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Improving Well-Being in Schools - Lessons Learned from IoT Experts

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Abstract. The Internet of Things (IoT) is a source of knowledge about the surrounding environment and people in such an environment. The insights collected by IoT can provide the knowledge needed to improve people's health and overall well-being. Schools are one environment where IoT is scarcely applied, yet, it is expected that this is where children and teenagers spend most of their time. Drawing on previous findings, this paper presents preliminary results from qualitative inquiry investigating how and what IoT-based solutions could support health and well-being in elementary educational settings.

Keywords. IoT, Well-being, Expert interviews, User requirements, Health

1. Introduction

Children, including teenagers, typically spend most of their time at the school premises, and their educational performance, health, and well-being may be affected by the school environment [1]. Moreover, the school environment also affects the well-being of teachers and other school staff. Therefore, ensuring that the school environment supports flourishing well-being is essential [2].

Technologies such as the Internet of Things can assess the quality of the school environment. The ubiquitous IoT sensors can measure indoor quality indicators, e.g., oxygen level, dust particles, CO2, and temperature, to name a few. IoT might also be used to assess the well-being and health of individuals using more (e.g., wearables) or less (e.g., infrared cameras) invasive technologies. Despite the availability of these technologies in the market, it is uncommon for schools to apply them. One reason is that we need more insights on how and what IoT-based solutions could help to fulfill the needs or requirements of school staff and students.

In this research, we aim to gain such insights by asking, *How can IoT improve the well-being of students and staff?* To answer this question, we use a qualitative inquiry based on the previous research's findings, where we identified user requirements[2] defined in the case of a Swedish school[3]. We engaged with IoT experts to identify

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[2] The research is part of a larger project IoT in Schools—collaborative project building IoT testbed in school, engaging industry and public sector.

[3] The school was for students of 7th-9th grade. Interested reader can find more information about the Swedish school system on https://www.norden.org/en/info-norden/compulsory-schools-sweden.

possible scenarios of using IoT to build solutions that aim at improving health and well-being in the context of elementary school. The reported results give preliminary insights into the collected data.

2. Method

The expert interviews were used as a method for qualitative inquiry. Eleven experts working in the industry and academia participated. All experts had IT backgrounds and worked as privacy and security specialists, IoT engineers, or in managerial and sales positions in IoT companies. The interviews were conducted online, recorded, and transcribed. Each interview was approximately an hour long. Six interviewees were Swedish, and others were from Norway, Spain, Germany, the UK, and the USA.

The expert interview is one of the qualitative methods which focuses on the interviewees' knowledge—their expertise in a given field [3]. We chose expert interviews for two reasons. First, because the study is part of a larger project and in the previous studies, we discovered that generally, people have very little or no knowledge about IoT. Second, the interviews were designed based on the findings from our previous studies, where we identified user requirements based on the needs of the school staff (teachers and healthcare personnel) and students. We assumed that IoT experts, understanding IoT's technological foundations, can relate better to user requirements and shed light on potential IoT-based solutions that could be applied in school settings.

We choose the semi-structured interview approach to ensure a space for conversations between the interviewer and experts instead the strict format of structured interviews or overly loose conversations when using unstructured interviews [4]. The previously identified user requirements were core for the interviews. The interview contained three questions. First, we asked participants to briefly explain their relationship with IoT, focusing on their professional role. Second, we presented participants with user requirements (**Figure 1**) and asked them whether they thought these requirements (some or all) could be fulfilled with any IoT-based solutions. We instructed participants that they could think of their "dream solutions" and discuss not only the existing technologies but also future solutions yet to come. This part of the interview was the least structured and often led to a dialogue between the interviewer and experts. Lastly, we asked participants whether they could think of any barriers to applying IoT-based solutions in school settings and how to overcome them.

