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BRINGING STUDENTS CLOSER TO THE ISSUES OF INDOOR ENVIRONMENTAL QUALITY AND TECHNOLOGY USING NEMOS DEVICE: AN EXPERIENCE IN ALBANIA

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Abstract. The article presents the outcomes of a monitoring campaign and a survey performed in a school building in Tirana. Included in the Bilateral Agreement between the National Research Council of Italy and the Ministry of Education and Sport of the Republic of Albania, the research is based on environmental analysis, collection of data from monitoring of environmental variables and students' feedback. The monitoring of Indoor Environmental Quality (IEQ) was carried out with a nearable Environmental Monitoring System (nEMoS) for IEQ purposes, designed and developed by ITC-CNR based on the Do-It-Yourself (DIY) philosophy. The proliferation of the maker movement philosophy has promoted the diffusion of DIY-based technologies. The spread of this movement is observed outside schools but there is a growing interest among educators to introduce this philosophy in the students' education, approaching to STEAM (Science Technology Engineering Arts Mathematics) in a different and more stimulating way. The application of two nEMoS devices in two classrooms (in different locations) aroused the curiosity of students, bringing them closer to the world of technology with a practical example. It also increased their awareness about the overall IEQ conditions in the classrooms where they spend a considerable part of their lives.

Keywords: IEQ, Albania, school, sustainability, survey.

1. Introduction

School buildings are fundamental in the education of future generations and to transmit them the desire for research and innovation, too. Coding and programming have emerged as the most desired success factors for society [1] where especially for the first one there should be considered its introduction in the didactic curricula in response to the labour market demand. The main difference among them is that coding is a part of programming and involving the translation of a written code by a machine; while the second is the process of creating a program following specific standards and performing a specific task, too. In the last decade, researchers and educators have developed tools to simplify the mechanics of learning computing at school, introducing new programmers to become more fluent and expressive towards new technologies [1].

New technological developments of microcontrollers, low-cost sensors and actuators foster the teaching of these new concepts [2]. Countries that are distinguished for their technologically advanced economies and societies are reconsidering their education policies by concentrating their economic efforts in the promotion of the STEM education (Science, Technology, Engineering and Mathematics) [3]. In this sense, Arduino-based projects can stimulate childrens' computing competences [4] as well 3D-printing approach can be a promising technology to engage students with hands-on interactions [5].

In the last years, the Indoor Environmental Quality (IEQ) in schools has attracted the attention of several researchers, since the quality of indoor spaces affects children's well-being, health, and productivity. Scientific literature reports several case studies focused on the evaluation of the IEQ in educational buildings, where children and teachers were inquired about their perception of the indoor environment. As planned in the two-year Bilateral Agreement between the National Research Council of Italy and the Ministry of Education and Sport of the Republic of Albania, a monitoring campaign was designed and conducted in a school in the outskirts of Tirana but in a reduced number of effective days due to Covid19. Therefore, it can be considered as a small-scale test and a useful reference to be reproduced in similar scenarios with a longer time span. The short three-day monitoring campaign made possible to comprehend whether the methodology based on the use of the nEMoS device [2], developed in the laboratories of ITC-CNR, can be used, on the one hand, to collect data on subjective and objective environmental quality in the classrooms

