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Conceptual IoT Implementation in Post-Pandemic School Activities: A Case Study in Elementary Schools

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Abstract:

Many studies empirically discuss the use of technology in overcoming pandemics in education. Generally, research discusses the use of technology in online teaching and learning activities. When viewed from the information technology layer, these studies focus on discussing the use of the software layer. This study examines conceptually about the utilization of the hardware layer in information technology, especially *Internet of Things* infrastructure which is used to help the community in carrying out their daily activities in the new normal era. Conceptual ideas are applied by taking a case study in education, especially in the elementary school environment. The urgency is that there are many stakeholders in the elementary school environment, especially children who need extra attention and supervision in carrying out post-pandemic activities outside the house. These stakeholders are a group at risk of being exposed to the virus because the majority have not received protection in the form of vaccination and the level of adherence to health protocols is low. This creates a risk for vulnerable groups, namely children, families, and teachers. It is necessary to integrate cyber physical systems that help minimize these risks. This conceptual idea describes the concept of IoT technology to minimize the risk of virus transmission and the strategies that allow it to be applied in the elementary school environment. With a top-down approach, it describes how the IoT system protects children and teachers from going to school, doing activities in the school environment, participating in learning in class, to completing learning.

Keywords: Elementary School, Internet of Things, Information Technology, Post-Pandemic

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Introduction

Restrictions on community activities due to the Covid-19 pandemic have been running for almost two years since early January 2020. The government has begun to relax the rules on activity restrictions and has begun to reopen public facilities and services in several sectors such as schools, shopping centers, tourist attractions, offices, and other non-critical places (Sundawa et al., 2021). All sectors such as business, economy, education, tourism, and the creative industry must recover soon (Bryant et al., 2020; Handayani et al., 2021). However, the opening of these public service facilities will be carried out in stages to prevent an increase in cases of virus transmission (Pratama et al., 2021). In the education sector, the opening of school facilities services is also implemented gradually (Safira & Ifadah, 2021). At the elementary school education unit level, it was initially doubtful to hold face-to-face schools because according to the cluster distribution data shown in Figure 1, elementary school education units accounted for the highest transmission cases.

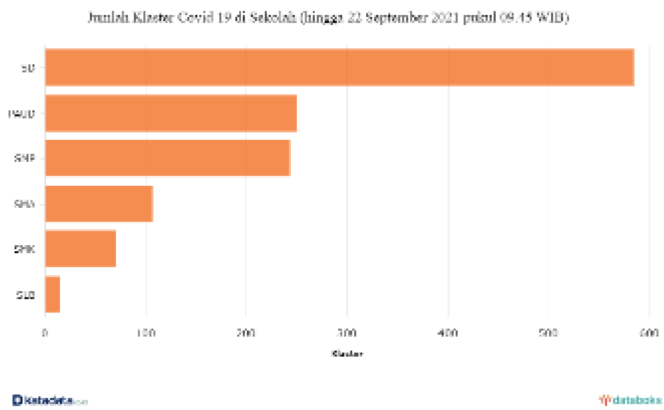

Figure 1. Distribution of clusters of Covid-19 transmission at every level of education
(ref:https://databoks.katadata.co.id/datapublish/2021/09/23/imbas-ptm-1299-sekolah-jadi-klaster-covid-19

Online learning is mandatory at all levels of education to minimize the spread of COVID-19. In supporting online learning activities, many online platforms were used, one of which is Google Classroom proposed by the Ministry of Education and Culture of the Republic of Indonesia. However, the sudden change from offline to online learning makes it difficult for students, especially elementary school students, to use the platform (Fauziah & Nurwulan, 2021; Zulherman; Zain, 2021). Elementary schools cannot rely solely on online learning because of various limitations ranging from ownership of digital devices to the digital competence of elementary school students, so it is still necessary to carry out face to face learning or online learning with various active learning methods (Hatta et al., 2020). Several studies also show that face-to-face learning provides better learning outcomes than online learning (Stevens et al., 2021). Viewed from the availability of human resources and users (in this case students), the elementary school environment also faces the risk of transmission because its human resources are prone to being exposed to the virus in terms of age.