2.1. Data analysis

The interview transcripts were analyzed independently by two reviewers. Thematic analysis was used to identify potential patterns forming in the dataset. We used reflexive thematic analysis, following the steps recommended by Braun et al. [5]. First, researchers familiarized themselves with the data by reading through the transcripts. Next, they generated codes applying inductive orientation and creating semantic and latent codes. Then researchers discussed constructed themes. Lastly, they revised and defined themes in an iterative process. The reported results are preliminary and focus only on the topic of well-being, omitting barriers to IoT-based systems in schools. A few central themes were identified in the data set: Improvement of learning conditions, Improvement of teaching staff conditions, Safety of the school environment, Waste management and cleaning, and Data aggregation.

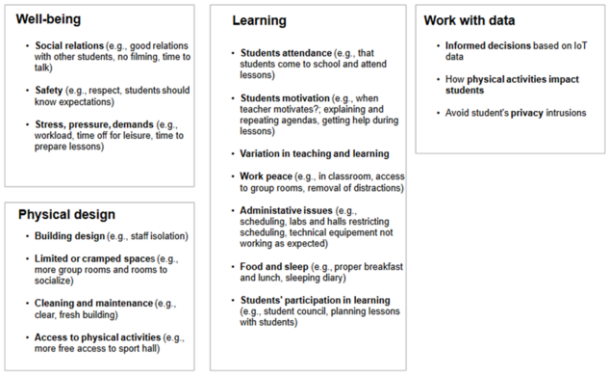

Figure 1. User requirements chart used during the interviews.

3. Results

Improvement of learning conditions. Experts discussed how IoT-based solutions could help students achieve better learning outcomes. They discussed how sensors measuring environmental changes, e.g., temperature, sound, and air quality, could be adjusted to ensure classroom well-being. They also discussed how IoT could help students learn programming or hacking devices implemented in school, preparing them better for their future digital life. Some mentioned how IoT could help detect learning issues just in time, e.g., by installing feedback devices in desks to enable students to ask questions anonymously. Teachers could receive questions immediately and address them. Such a solution could benefit students lacking self-confidence or who have learning difficulties. "You have a little button that you can press when you are confused. Well, obviously, you [...] might not want to be the one that says: I don't understand, and you know how it works. Like you always want someone else to be the one."

Improvement of teaching staff conditions. Experts mentioned how IoT could help teachers with assessing their own performance. E.g., microphones tracking changes in the voice tone could help teachers detect whether they are monotonous during lessons. Another idea was to use microphones to recognize how the teacher asks questions: is it a way that leads to pupils' engagement, or the teacher asks yes or no type questions? Others talked about creating better conditions for teachers through adjustments based on environmental sensors, as mentioned in the context of students. Similarly, sensors such as RFID could be used to measure attendance or automated adjustments of lightning in the classroom, potentially relieving teachers of some of their classroom duties.

Safety of the school environment. Interviewees talked about safety from two different points of view. First, they referred to safety in the context of incident response. E.g., wearable sensors or infrared cameras could automatically detect whether something happened to a student, e.g., a student fell. They also mentioned alarm systems, e.g., IoT buttons, that could be pressed in distress. The second point of view was to use environmental sensors to help detect harmful substances in the building, e.g., if there are any changes in the air (e.g., gas) or if students would smoke cigarettes at school premises.

Waste management and cleaning. Although intuitively, there might not be a direct link between well-being and waste management, some experts discussed it in the context of the school cafeteria and problems that often occur considering the dietary habits of youngsters. IoT could measure students' food consumption and inform the

kitchen about food popularity. Sensors could also help the cafeteria staff with recycling, e.g., cameras detecting where given items should be recycled, relieving the staff from the cognitive workload and potential stress. IoT-based solutions for cleaning and maintenance were obvious, e.g., cameras or sensors detecting dust particles or toxic substances in the air. Some suggested AI-based systems that cleaning companies could use. For instance, "I think IoT could play a vital role in like measuring air quality and it could also most likely just measure [...] how often the facilities are cleaned and maybe if you have some AI interpretation of what the cleaner looks like or [...] you could tag [the cleaner with something] that would, you know, be recognized by an AI solution."