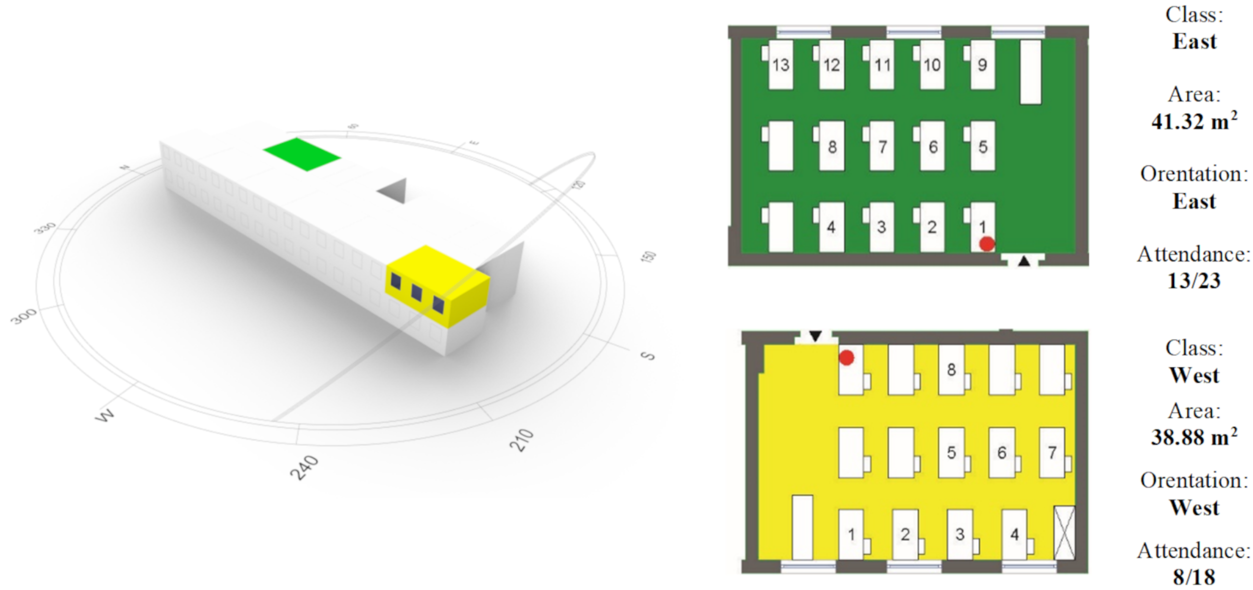

Figure 1. School building with sun path for the considered class period (November 16th–18th), classrooms configurations and position of nEMoS devices (in red) during the campaign.

where students spend most of their lives; on the other hand, to raise students' awareness regarding the importance of assessing the environmental quality in the classrooms thanks to a DIY-based and 3D-printed monitoring device. In this case, the pupils are not involved in the production of the devices, but they could be in the future. This pilot project can be seen as an opportunity by stakeholders to integrate new technical disciplines in the educational background. To acknowledge pupils and teachers with the results of the experiment, the research team delivered a final report to the school's board.

2. Case study and methodology

The case study is the "Kolë Jakova" school (Figure 1), located in the North-Western suburb area of Tirana (Lat. 41° 21′ 28″ N, Long. 19° 45′ 44″ E). Built in 1983[1] and with a capacity of 12-classrooms[2], it is among the most diffused typologies in rural areas during the period 1945–1990 in Albania.

Nowadays its capacity represents a limit because the demand for classrooms is higher and consequently it constraints the split of the didactic activity for some classes in the morning and for others in the afternoon. Indeed, the school hosts 420 pupils for a total of 18 classrooms (elementary and lower secondary cycle) but during the monitoring campaign all classrooms were at half capacity due to the COVID-19 restrictions. The classrooms chosen for the campaign were positioned on the opposite sides of the building (East and West facing) to comprehend the impact of different orientations on people comfort perception.

Besides being built in the 80s it has undergone to partial renovations including the installation of a heating system not expected in the original design. The vertical opaque components are uninsulated brick-based walls (U-value = 1.26 W/m^{2}K). The flat roof was insulated with 0.05 m thick polystyrene layer with a waterproof layer on top (U-value = 0.48 W/m^{2}K). The windows (130 × 160 cm) are single-glazed with aluminium frame (U-value of 6.8 W/m^{2}K and SHGC = 0.7). The heating system is a centralized two-stage plant with power ranging between 178–391 kW with radiators in each classroom, but inactive during the survey, whereas two separate boilers guarantee the production of Domestic Hot Water (DHW).