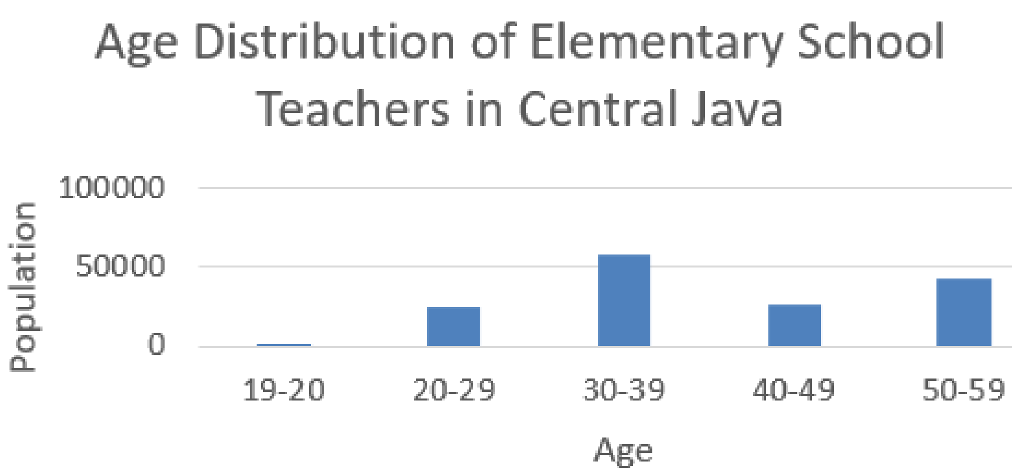

Figure 2. Distribution of Teachers Age in Central Java, Indonesia
(sumber: http://statistik.data.kemdikbud.go.id/index.php/page/sd

Figure 2 takes a sample of data for the Central Java region because it is one of the provinces with the worst virus spread rate in Indonesia (Fransiska, 2021). The diagram in Figure 2 shows that the largest population of teachers is in the age range of 30-39, followed by the range of 50-59, and the third of 40-49. The population is clearly larger than teachers in the age range of 20-29, who are claimed to have good immunity and the majority do not have comorbidities. The most of the covid patients were over 40 years old. Furthermore (Aritonang et al.,2020). The mortality rate for Covid patients was dominated by this age (Rory et al.,2021). This is in contrast to the three age ranges above, which are individuals at risk of contracting the virus. However, with various considerations, face to face learning must still be carried out with strict health protocols.

The level of compliance with health protocols in the school environment is also an important issue (Ludvigsson, 2020), especially in the elementary school environment. Various efforts in the form of written and mandatory policies regarding health protocols did not really increase the level of compliance. Another technology-based method is needed to overcome this problem. This study describes the application of information technology, especially the Internet of Things, to support a smart school environment that is able to maintain and force the people in it to implement health protocols. Such an application was done with a conceptual elaboration model accompanied by a study of the successful application of IoT in the environment before and after the pandemic. This article describes how IoT involves people in the environment they are in, and how the IoT works to form a force compliance system for the health protocol aspects of people who carry out activities in elementary schools during the post-pandemic period.

Related Works

Internet of Things (IoT) is a data communication concept where a certain object has the ability to transmit data via a network and without any interaction between humans or from human to computer device; communication occurs between machines (Atzori et al., 2010). Internet of Things is often identified with the use of wireless devices as communication devices to deliver data in internet communication lines. IoT devices can also include the use of sensor technologies that transmit data to each other that is used for the communication process.

In the last ten years, IoT has begun to be applied in various fields, starting from applications in the field of defense and public security (Fraga-Lamas et al., 2016); industry and manufacture (Wollschlaeder et al., 2017); smart city infrastructure fully supported by automation technology (Zanella et al., 2014); health care services and medical records; optimization of agricultural management through smart agriculture (Tzounis et al., 2017); service automation in offices, schools, and universities (Sharma et al., 2020; Tokarz et al., 2020); and context-aware setting towards a smart environment in general (Al-Fuqaha et al., 2015).