Data aggregation. This theme was reoccurring among the experts' responses; IoT might not be sufficient to help ensure well-being in school settings. Its role is significant, but there is a need for algorithmic transformation of data and correlation of information coming from various IoT sensors. Other information, e.g., self-reported data, performance, food consumption, or external events that might affect students' behavior (e.g., sporting or gaming, which may affect students' sleep and, consequentially, school performance), should also be considered.

Levels of CO2 in a room could be correlated with students' cognitive performance to enable an understanding of what exact CO2 levels the classroom should have to ensure students' progress. Similarly, combining information about the number of students in the cafeteria with details of food consumption could be used to prevent students from leaving school premises to purchase takeaway; "[IoT can] measure the number of students that actually sit down and eat. [...] but you need to correlate the IoT data often with other data points like today it was lasagna, and we had 95% attendance from the students." Live information about the food through a system connecting with students' mobile phones or public displays could encourage students to stay in the school cafeteria, "in winter, we want […] the soup hot. […] I receive a signal that the soup is hot, [...] they receive the same message at the same moment, they would all run to get the hot food."

Experts mentioned how information from more sophisticated sensors measuring physiological responses could be used with machine learning to gain more insights into students' well-being. E.g., "So if you talk about future solutions, anything related to focus and even happiness, emotions, I think it would be very interesting if you could capture them and then take that data, crunch it to try to find some sort of meaning."

Correlated data can help with scheduling; e.g., indoor quality indicators combined with data from wearable sensors may predict when people should take a break and leave a classroom. "[I]f there are many people there and we can measure […] bad air and we can see that people's pulses, for example, increasing [...] we could just possibly [say] you need to get out of the room for 10 minutes and take a break."

4. Discussion

The interviewees gave good examples of approaching and designing IoT solutions to improve well-being. Only some of the requirements were left without any design proposal, implying that IoT is of interest to the school environment. The design varies concerning how data should be collected to meet the requirements. One example is the suggestion to correlate the information to help schedule attendance, e.g., RFID solutions. That the design varies implies a variation in implementations, requiring a high grade of knowledge about collecting data. Nowadays, the solutions are mainly stand-alone, meeting one or two similar requirements and failing to support student and staff well-

being fully. AI and ML could be utilized in systems integrating data from various sensors to present it in an understandable and useful manner. Although technically, such systems can be developed, their use might be constrained due to privacy and security risks, which are particularly important when processing data about vulnerable populations, such as minors. Currently, few IoT solutions focus on improving student and staff well-being. One reason could be the need for IoT knowledge within elementary schools or organizations supporting schools' IT solutions. The required knowledge is unique and limited to many IT staff working mainly in IT consultant companies. Another reason could be that well-being is subjective and, therefore, experienced as hard to measure objectively. Still, the findings show realistic ways to measure what is subjective, such as microphones assessing teachers' performance. Lastly, it might be that IoT suppliers do not focus on designing solutions within the school environment.

4.1. Limitations and future work

The present study was preliminary, being part of a larger project, and could be improved. E.g., we did not interview health professionals. However, the user requirements = used in the expert interviews were based on the school staff, including health personnel. Moreover, as the present research aimed to identify potential system design recommendations, non-tech professionals might lack an understanding of technology and are unlikely to provide significant contributions. Still, future work could target health professionals to assess their views on IoT-based systems for school well-being. Lastly, we applied an inductive approach that was suited to exploratory study. Future studies could apply a specific theoretical framework and deductive analysis.

5. Conclusions

Based on previously collected requirements, the IoT experts presented various ideas for designing IoT-based solutions and how data should be collected and aggregated to meet these user requirements. Nevertheless, the discussed solutions were stand-alone, adding to the complexity of using them to meet the requirements. We conclude that IoT suppliers see potential in designing IoT applications to increase the well-being of students and staff. Nevertheless, they still need to discuss how to present the data to decision-makers—staff, students, or caregivers.

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