The monitoring campaign and the survey aiming to collect of subjective and objective data was carried out between November 16th–18th, 2020 in the middle fall/winter school session in Albania. The objective monitoring of indoor environmental variables was carried out using nEMoS [3, 4]. Before the campaign, students were introduced to concepts of computing and 3D-printing (the pillars nEMoS was built) and IEQ. The nEMoS device gained great attention among students in both classrooms. They were not informed regarding any instant value of the acquired data to avoid any eventual influence on their responses. Before the start of the campaign, students were informed regarding the purpose of the monitored Environmental Factors (EFs) measured by the nEMoS device.

The monitoring campaign was performed for three consecutive days in each classroom. A simplified survey form was elaborated to acquire the subjective data of pupils' perceptions in order to avoid any eventual confusion and misunderstanding. As illustrated in the Figure 2, the questions were focused on the thermal

[1]Referring site plan file at the Central National Technical Archive: "Shkollë në fshatin Bregu i Lumit dt 10.05.1983" (School in the village of Bregu i Lumit dated 10.05.1983).

[2]Technical name of the project at the Central National Technical Archive: "Shkollë 8-vjeçare me 12 dhe 8 klasa 73.6" (8-year cycle school with 12 and 8 classrooms 73.6).

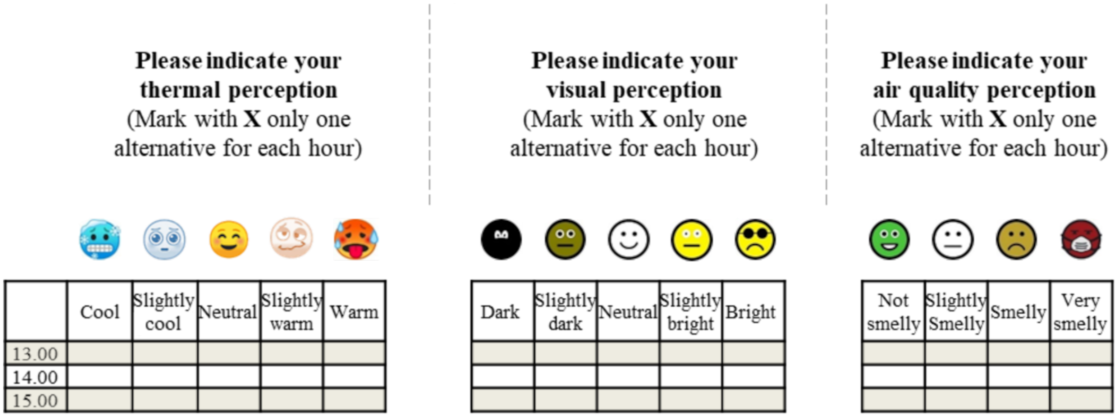

Figure 2. Questionnaire structure about thermal, visual and IAQ perception (translated from Albanian).

Classroom	Total [-] Total (M–F)	Age [y] Avg ± std	Weight [kg] Avg ± std	Height [cm] Avg ± std	Iclo [clo] Avg ± std	Metst [met] Avg ± std
East	13 (6–7)	14 ± 0.5	57.92 ± 14.38	164.32 ± 13.01	0.73 ± 0.11	1 ± 0
West	8 (4–4)	13 ± 0.5	50.42 ± 6.42	166.73 ± 6.62	0.78 ± 0.10	1 ± 0

Table 1. Data of the 21 students involved in the study.

and visual perception, based on the five-point bipolar scale (from “cool” or “dark” = −2 to “warm” or “bright” = +2), while the question about the Indoor Air Quality (IAQ) perception was based on a unipolar scale (from “not smelly” = 0 to “very smelly” = 3).

As mentioned above, due to the restriction because of COVID-19, the classrooms were not at full capacity. The subjective data were collected from the pupils’ perceptions expressed in the specific questionnaire regarding the three parameters of the IEQ during the didactic activity. During three consecutive one-hour intervals, between 1.00 p.m. to 3.00 p.m. the pupils had to express in the questionnaire their thermal, visual and IAQ perceptions. All the 21 pupils that took part in the campaign, have been grouped for each class in the aggregated data as listed in Table 1.