There has been no research that discusses conceptually in the form of literature reviews, critical reviews, ideas, or case studies on the application of IoT in the elementary school environment. Seeing the background on the level of compliance with health protocols in the elementary school environment during the post-pandemic period (Lee & Raszka, 2020; Ludvigsson, 2020), this idea is needed as a guide for creating an IoT system framework as well as a guide for further development. This article reviews the implementation of IoT infrastructure in the elementary school environment. The discussion is about the application of IoT for environmental sensing, context-aware systems, object detection, automation, and notification of the role of each environmental sensor to an integrated system whose data can be utilized by stakeholders. This IoT case study is expected to help minimize pandemics in the elementary school environment.

Before entering the discussion about the application of IoT at the elementary school level, it should be noted that IoT has been applied in the educational environment. In the educational environment, IoT is applied as the main supporting device for smart school infrastructure. Smart school refers to the integration of information technology in the form of a cyber physical system that supports the automation of the school environment in the form of environmental sensing, automatic classroom management, automatic class attendance, remote laboratory, laboratory automation, electrical automation, smart doors, and several other environmental automation based on electronic devices controlled through the internet (Kassab et al., 2020). For example, the application of IoT for building automation and electronic devices in an educational laboratory environment is proven to be able to streamline electrical power consumption (Hatta & Budianto, 2019). In addition, there are also examples of successful applications of IoT for automatic attendance systems and automated payroll systems in higher education environments that have received good responses from users (Al_Janabi, 2020). In terms of supporting practical laboratory facilities, IoT can also have an important role. IoT can be applied as a remote laboratory, especially for practical facilities in the fields of mechanical engineering, robotics, and control engineering. Through a remote laboratory, students can remotely control practical devices, this is very useful during a pandemic (Tokarz et al., 2020).

So far, the application of information technology as one of the tools to suppress the pandemic in the world of education, the majority talk about its advantages in supporting online learning such as the use of e-learning tools and their learning strategies (Rahma et al., 2020; Zulherman; Zain, 2021).. By referring to the research background and relevant research that has been described previously, the novelty aspect of this article is to take the discussion domain of one of the contemporary information technology products, namely IoT, and conceptualize it to be applied in elementary schools as the urgency of its application in elementary schools has been described in the research background. This research can also be used as a reference for further research on how IoT influences interdisciplinary fields: health, social-humanities, and education.

Research Method

This study used a qualitative approach with a literature review research design and a case study. The research steps are shown in Figure 3, starting with a literature review, selecting case study sites, designing an IoT framework, analyzing the results of the design and validation, and drawing conclusions. This study used secondary data, namely by conducting a literature review on scientific articles published and indexed on the reputable scientific article indexing engines, Scopus and DOAJ. Articles that are used as references are articles published in the 2010-2021 period. The keywords used during the search stage were internet of things, internet of things smart school, internet of things education, internet of things pandemic new normal covid-19.

