IoT for Health and Well-being: A case study and call for action

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ABSTRACT

In this short paper we describe the implementation of an IoT test-bed in an elementary school. We argue that by adding additional IoT senors to an existing IoT system it is possible to evolve an indoor climate control system into a indoor milieu control system aimed at improving the health and well-being for both pupils and staff who spend their days working in the school environment. Lastly, we call for multidisciplinary action as the domain IoT for health and well-being spans across several different knowledge domains.

CCS CONCEPTS

• **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability.

KEYWORDS

Internet of Things (IoT), Health and Well-being, Indoor climate system, School environment

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1 INTRODUCTION

The disruptive impact of digitalization in general, and the internet of things (IoT) in particular, has led to a completely new range of service innovations and the servitization of existing business models. Systems for automatic regulation of indoor climate have been around for quite some time, but today, these systems are no longer stand-alone systems. Today they utilize interconnected IoT sensors placed within a building. Data from the sensors can be fed into cloud-based AI models that can utilize weather data to determine the output of the system. Furthermore, in addition to measuring temperature and humidity, IoT sensors can measure other variables, such as CO2. As high levels of CO2 have adverse effects on human productivity, the main argument for selling indoor climate has evolved from saving money on energy costs to instead enhance staff productivity, simultaneously affecting their overall well-being. Given the increase in available IoT sensors that can connect to the existing infrastructure of a cloud-based climate control system, it is possible to expand the notion of indoor climate to encompass multiple aspects of the indoor milieu.

2 THE CASE STUDY

The case study presented in this paper aimed to create a test bed for measuring students' health and well-being in an elementary school. The objectives of the test beds have been to create insights and learning for developing new IoT prototypes of solutions and functions and new working methods, processes, and business models. The measurements were supposed to improve the students' subjective well-being and health and to work for a better daily life through the application of IoT in school. The way to do this was by using IoT devices to increase learning and create a better life for everyone. IoT devices can also give students better access to everything, from learning materials to communication channels, and allow teachers to measure knowledge development in real time. This case study was conducted in collaboration between Arvika municipality, DigitalWell Arena, Karlstad University, and Scaaler IoT Labs and was financed by Vinnova (the Innovation Agency in Sweden).

The participating elementary school in this project was a newly built school adaptable to individual student needs. The school is designed so that students can choose between social interaction or individual recovery in impression-reduced environments. The physical building is divided into home nests, cafeterias, and group rooms. The home nests have room for 100 students each and are designed to act as smaller schools. In each residence, three classrooms are separated from the rest of the school, and only the students who belong to that residents have access. The home nests aim to avoid unnecessary classroom movements and thereby reduce stress. The students can meet friends from other classes and residences in the cafeteria. An overall strategy for the school's staff is to develop inclusive and accessible learning environments to improve students' mental health, decrease long-term school absences, and increase student well-being.

Well-being can be defined as a "positive state experienced by individuals and societies. Similar to health, it is a resource for daily life and is determined by social, economic and environmental conditions" [4]. Educational institutions frequently position well-being as a goal or aim in their curricula, but, in practice, focusing on young people's physical and psychological health might be insufficient [3]. Still, some sources identify evidence-based determinants that contribute to well-being in schools. These include positive adult–child relationships, a sense of belonging, positive self-esteem, and the possibility for pupils (in the school setting) to be involved

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in the decision-making processes, giving students responsibility and enhancing their perception of ownership [2].

3 THE TEST BED

The IoT test bed included multiple types of sensors enabling the measurement of different indoor environment quality indicators. In particular, sensors allowed for measuring TVOC (total volatile compound emissions), carbon dioxide, temperature, and humidity. The employment of a long-range wide-area network (LoRaWAN) allowed easy integration of sensors. LoRaWAN is an open-source technology allowing for the inexpensive creation of private networks without the support of third-party infrastructure [1]. The solution allows data transmission over the long-range, even in rural areas up to 10-20 km, because of its high sensitivity associated with long-distance communication. There are many benefits of using LoRaWAN, for instance, wide coverage, low bit rate and low power consumption, security, and easy management. There are, however, some potential issues related to the scalability of LoRa-based solutions, but they are not relevant to the present paper.

Next to the LoRaWAN solutions, the project also included proprietary software provided by Swegon, one of the project partners. This software enabled reporting about the data collected by IoT environmental sensors. Through sophisticated algorithmic manipulation based on the international standards for indoor environmental quality (e.g., ASHRAE, R1, and WELL guidelines), the tool presented not only an analysis of the data, but also the best recommendations for specific school rooms.

