quality (IAQ), and students' performance is discussed. According to the Centers for Disease Control and Prevention, due to poor air ventilation, asthma is one of the leading causes of school absenteeism. It is also found that children overall performance decreases with illness and absences from school as stated by Moonie, Sterling, Figgs and Castro in [13]. The research in [1] proved that most schools ventilation rates are below recommended levels, and also that improved IAQ

increases productivity and improves the performance of mental tasks, such as students' concentration and recall (CDC). Therefore, learning environments' quality is still a problem that schools and institutions face, especially with the major impact that low quality learning environments have on reducing students' performance in acquiring knowledge and passing tests.

On the other hand, the work conducted in [9], highlighted a problem of limited data on indoor air and environmental quality (IEQ) in schools, and how IEQ affects attendance, health, or performance, which makes problem diagnosis more complicated.

As a result, the conclusion that can be made is the existence of a need for an automated system that allows an intelligent management of IEQ factors such as CO_2, humidity and temperature in order to make accurate decisions for the improvement of learning conditions, to attain the main objective of finding the best environment for maximum students' performance. And those are our motivations to create a WSN based IAQ monitoring system.

WSN Technology in Learning

As discussed in the previous section, learning environment is an essential component in the success of the learning process, and the use of technology is needed to create an instructional system that suits the new trends of learners.

Wireless Sensor Networks is considered as one of the major growing technologies, due to its big capacities in presenting information about physical world in an accurate form. The tiny microcontrollers are gaining, day after another, more trust by businesses, governments and even by individuals to be used in their lives. WSN applications are overwhelming, and this technology can be found in many sensible fields such as the army, healthcare, transportation, supply chains, buildings fire protection and much more. In addition to that, the low price of those sensors make them an optimal choice for every system that needs information about its physical environment and have a small budget.

Due to the importance of WSN in real life, this work present the use of WSN in the learning system to make a smart environment that allows a better knowledge acquisition, an IAQ remote monitoring and learning system's intelligent development.

The Main Idea

When studying physical environments such as class rooms, where a continuous information exchange take place, the relationship that exist between the quality of this environment and the quality of learning is overwhelming, which is related to many factors. For example, a factor such as the number of students per class can give an idea about how much those students are interested to the given material, especially when for a given class the number of students at its end is much lower than the number at the beginning. In addition to that, more measurements can be made in real time about many aspects of the classroom, such as room temperature, CO_2 levels and others.

This study suggests the creation of an intelligent system based on WSN that allows in real time to:

- Count how many students attend the class, what allows to overcome the problem of presence management.
- Detect the room temperature and adjust it intelligently when it is bellow or above comfort level.
- Detect the room CO_2 level and alert when it's above or below the normal level, and from another side to make decision about the optimal level for the optimal learning.
- Detect the room noise level and alert when it is above or below the normal level in order to maintain the optimal learning environment.

  Consequently, a system that allows a better monitoring of IAQ in classrooms, and makes finding the optimal conditions for better knowledge acquisition easier is created.

System architecture

To give an overview of the suggested system and its different component, the following figure summarizes its architecture:

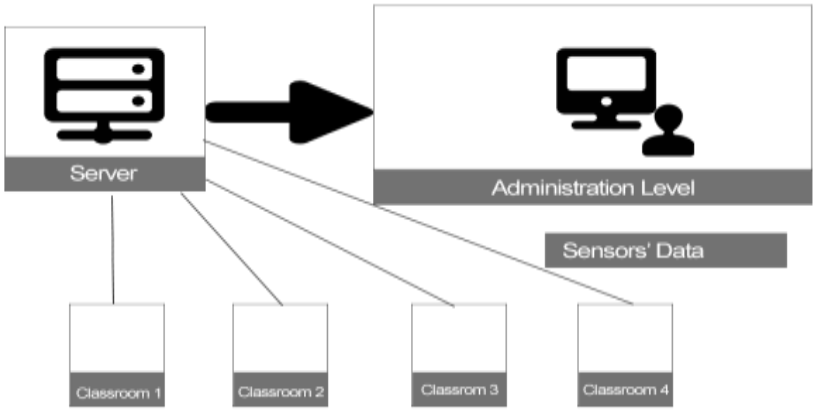

Fig 1. System Architecture

As shown on the figure above, the system is composed of:

- A web server: to host the deployed web platform and services.
- A relational data base: to store captured raw and processed data, in addition to data related to classes, users and sensors.
- Sensors: deployed in class rooms to collect data.
- System users: to manage and use the system for data analysis and monitoring.