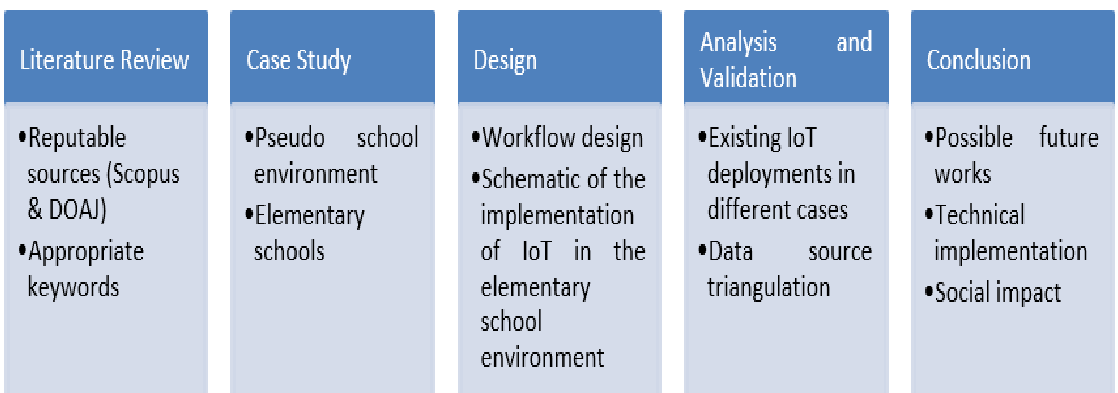

Figure 3. Research Design

After filtering the articles according to the discussion and data as needed to conceptualize the IoT infrastructure, the next step was to choose case study locations. Since elementary schools have a low level of awareness of health protocols and a high transmission rate because the students, teachers, and staffs had not been vaccinated and many were in the vulnerable age range, elementary schools were used as the case study place for the application of IoT.

The next stage was to design the IoT infrastructure framework. The framework design used the workflow design approach (Raibulet & Arcelli Fontana, 2018). By employing three actors in the workflow design, namely students, teachers, and stakeholders. To show how it works, the work steps start from the scenario of students and teachers leaving for school, entering and engaging in school activities, and having teaching and learning activities in the classroom and laboratory. Stakeholders obtain all activity data of IoT devices that interact with teachers and students which are processed in the cloud infrastructure.

After designing the framework, the next step was to analyze and validate the framework design. Validate data sources by comparing the findings of previous studies contained in scopus indexed journal articles. The analysis was carried out by identifying and determining the type of IoT technology in the design framework, then the application was triangulated with the application of IoT that already existed in secondary data sources. The last stage in this study was drawing conclusions that lead to recommendations for the next possible research in terms of technical implementation and the social impact of the application of the IoT.

Results and Analysis

This section describes sequential start from the proposed framework, a description of the IoT infrastructure and its supporting components given a numbered index, as well as how sensors and actuators work in the school environment when responding to system users (in this case teachers, students, and stakeholders). The next sub-section is to analyze the possible implementation and the way IoT components work which are explained by triangulation of data on secondary data relevant to this study.

Proposed Framework

The proposed framework was designed based on a pseudo-case study, which means that it can be applied to the majority of elementary school environments. Pseudo case studies are taken based on references from previous research. The application of IoT concepts in virtual schools. Because this research conceptualizes the application of IoT for an ecosystem in which there is a lot of human interaction, references are also taken on the application of the IoT concept to public facilities (Saheb & Mamaghani, 2021). The pseudo case study was chosen because there was no research sample that discusses the complete application of IoT integration in the elementary school environment. Previous studies that have been reviewed have only discussed the application of IoT in partial handling (sub system) of the pandemic, for example, only discussing the detection of masks or body temperature. There had been no research that discusses the complex integration of IoT for handling pandemics in the elementary school environment. Because it took a pseudo case study, the design of this proposed framework can also be applied to various school environments that have the same characteristics (having entrance gates, indoor areas, outdoor areas, and crowded activities). Figure 4 below is a conceptual design of IoT infrastructure applied to elementary schools in the post-pandemic era.

