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A Preliminary Study on Promoting Contextual Teaching and Learning Using Smart Water Quality Sensors

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ABSTRACT

Building awareness among students on the issues of natural environmental phenomena has always been a challenge due to the difference in location between the student and the observed phenomena. The issues of the natural environment have been a part of the curriculum in elementary schools. One of the lessons taught on the natural environment in elementary schools is related to the water condition in various areas filled with water, such as ponds, rivers, lakes, etc. Currently, learning in the natural environment is based on text, images, and videos, and learning activities using real-time data is still rare. This study presents the development of an IoT-based Smart Water Quality application prototype. The prototype consists of conductivity, pH, oxygen levels, salinity, and turbidity sensors. The IoT prototype can also be used to automatically monitor fish, shrimp, and other species in aquaculture ponds. Using the IoT-based Smart Water Quality application prototype, teachers can enhance students' higher-order thinking skills by designing learning activities using real-time data to identify, compare, and classify various concepts or phenomena.

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I. Introduction

In a green economy, business growth is carried out by public and private investment through economic activities, infrastructure, and assets that encourage the reduction of carbon emissions and pollution, increase energy and resource efficiency, and prevent the loss of biodiversity and ecosystems. Green economy refers to an economic model that increases human well-being and social equity while significantly reducing environmental risks and ecological scarcity as mandated by the United Nations Conference on Sustainable Development (Rios+20). This declaration affirms and supports the concept of the green economy in the form of job creation and skills development, to lift people out of poverty and build greater social cohesion [1].

The use of smart water sensors based on the Internet of Things (IoT) technology aligns with the principles of the Green Economy in several ways. Smart water sensors enable real-time monitoring and data collection of parameters such as pH levels, dissolved oxygen, turbidity, and pollutant concentrations in water bodies. By promptly identifying and addressing pollution issues, these sensors contribute to preserving and conserving water resources, which are vital for sustaining ecosystems and supporting various economic activities. This tool optimizes water management practices. By efficiently managing water resources, unnecessary wastage can be minimized, reducing energy consumption and costs associated with water treatment and distribution. This optimization aligns with the principles of resource efficiency and sustainable resource management promoted by the Green Economy. Developing, producing, and deploying these sensors create new job opportunities and drive technological advancements in environmental monitoring. As businesses and industries embrace these technologies, they contribute to the growth of a green tech sector, which plays a significant role in the transition to a more sustainable economy. This awareness can be built through education by integrating a structured green economy into the curriculum [2].

The obstacle faced in building awareness of this global issue is that it is still difficult to present real natural phenomena to students, particularly due to the distance between the location of students and the observed phenomena. So far, the learning material is based on text, images, and videos. Furthermore, relatively few learning activities still use real-time data to gain actual experience. The limited availability of media causes the level of interaction of students with actual phenomena to be less than optimal. In line with this integration goal, IoT-based devices can be used to experience a phenomenon in real-time in learning [3]. IoT is a technology that can be used to observe and monitor phenomena using smartphone sensors anywhere and anytime in real time [4]. Many studies confirm that IoT brings good changes for educators in bringing phenomena into learning [4]–[7]. IoT technology can be developed to build awareness of the natural environment. Thus, it is crucial that IoT is introduced to children at an early age in elementary schools. Theories related to cognitive development explain that elementary school students are still in the stage of developing their concrete ways of thinking [8]. In the elementary school curriculum, the topics on the natural environment are covered in 3rd-grade elementary school [6], in which one of the activities relates to water conditions in various places such as ponds, rivers, or lakes. Using the IoT device as a learning tool, higher-order thinking skills at this level can be developed by designing activities that allow students to identify, compare, and classify various concepts or phenomena. Teachers need to develop a learning module that includes IoT technology; however, learning activities that include IoT in learning the natural environment at the elementary education level are still lacking. This study attempts to address this issue by developing an IoT-based Smart Water Quality prototype that uses sensors to monitor water conditions by capturing data on the water's conductivity, pH, oxygen levels, salinity, and turbidity using sensors. The IoT prototype can be used for automatic monitoring of fish, shrimp, and other aquaculture ponds. The learning activities that include using data captured by the IoT device in real time could enhance students' critical thinking skills, thus, internalizing their awareness of the natural environment from an early age.