  Noting that the web nature of the system was selected to allow multiple simultaneous access, in addition to the following advantages:

- A centralized data base where access to data for analysis is easier.
- A deployed web platform on a web server for rapid and efficient problems and/or updates.
- Extensible architecture for mobile devices such as smartphones and tablets.
- Reduction of interoperability and hardware requirements problems when using multiple access environment and reduce it to a simple web browser.

A. Classrooms:

After installing sensors to collect data for the monitoring system, classrooms are envisioned to have the following form:

Fig 2. Classroom overview

As it can be noticed, sensors to monitor temperature, noise and CO_2 levels are installed in strategic locations of the classrooms, in addition to presence sensor to give the actual number of presence students. The collected data is sent in real time to the central server in order to be presented to users.

B. Administration level:

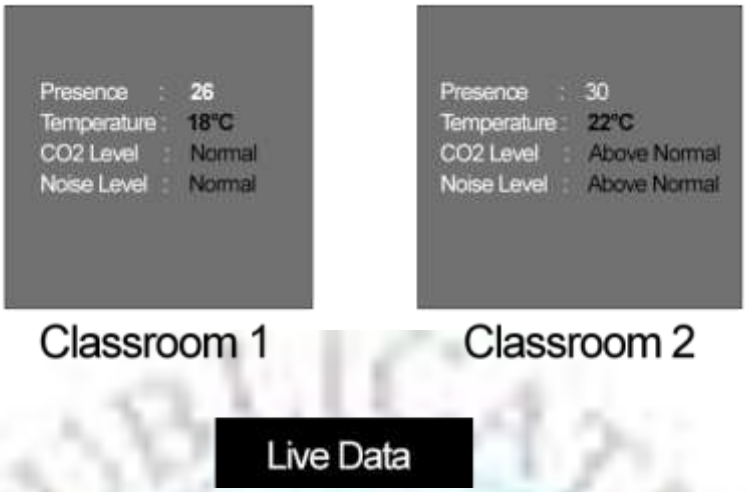

Fig 3. Administration level of the suggested system

At this level, administrators have real time and historical information about every class. Moreover, information can be accessed by the class mentor, in order to make the process of students counting easier. For this reason, the use of a mobile application is envisioned to be accessed only by the class mentor.

Fig 4. Teachers' interaction level of the suggested system

Noting that students counting is a sensible and an error prone procedure. At every moment, the mentor can give the real number of students that are present in his class by using this application. As a result the system will register this data in order to be used for future decision making.

C. Monitored factors

1) People Counting

Counting the number of people that are present in a certain area can be very important in many applications, as it's the case in public transportation, commerce or in buildings' security. Additionally, in learning environments, counting the real number of attending students is a procedure which can take, depending on the number of students, an average amount of time between 10 and 20 minutes. This time can be strategically deployed in a more important issue. Moreover, in other cases, the difference between initial and final attendance for a class can be used to evaluate the quality of the given material. In this latter case, the mentor can judge how much students were interested to his class. Moreover, administrations can follow this measurement as an indicator for their decisions for classes scheduling, to know the available classes in real time or also to figure out the optimal students' number for a high degree of knowledge acquisition.

In order to implement this functionality, WSN provide many low cost and effective solutions. Based on the findings in [7], infrared sensors were combined to pattern recognition algorithms in order to count the number of people, even in a moving state, inside a room with a claimed accuracy of 95 percent. From another side, the work [1] provided another solution to determine the exact people count, they based their work on the use of pyroelectric low-cost sensors with an accuracy of 89 percent in case where people are walking in line and 75 percent when they are walking in side by side, however this method demands the deployment of multiple sensor nodes for each entry or exit point what make it more expensive than the former method. As a result, it is clear that WSN provide different solutions that can be implemented for students counting inside class rooms, or even in a more general level as inside the entire school or learning institution.

2) Temperature

Noting that schools that have a better environmental conditions (temperature, CO_2, humidity…) show improved academic performance, and schools with less quality in those conditions show less performance as stated in [2] One of the most important measures inside every work environment is temperature. For this reason, there is a need to monitor the ambient temperature inside a classroom in real time, and to make decisions about the optimal temperature based on the installed sensors data. Consequently, air conditioners inside classrooms can be adjusted intelligently in order to improve the learning circumstances that will provide the best knowledge acquisition, and helps.