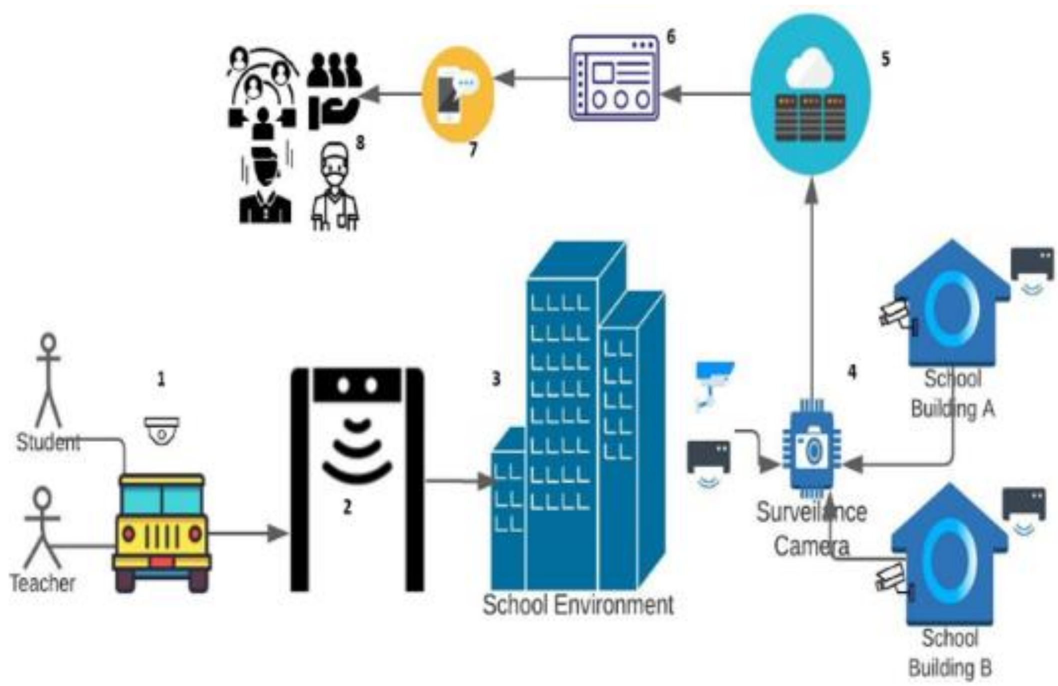

Figure 4. Conceptual Model of IOT in Primary School Post Pandemic

Figure 4 above describes the conceptual model of the IoT framework that can be applied in elementary schools in the post-pandemic era. In the figure, a small numbering indexation is provided to describe the IoT infrastructure in the form of sensors. These sensors work on each teacher and student activity. The ecosystem can essentially be used for anyone who has activities in the school environment, but in the conceptual design, only two actors are described, namely teachers and students, who carry out full activities in the school environment. Students are not limited to students who go to school by the school bus but also those who go by themselves and are dropped by their parents that can use this system from number 2 (smart school gate) before entering the school environment. Screening of activities that can be monitored by the IoT infrastructure will continue after the teacher or student enters the school gate. After the teachers and students enter the school gate, the next task is the activities around the school environment as shown by index number 3 in Figure 4. In these activities, teachers and students also interact with the existing IoT ecosystem. Proceed to activities in the school room, students and teachers follow and carry out classical teaching and learning activities or practicum in the classroom and laboratory (shown by index number 4). A detailed explanation of each component depicted in Figure 4 is provided in Table 1. The IoT infrastructure that can be applied to the school environment include the following elements.

Table 1. Mapping and Identifying IoT Technologies in Conceptual Model

Index Number	IoT Infrastructure/Feature	Device Involved	Technology Readiness
1	• Smart Vehicle/Bus	• Arduino UNO • Digital temperature sensor and LCD • IP Camera for face mask detection	• TRL Level 9
2	• Smart School Gate	• Arduino UNO, Raspberry Pi • IP camera for mask detection • Body temperature sensor • Automatic hand sanitizer • Sanitation tunnel (if possible) • UV Sanitation (if possible)	• TRL Level 9
3	• Entire school environment (outdoor area)	• Arduino UNO or Raspberry Pi • IP Camera for mask detection and social distancing • Automatic hand sanitation • UV sanitation	• TRL Level 9
4	• School environment (Indoor area, classroom, and laboratory)	• Arduino UNO or Raspberry Pi • Surveilance camera • Indoor air quality monitoring • Mask detection • Contactless attendee • Automatic hand sanitation	• TRL Level 9
5	• Cloud IoT data processing	• ISPs, broadband network access • Cloud servers/VPS • Operating system	• TRL Level 9
6	• Data dashboarding	• Web interface • Database	• TRL Level 9
7	• Notification sent to stakeholder	• Mobile phone	• TRL Level 9
8	• Stakeholder and decision maker	• Policy for safety, tracking, and compliance management	• TRL Level 9