II. Theory

IoT in Learning

IoT is a technology that can be used to monitor various conditions using the internet network so that data can be obtained remotely using a smartphone or other device [9]–[11]. Three characteristics state a technology using IoT: being able to observe phenomena remotely in real-time, provide information quickly and accurately and display multiple data in one device [12]. IoT can be used to help provide an explanation of abstract concepts for understanding a phenomenon. Currently, IoT is widely used in industry, games, medicine, and the military, while in education, it is still rarely used [12], [13]. There are many ways to use IoT in learning. IoT can be integrated with worksheets. The characteristic of a good worksheet is the existence of directed activities in independent learning. A good worksheet contains reading menus, assignments, exercises, and evaluations. IoT in the worksheet can be inserted into the assignment activity. After reading the material, students will gain better prior knowledge. Furthermore, in the assignment activity, students can monitor certain magnitudes of the observed phenomena and compare various conditions. Teachers can create scenarios to compare places where IoT has been installed.

IoT-based Worksheets and Learning Outcomes

IoT is one of the technologies that developed rapidly in the era of the Industrial Revolution 4.0 [3], [11]. The potential of IoT is widely used in various fields to increase productivity. In education, IoT-based learning media, including worksheets, also influence learning practices [5]–[7]. The level of ability to present a condition remotely in real-time allows student interaction and the concepts being studied to be higher. IoT can present various phenomena that are relatively difficult to present in the classroom due to various limitations. The level of interest in learning in certain fields can be increased by using more interactive media and explaining phenomena more concretely [9], [13]. IoT-based devices can also be used in science to explain various concepts, including climate change. The provision of IoT-based media that explains this phenomenon is an alternative to increasing understanding of global issues, one of which is water quality monitoring which triggers increased learning outcomes.

In many research studies and theories, interest in learning can be used as a predictor for learning success. The more interested students are in the content being studied, the more students spend time and effort to master the material so that it has an impact on performance or learning outcomes [14]. Conversely, when students lose interest in learning, it significantly affects learning outcomes negatively [15]. Psychological studies also show that interest in learning can mediate learning outcomes [16], which can be explained by self-determination theory [17]. Included in recent learning research using IoT-based media also shows this relationship in various subject matters [18]. However, it is undeniable that there are concerns that this media only makes students interested in

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the media itself because IoT-based media is something new both at the interactive and technological levels. This concern is valid as students are not familiar with the use of IoT technology in their learning. Studies that discuss this relationship can provide information on integrating IoT technology with suitable learning strategies to optimize the learning process.

Conceptual Model

Based on theoretical studies and similar research results, the conceptual model for this research is shown in Figure 1.

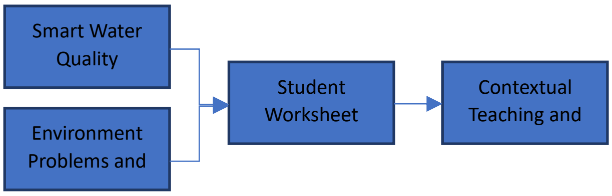

Figure 1. Conceptual Model

III. Method

Research Context

Various purposes can use this IoT-based application. This can be seen in the sensors installed in the application. However, the focus of developing this application is to support learning, particularly relating to the natural environment with the CTL approach. The supporting tools for this research are HP Core i3 Laptops, Android phones, various sensors, and Blynk software. This study adopts design research as the research model with the stages of needs analysis and prototyping.

Needs analysis was carried out by conducting interviews and focus group discussions (FGDs). Student interviews were conducted to understand the characteristics of students as users. The FGDs involved teachers, material experts, and learning experts to determine the appropriate level of using this tool in a learning environment according to learning competencies. The implementation has yet to be carried out at this stage in learning. Several possible applications with multiple learning modes are discussed in the discussion section.

System architecture

Figure 2 presents the block diagram of the IoT-based Smart Water Quality application. The IoT-based application consists of four layers: sensor, control, cloud, and output. The sensor layer consists of all four sensors. These sensors capture the data from the water and send the data to the control layer. In the control layer, the microcontroller will read the data and sends the data to the cloud that resides in the cloud layer. In the output layer, the data will be visualized as a dashboard in the user's smartphone through the mobile application. The mobile application was developed using Blynk software. Blynk is used to manage communication between IoT devices and smartphones. The software was downloaded from http://j.mp/blynk Android or http://j.mp/blynk iOS. The Blynk platform controls the IoT device and displays, stores, and visualizes the data. IoT device is equipped with a microcontroller board and sensors.