As a result, temperature detection sensors can be installed in classrooms to send continuously their data to decision makers.

3) CO_2 level

In addition to temperature, one of the important factors that influence the comfort of students in their class rooms is CO_2 level. This criterion is highly related to the number of present students in the same class room, what make it important to analyze especially that high CO_2 level in classes' leads to low students' attendance based on the findings of [9]. Consequently, WSN based monitoring system of the class will send alerts to decisions makers if CO_2 level is above the normal level, and also will allow them to find the better circumstances of learning.

CO_2 level monitoring can be easily implemented using wireless sensors that are available in markets today for low prices, which allows to capture this information in a continuous manner.

4) Noise level

Finally, the forth factor which is considered in this work to contribute to the creation of a better learning environment is the level of noise inside classrooms This is done by following whether its level is within the normal limits. Based on the research conducted by The Government of South Australia [5], the normal range of hearing for a healthy young person is from approximately 20 Hz (Hertz) to 20,000 Hz (20 kHz).

Noise is an unwanted or damaging sound that may damage student hearing ability and harm their health. Sources of noise inside learning environment can be loud road work in its perimeter, the misuse of speakers during class or different voices interfering with mentor voice. Consequently, based on noise level, learning environment quality can be measured, so this information can contribute to the continuous development of the educational system intelligently using WSN capabilities.

System Implementation

In the sake of creating the envisioned system discussed in the previous section, the behavior of the needed sensors (presence, CO_2, temperature and noise level) was simulated and a web application that can be accessed by administrators from the learning organization was developed.

Noting that the web application was developed using ASP.NET/C# programming languages, and SQL Server Express Edition as a Data Base Management System (DBMS), to store the collected data. Moreover, this system allows to:

- Create classrooms that contain the sensors.
- Monitor in real time presence, temperature, CO_2 and noise levels.
- Alert when temperature, CO_2 or noise levels are abnormal.
- Get statistics for every class individually and for every sensed factor.
- Make decision about the quality of learning environment based on the collected data.
- Measure how much attendance a certain class have, and try to find the best factors when the class attains it optimal performance.

After implementing those functionalities, results in the simulated system can be seen in the following figure:

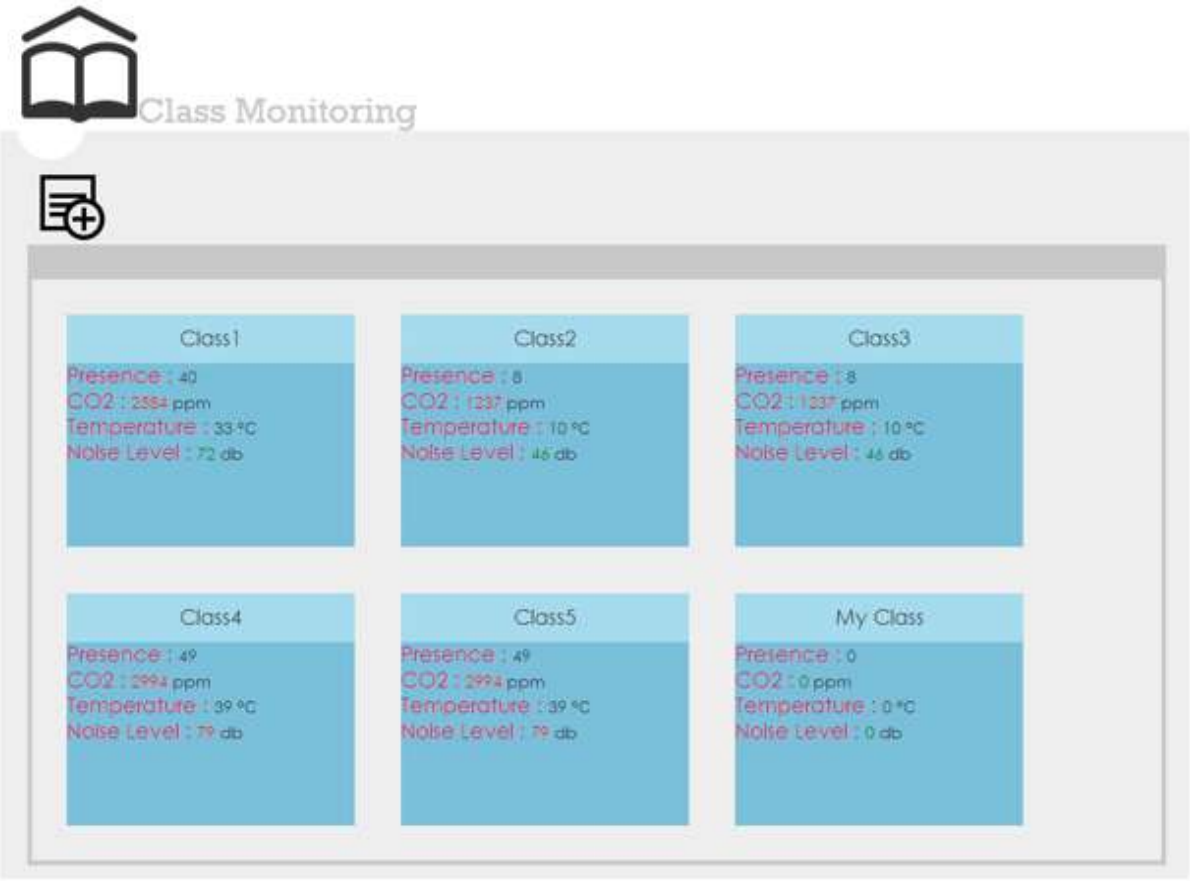

Fig 5: Administration implemented level of the suggested system

This figure shows an overview of simulated classes with real time data from different sensors, whether the sensed data is in a normal state or not, and the number of students in every class in real time.

In addition, if the user selects a specific class, and click on it, detailed data will be displayed for every variable, and presented as a chart that can make the reading easier for decision making. The following chart represents the average number of present students per month for the selected class:

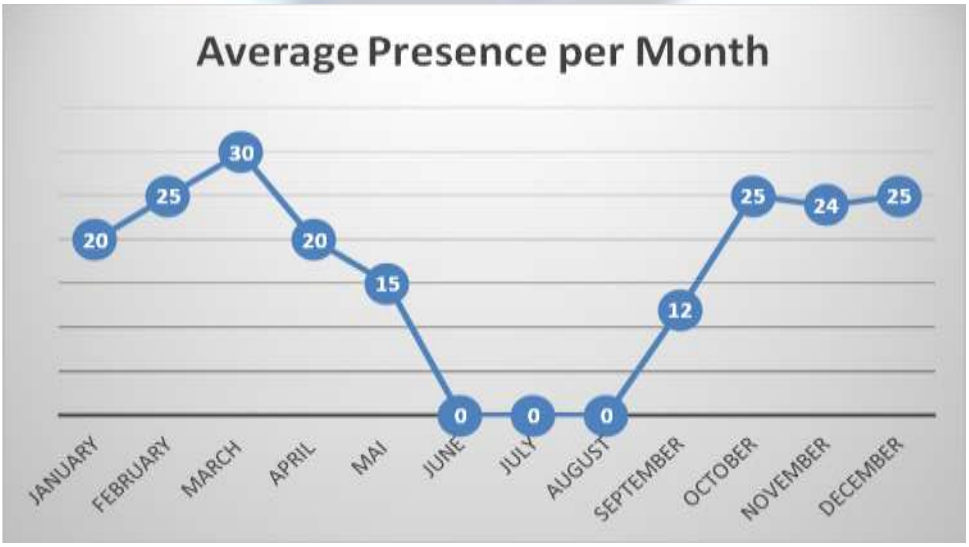

Fig 6: Detailed implemented statistics of the suggested system, presence example

This information can be used by decision makers for many applications, when combined with other data such as students' grades and satisfaction, the learning quality can be improved by finding the optimal number of students per class that allows higher students grades and satisfaction.

Related Works

Many studies highlighted the relationship between IAQ and students' performance and called for a better management of education environment conditions, especially in children schools, as discussed by United States' Environmental Protection Agency in [14] that showed the high negative impact of such low conditions on students' health. Findings of [12] showed that students in classrooms with higher outdoor air ventilation rates scored up to 15 percent higher on test than other students in classrooms with lower outdoor air ventilation rates.