Students brought the parental consent to take part in the survey. From the analysis of participants’ answers it was possible to calculate the thermal resistance of their clothing in compliance with Annex C of the Standard EN ISO 7730. An additional thermal resistance of 0.1 clo for sedentary activities due to the standard school chair is considered [5]. The standard metabolic rate Metst was defined in accordance with the value reported in Annex B of EN ISO 7730.

3. Results and discussions

For a better evaluation of the impact of the orientation and direct daylight exposure, the chosen classrooms are positioned on the opposite sides of the building as illustrated in Figure 1. In Figure 3, there are reported the environmental data acquired during the monitoring campaign in the chosen classrooms, whereas in Figure 4 are reported the subjective responses of students on the considered aspects.

The assessed classrooms have similarities regarding the measured levels of air velocity (AV) and relative humidity (RH). The AV levels highlight lower averages and limited variation, determining ideal conditions for low draught. On the other hand, RH levels highlight moderate variations and mean values slightly higher than 60 %, not distant from the standard design value of 50 %.

There is a slight difference regarding the illumination (IL) levels between the classrooms: although the mean IL values are almost the same, the data variation in West classroom (yellow device) is higher compared to the East classroom (green device). Evident differences between the two classrooms emerge from the comparison of the operative temperature (OT) and carbon dioxide concentration (CO_2) levels in terms of mean values and variability. Indeed, in the East classroom (green device) are registered the highest mean values for OT (19.8 °C vs 18.5 °C) and CO_2 (1800 vs 1200), as well the highest CO_2 variability, while the West classroom (yellow device) highlights the highest OT variability. The huge variability in CO_2 concentration is essentially due to the natural ventilation assured in both classrooms [6].

The analysis of subjective responses partially confirms the IEQ monitored data (Figure 4). Analysing Visual Comfort (VC) perception, 74 % and 71 % of the respondents respectively report a neutral room brightness. In East classroom the percentage of pupils perceiving a “slightly bright” condition is more than three time higher than in the West classroom (18 % and 5 % respectively). And conversely the percentage of pupils perceiving the “slightly dark” condition is three time higher in West than XIB (24 % and 8 % respectively). Previous results suggest that a mean

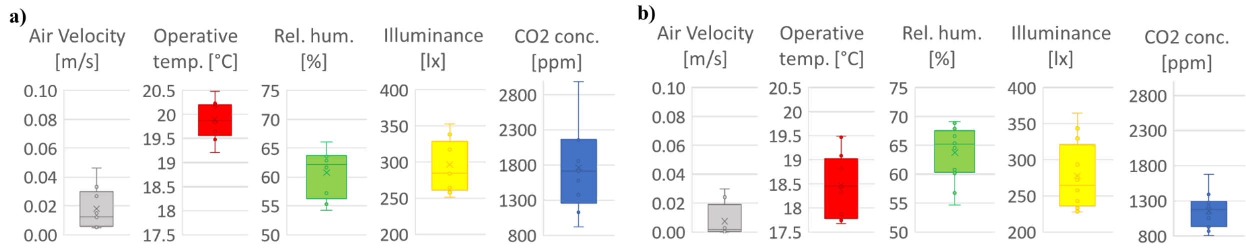

Figure 3. Monitored environmental data: a) East classroom; b) West classroom.