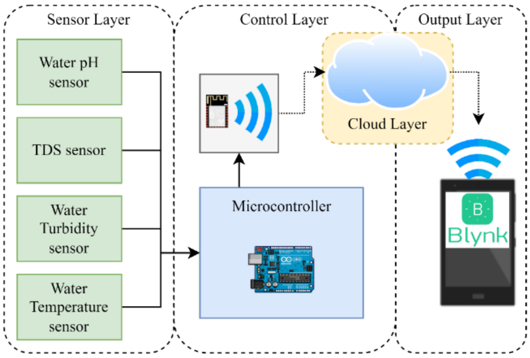

Figure 2. IoT block diagram

Table 1 presents the microcontroller board, sensors, and indicators measured on IoT devices. The BNC PH sensor module with PH Probe and MSP340 sensor measure the water pH levels. The total dissolved solids (TDS) in the water are measured using the TDS probe with SEN0244. The TDS is used to measure the conductivity, that is, the cleanliness of the water. The turbidity probe with the SEN0189 sensor was used to measure the water's clarity. The DS18B20 sensor is used to capture the temperature data of the water.

Tabel 1. Sensors and indicators

Indicator	Device Name/ Sensor
Water pH	BNC PH Probe + MSP340
TDS	TDS Probe + SEN0244
Turbidity	Turbidity Probe + SEN0189
Temperature	DS18B20

IV. Results and Discussion

Results

This section presents the design of the IoT-based Smart Water Quality application prototype. Figure 3 presents the IoT-based Smart Water Quality application schematic diagram. The diagram shows the four sensors and their respective probes connected to the Arduino board.

Figure 4 shows the probe sensors used to measure the water. The pH level, conductivity, turbidity, and temperature probes are put into the water. The probes sensor captures the data from the water and sends the data to the cloud through the Arduino board for the Blynk application to process and display the data.

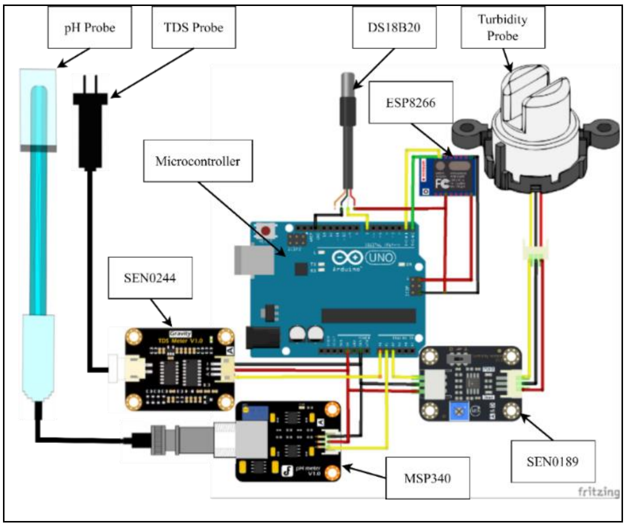

Figure 3. Schematic of IoT-based Smart Water Quality Application

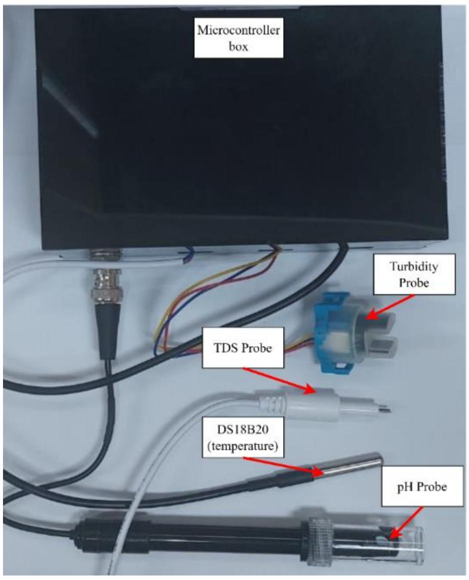

Figure 4. The Probes Used to Capture Data

In learning, this IoT-based device can be used anywhere because of its small physical size with dimensions (7cm × 10cm × 4cm) with several sensor probes. Users can download and activate the application using a barcode. When the probe enters the water, the water condition triggers the sensor and sends data to the Blynk cloud, which is read on the smartphone. Users can monitor changes in this data and use it as needed. Water condition data readings captured by IoT devices are monitored through the Blynk application. Users can see this application on their smartphones with an installed interface. Figure 5 shows the user interface of the monitoring dashboard. The dashboard interface consists of water pH, TDS, water turbidity, and temperature indicator.