Additionally, the use of WSN technology in physical environment monitoring can be found in many fields, such as in flood forecasting, buildings fire detection and field monitoring. The work in [10] proved how much monitoring different indoor environment conditions improves the quality and the comfort of life. However, a weak integration of such technology to the educational system was noticed, which represented for us the biggest challenge.

Results Discussion

As it can be seen in section 6, the created system resolves many problems that needed a rapid intervention, more resources and more accuracy. In this system, administrators can easily make decisions about the average student attendance of a class, in a certain period and for a certain mentor. Additionally, this system allows teachers to follow in real time how convenient the class conditions are for better learning and knowledge acquisition.

By analyzing the elaborated system, and the envisioned concept of the smart learning environments of tomorrow, the number of solutions and advantages of the use of WSN inside learning environment is overwhelming.

Conclusion

This work discussed the integration of technology, in particular WSN, in education, and proved, through the creation of the presented system, how much benefits this incorporation can provide to students, teachers and administrators.

Additionally, the discussed IAQ factors that were considered to have a radical impact on the quality of knowledge acquisition (CO_2, noise, temperature levels and students count) can become, because of the suggested system, easier to monitor, and allowing the possibility of an intelligent management of learning environments without any distraction to the learning normal process. However, as this work present a way to incorporate technology to education, there is much to do at this level, especially through the analysis of the collected data and the automation of the different possible aspects of educational institutions to create an optimal learning environment for a better performance.

References

[1]. California Energy Commission. (1995). "Air exchange rates in non-residential buildings in California". California Energy Commission.

[2]. D. Branham, "The wise man builds his house upon the rock: The effects of inadequate school building infrastructure on student attendance". Social Science Quarterly, 2004, 85(5), pp. 1112-1128.

[3]. DG. Shendell, R. Prill, WJ. Fisk, MG. Apte, D. Blake and D. Faulkner, "Associations between classroom CO2 concentrations and student attendance in Washington and Idaho". Indoor Air 14(5), 2004, pp. 331-41.

[4]. G.I. Earthman, C.S. Cash, & D. Van Berkum. "Student achievement and behavior and school building condition. Journal of School Business Management", 1995, 8(3).

[5]. Government of South Australia, "Noise in the workplace, what you should know", 2008.

[6]. J., Levin, H., Nazaroff, W. W., Cain, W. S., Fisk , D.T. Grimsrud and C. J. Weschler. "Ventilation rates and health: multidisciplinary review of the scientific literature". Indoor Air 21, 2011, pp. 191-204.

[7]. K. Hashimoto, K. Morinaka, N. Yoshiike, C. Kawaguchi and S. Matsueda. "People Count System using Multi-Sensing Application". In Proceedings of International Conference on Solid State Sensors and Actuators. TRANSDUCERS, 1997, pp. 1291 –1294, volume 2.

[8]. MD. Silverstein, J. E. Mair, S. K. Katusic, P. C Wollan, E. J. O'connell and J. W. Yunginger. "School attendance and school performance: A population-based study of children with asthma". Journal of Pediatrics 139(2), 2001, pp. 278-283.

[9]. M. Schneider, "Public school facilities and teaching: Washington, DC and Chicago". 21st Century School Fund, Washington, D.C, 2002.

[10]. N. Sun-Kuk , K. Kuk-Se and J. Yoo-Kang, "Design of a Room Monitoring System for Wireless Sensor Networks". International Journal of Distributed Sensor Networks, Volume 2013, 2013.

[11]. P. Zappi, E. Farella, and L. Benini, "Enhancing the Spatial Resolution of Presence Detection in a PIR based Wireless Surveillance Network". In Proceedings of IEEE Conference on Advanced Video and Signal Based Surveillance, AVSS, 2007, pp. 295 –300.

[12]. RJ. Shaughnessy, U. Haverinen-Shaughnessy, A. Nevalainen and D. Moschandreas. "A preliminary study on the association between ventilation rates in classrooms and student performance". Indoor Air 16(6), 2006, pp. 465-468.

[13]. S. Moonie, D.A. Sterling, L. W. Figgs and M. Castro, "The relationship between school absence, academic performance, and asthma status". Journal of School Health 78, 2008, pp. 140-148.

[14]. United States Environmental Protection Agency EPA, "Student Health and Academic Performance, Quick Reference Guide", 2012.