Let us consider one example. In the school building, some rooms experienced high concentrations of TVOC emissions, and the system marked them as having potential for improvement. However, since the system considered the frequency of high emissions, the improvements were not urgent. Regardless, the system explained what TVOC is and pinpointed the high TVOC concentrations, explaining that they occur when ventilation is reduced (outside of working hours). Additionally, the system recommended preventive measures: "favor low emitting materials and allow an off-gassing period in a non-occupied ventilated room for new furniture. As corrective measures, increasing ventilation (also outside working hours) is recommended until emissions decrease." Based on the algorithmic manipulation, such recommendations can be easily used by people responsible for indoor quality, e.g., building managers, to ensure that the climate does not negatively affect the building residents.

It should be noted that the system offers a broad range of functionality offering very detailed reporting, which, in some cases, might exceed users' needs and expectations. As much as a curious user might be willing to dedicate time and cognitive effort to understand what information might be the most important, without proper identification of user needs and information that might be useful for a specific type of user (e.g., classroom teacher might have different needs than a maintenance manager), and without training and education, the system reports may have an adversary effect, e.g., reducing staff efficiency or causing stress. Also, the currently implemented solutions consist only of IoT solutions connected to the physical environment, which are the most available in today's market. Only a few solutions are connected to subjective information, such as suitable conditions for learning. In order to meet the needs linked to students' well-being at school, the range of IoT solutions needs to be increased—everything from those that exist today to those that need to be developed to include subjective measurements. There is also scope in showing both individual and aggregated data to reach the well-being of the individual and the well-being of a group or an entire school.

4 IOT FOR WELL-BEING

Although the information from indoor environment sensors can help ensure that the school atmosphere contributes to the staff and students' well-being, it might be insufficient. Considering the user needs identified in the present project, many issues that school personnel and students experience require integrating other technologies to build systems that may improve health and well-being. Let us consider the attendance. By automating the count, IoT could relieve teachers from checking students' class participation. However, for school staff, it is essential not only to know that students are absent but also why they are absent. Here, ML could help identify student participation patterns and alarm teachers when such participation reoccurs and should be further investigated by school personnel.

The data collected from the sensors helps in several ways, such as supporting decision-making or follow-up situations. Data must be interpreted to become information, meaning different groups do it differently, depending on their professional role or interest as caregivers. By extension, this means that the stakeholders have their view on what is interesting data to collect and present as information. The stakeholders' knowledge in interpreting data and information matters regarding how and which data should be presented and whether it should be interpreted as information. Therefore, it is interesting to understand how to find and use the requirements of data and information from various stakeholder groups and their intention to use it.

5 CALL FOR ACTION

Given the development of indoor climate systems into IoT platforms prepared for the inclusion of novel sensors, it has become easy enough to deploy an indoor milieu measuring platform. The basic principle of an IoT-based model for health and well-being can be described as a system centered around an individual comprising of the three elements Health and Well-being, Sensors and Data, and Services.

- Health and Well-being relate to all aspects of an individual's subjective experience or objective status. In regards to current systems of indoor climate control, it relates to comfort as an effect of indoor temperature and productivity as an effect of lack of oxygen.
- Sensors and Data relate to all aspects of sensors and external sources for data collection and data processing. Current systems typically measure temperature and humidity as well as CO2 levels.
- Services are all automatic or manual ways in which the output from the data processing is utilized to affect the individual's health and well-being. This is typically achieved

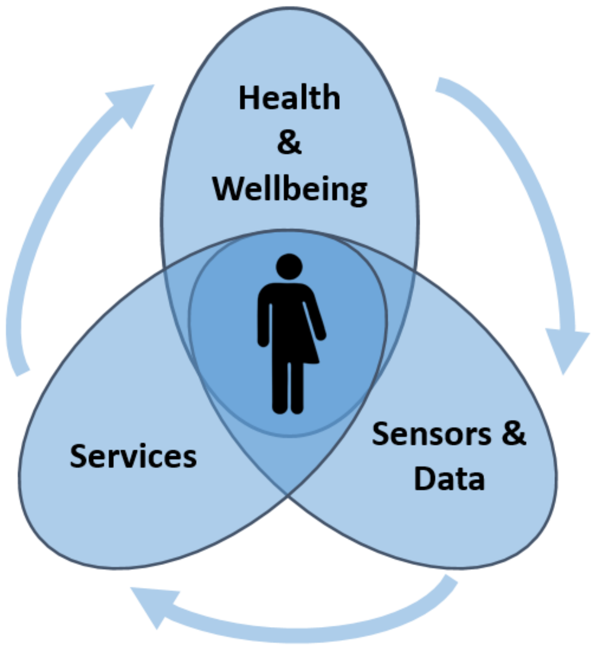

Figure 1: IoT for Health and Well-being

through the automatic control of airflow and heating or through dashboards showing the current status of the system.

However, given the multifaceted scope of the problem, in order to successfully implement such a system it is necessary to include expertise from several domains. By combining the domain expertise of researchers from various disciplines such as psychology, nursing, computer science, information systems, and service science research it might be possible to create IoT augmented milieus for health and well-being.

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