In table 1, we divide the IoT infrastructure into six main indexes that have their respective roles. The first index, IoT infrastructure is placed on student shuttle vehicles (if the school uses shuttle vehicles). The second index, IoT infrastructure is placed at the school entrance gate. The targets of technology in the second index are teachers and students who will enter the school gate. The third index, IoT infrastructure is placed in the outdoor environment of the school. The target of technology in the third index is people who are active in the outdoor environment at the school. The fourth index, IoT infrastructure is placed in the indoor environment (classrooms, teacher offices, and laboratories). The targets of technology in the fourth index are people who are active in the school rooms: teachers, employees, and students. The fifth index is a cloud-based computer network infrastructure that is used as a data processing platform obtained from environmental sensing in the first to fourth indexes. The captured data are then displayed statistically on the dashboarding data in the sixth index. The data will be sent to stakeholders, namely the regional COVID-19 task force, teachers at the managerial level positions, and other stakeholders. Technology Readiness Level, hereinafter abbreviated as TRL, is the level of maturity or readiness of a technology research and development result that is measured systematically so that it can be adopted by users, either by the government, industry or society. TRL Level 9 means the System is truly tested through successful operation.

The explanation of each IoT infrastructure mentioned in Table 1 will be described in more detail in the following sub-topics.

1. Body Temperature Sensor

Measurement of body temperature can be the basis for determining the health level of students who will go to school using a pick-up vehicle. Knowing a student's body temperature is a reference to find out whether the student is experiencing the initial symptoms of COVID-19, namely fever. Body temperature measurements generally use an infrared thermometer and are carried out manually by officers. In the measurement process, the obstacle that occurs is that the officer must be close to an object that might increase the risk of being infected with the COVID-19 virus and will cause an increase in cases. By making a body temperature measuring device using IoT technology and then placing it at the main entrance, namely on public transportation and school entrance gates, the body temperature of teachers and students can be monitored (Yousif et al., 2021).. If the body temperature exceeds the threshold, then the teacher or student is not allowed to enter the school environment.

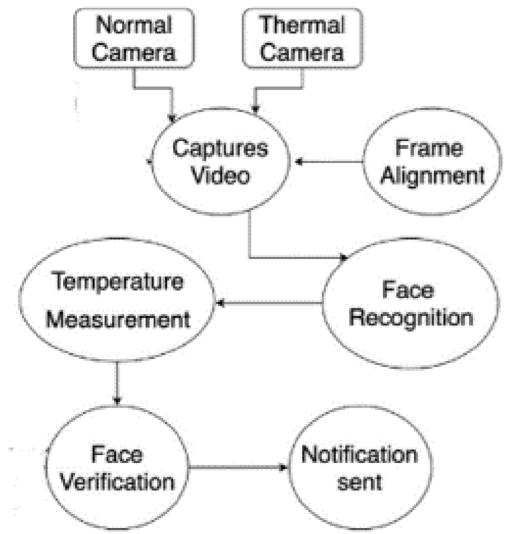

Figure 5. Body Temperature Detection Workflow

Thermal sensors are integrated in the camera that detects students or teachers when they are about to cross the gate. The data captured by the camera is the face of the person scanned by the camera. Data are captured using face detection technology. The flow of how the system works is as follows. People's faces are captured by thermal cameras and normal cameras, then formatted in the form of video capture. At that time, frame alignment occurred to detect people and classification based on the temperature obtained. The system will display the status of people whether they have a fever or not.

2. Mask Detection

The detection system for wearing masks does not absolutely prevent the spread of COVID-19 in the elementary school environment. However, it can give positive results as a controller for compliance with the use of masks in the environment (Bonal & Meti, 2021). The mask detection system can be integrated with smart homes using IoT. Mask detection is carried out via an IP camera that will send an alert if there is a violation of the mask use protocol (Cerit & Bayir, 2020). Previous research throughout 2020-2021 has succeeded in applying AI technology with deep learning methods applied to IoT infrastructure; this technique plays a major role as the basis for mask detection technology (Alsaydia et al., 2021; Elsayed et al., 2021; Gedik & Demirhan, 2021; Kumar et al., 2021; Lad et al., 2021).