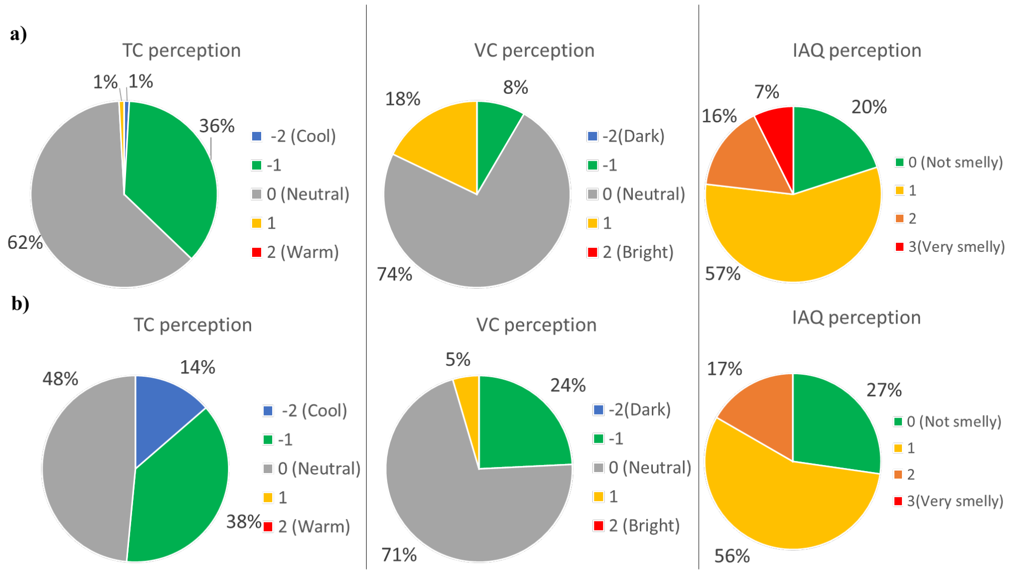

Figure 4. Subjective perception of Thermal Comfort (TC), Visual Comfort (VC) and Indoor Air Quality (IAQ): a) East classroom; b) West classroom.

illuminance value around 300 lx implies a perceived neutral or bright environment for at least 3 out of 4 users, confirming the findings of [7] for similar buildings and students age.

The IAQ perception partially reflects the analysis of the corresponding monitored data (CO_2). Despite a consistent difference in CO_2 concentration values (the East value is 600 ppm higher than the West value), only 7 % of East perceive the air as "very smelly", while the most common perception for both classrooms is "1 – low smelly". A reason for this could be the low sensitivity of users to air quality, since other IEQ aspects are more immediate to assess (i.e., room brightness, temperature level). Even though the reduced number of pupils for classrooms, due to the pandemic, the finding related to IAQ data, both monitored and perceived, are in line with [8].

Finally, the TC analysis confirms the measured data (East classroom warmer than West classroom). The East classroom shows a higher neutral perception (62 % vs 48 %) and a lower "−2 – Cool" perception (0 % vs 14 %) than the West classroom. The TC subjective responses also reflect the main OT variability in West classroom as long as it causes a high thermal adaptation body activity of the users.

4. Conclusions

The monitoring campaign and the survey have been performed in an unusual period because of the ongoing pandemic situation worldwide with didactic activities performed with reduced number of pupils. Another important limitation of the study is related to the resolution of the monitoring campaign: only one measuring point for each classroom. In addition, it was not possible to record the status of opening or closing doors and windows. This would have allowed identification, without speculation, of what the effect on CO_2 concentrations might be. This is an improvement that could be considered in a future monitoring campaign. Nevertheless, monitoring based on the use of low-cost, 3D-printed solutions represents a great stimulus to arouse students' interest in the topic of growing field such as (IoT) and increases their awareness regarding the indoor comfort issues. The main differences of monitored data between the two classrooms are identified in OT with the lowest mean value recorded in the West classroom, and CO_2, with the highest value monitored in East classroom. Probably the main differences in OT data can have influenced the Temperature Comfort (TC) perception, thus allowing to justify 14 % of West classroom perceiving "Cool". The

CO_2 differences are not reflected by IAQ perception and this probably may reveal students' adaptation to this environment condition [7].

These aspects could be considered to improve the overall IEQ in classrooms performing participatory activities where students can be engaged with hands-on interactions, using self-developed monitoring devices. In this sense, it might be possible to bring students close to the themes of IEQ and technology. Measurement performed on a large scale, with devices such as nEMoS, along with feedback provided by a larger number of participants, will make it possible to identify more accurate differences between objective data and subjective perceptions in relation to the considered EFs and the target audience.

Acknowledgements

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