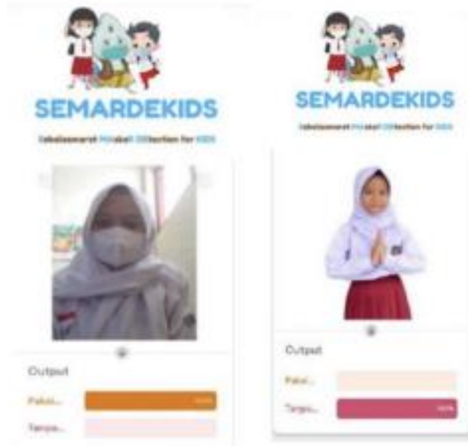

Figure 6. Mobile Based Mask Detection for Primary School Student

The application of mask detection is one of the most popular studies on the topic of preventing COVID-19 based on IoT technology in the 2020-2021 period. Various public areas such as airports, train stations, shopping centers, and other public areas have implemented this mechanism. In the elementary school environment, the mask detection system can be applied to various crowd-prone locations such as school entrance gates and the entrance of every important room in the school (Varshini et al., 2021),: classrooms, teacher rooms, laboratories, and some other indoor areas (Takrim et al., 2021), canteens, and outdoor area.

3. Disinfectant Tunnels

To treat infections that are spread through contact with contaminated surfaces, disinfectant tunnels can be applied. A disinfectant tunnel is more complex than hand sanitizer, because it not only disinfects hands, but all surfaces of objects. It can also be determined whether to use water-based or fogging-based sanitation. The disinfection material can be sodium hypochlorite solution with a concentration of 0.1%; it can eradicate the virus within one minute (Panda et al., 2021).. Another compound that can be used in the tunnel is povidone iodine, which has the same properties as sodium hypochlorite but with a safer effect on people (Mohtar et al., 2021).

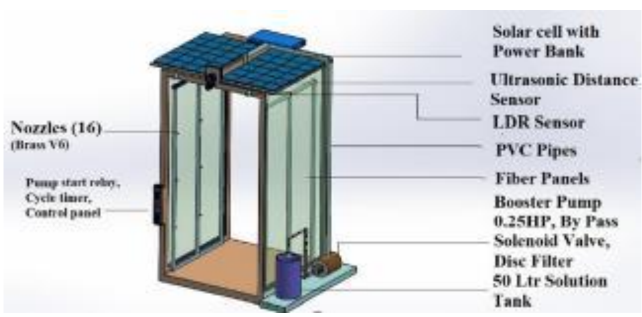

Figure 7. Example Prototype of Disinfection Tunnel (Pandya et al., 2020)

Placing the disinfectant tunnel at the school entrance gate is enough, because the cost of making it is not cheap and the manufacturing stages are quite complex. Disinfectant tunnels can be integrated with IoT to automatically disinfect people detected passing through the tunnel (Pandya et al., 2020).. In a more advanced application, disinfectant tunnels can be integrated with body temperature and face mask detection facilities and automated through IoT devices (Bhogal et al., 2021).

4. UV Disinfection Machine

The increasing COVID-19 threat in public facilities with the interaction of object exchange is the basis for the idea of making UV disinfection. UV disinfection can be applied in classrooms, teacher rooms, laboratories, and several other indoor facilities, as is described in the previous research on the application of UV machines in public spaces (Sonawane et al., 2021). The simplest use is to install a UV lamp as a means of passive and constant disinfection in indoor spaces; this will help disinfect the surface of objects (Lualdi et al., 2021).

Figure 8. Example of UV Disinfection Lamp

Another form of UV disinfection is for surface sterilization or a toolbox for conveyor-shaped disinfection that can be controlled via IoT devices (Yadav et al., 2021). The application of this conveyor disinfection model is more expensive than UV lamps as it can be applied to conveyor machines in public transportation stations. It can also be applied to the school cafeteria. The disadvantage of this UV conveyor is that it is more expensive than UV lamps.

5. Indoor Air Quality Monitoring

During a pandemic, good air circulation can help prevent the virus from entering the body through breathing. Indoor air is potentially more polluting than outdoor air. This air quality monitoring system has been implemented in the hospital environment because hospitals with isolation facilities became one of the clusters for the spread of the virus (Kenarkoohi et al., 2020). Previous research also discusses the application of a data driven air quality prediction system in the university environment (Tagliabue et al., 2021). Referring to the previous research, the air quality monitoring system is also very possible to be applied in the school environment, especially elementary schools. In the elementary school environment, most activities are carried out in classrooms or other indoor spaces. Thus, it is necessary to pay attention to air quality and circulation to reduce the possibility of virus transmission in the room.

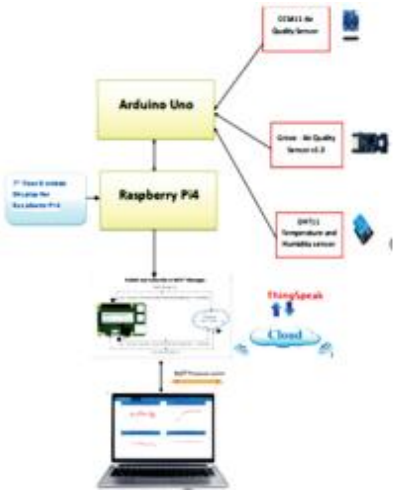

Figure 9. Low Cost Air Monitoring using Arduino and Raspberry (Faiazuddin, 2020)

Air quality monitoring system can be implemented with low cost by using Arduino microcontroller board (Kaliszewski et al., 2020) or to be more advanced, by using a Raspberry Pi microcomputer (Faiazuddin, 2020) as shown in Figure 9. The two mechanisms can be controlled through a series of IoT infrastructure to produce an intelligent air monitoring system. By looking at the population and activities in elementary schools, which are quite dense and intensive, if the air quality monitoring system is further developed, it can be used as a predictive analytic engine (Mumtaz et al., 2021) or early warning system

(Peladarinos et al., 2021) to detect the potential for transmission in the elementary school environment. This will greatly assist in handling the outbreak and controlling the transmission of COVID-19.

6. General Building Automation for Classrooms and Laboratories

   The last sub-system from this proposed framework is general building automation based on IoT. General building automation includes smart doors, automatic lamps, automatic air-conditioners, and other forms of home or building automation. Building automation in the context of use in the school environment is not much different from building automation in the office environment. The concept of building automation that can be applied to this framework includes, among others, the contactless attendee management system (Yousif et al., 2021), automatic classroom, laboratory, and office doors (Hatta & Budianto, 2019; Varshini et al., 2021) and laboratory automation that prioritizes remote activity and contactless features (Bindu et al., 2021; Tokarz et al., 2020).

   The main purpose of general building automation in the classroom, office, and school laboratory is solely to reduce people's contact with the surface of room facilities, not to prevent full virus transmission. Compliance with applicable health protocols is still required, assisted by an automatic compliance management system from the five aspects of the IoT sub-system that have been discussed previously.

Conclusion

This article describes a conceptual framework about contemporary technologies that are integrated into the IoT system as an infrastructure to help prevent the transmission of the COVID-19 outbreak in the elementary school environment. The elementary school environment requires special attention regarding its relationship with the possibility of the formation of new clusters of the spread of the COVID-19 virus. This makes the development of the IoT framework as described above necessary. Based on a literature review of secondary data taken from indexed articles of reputable publications, many similar systems have been developed, but they do not specifically address the application in elementary schools. The results of the review show that a similar system can be applied in elementary schools because the majority of systems are stated to have technology readiness at level 9 (TRL level 9) and a good success rate of application in each application domain, although it does not eliminate the virus. Future studies are needed on the successful implementation of social aspects such as the level of technology acceptance, ease of use, user experience, and usability. In addition, the success of implementing this system in reducing the rate of transmission of COVID-19 in the elementary school environment also needs to be measured comprehensively.

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