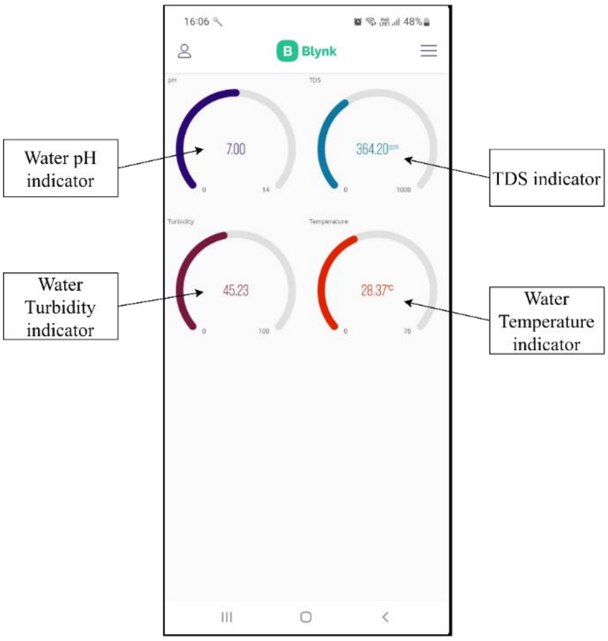

Figure 5. Water Quality Indicators Dashboard

Discussion

IoT devices use sensors to capture data and send the data to the Internet using certain communication standards and protocols. The data this device reads can be accessed by all users anywhere and anytime. The advantage of using IoT in the classroom is that it can be used as an alternative to collaborative learning. Students from different locations can view the state of the water at certain locations in real-time. Different data representing the quality from various water sources becomes a source of learning to improve critical thinking skills. Teachers can apply problem-based learning with collaborative activities to solve problems related to water quality as part of learning about the natural environment. Other activities can be developed that are in line with the subject matter. Furthermore, these strategies that utilize this technology can encourage the development of more activities for STEM-based learning.

The data related to the water quality can be obtained from the water source in real-time and directly measured in class. The data is stored on the cloud, thus making it accessible to other students from different schools. Students from different schools can do the same or different activities using the same or different data sets. This encourages flexibility in the student's learning. Students can learn about water quality with or without IoT. Learning with IoT has its benefits. Students can observe the water quality directly and predict the environmental factors that affect water quality. Any discussion regarding water quality, environmental impact, actions to be taken to improve water quality, and others can be conducted on-site. Students near water-filled areas such as rivers, ponds, lakes, and others have this advantage. Students located far away from the water-filled area will benefit from using IoT. The IoT-based Smart Water Quality application enables students to monitor water quality from anywhere. In this setting, students in the tropics can access water

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quality data in sub-tropical or polar regions. The data captured by the sensors attached to the device is stored in the cloud, making the data accessible to students from different schools. This promotes collaborative learning as students from schools located in various locations can jointly observe the water quality data in real time and perform activities that use these data collaboratively. In a nutshell, many possible learning strategies based on contextual teaching and learning can be developed because there is no time and place limit in observing the surrounding environment.

Teachers can design activities that allow students from other schools to collaborate. Groups can consist of students from one school or different schools using various online learning features. Students use digital worksheets to carry out activities that the teacher has designed. Based on the findings, students discuss solving real problems collaboratively. Data that is diverse and associated with observed natural conditions can encourage the development of higher-order thinking skills. This strategy can also be carried out at various levels in the school by determining the level of complexity of learning activities. This complexity is related to the depth of data analysis obtained from smartphone sensor readings. For low-grade students (1 to 3), the teacher can provide activities to compare the conditions of various water sources from different sources. The teacher can also ask about the cause of the difference in water quality.

For high-grade students (4-6), the teacher can provide more advanced activities by tracing the causes of poor water quality, looking for other supporting data to strengthen arguments, or manipulating data from various data to gain new understanding and, for example, analyzing river water conditions at various points from downstream to upstream. See if there is a difference, what is the cause of this difference, what is the impact of this difference, and what are the solutions if a problem occurs. Teachers can develop many activities that encourage the search for solutions to various environmental problems. Learning activities using IoT have also been confirmed by many researchers related to the issue of climate change and its impact on life at various levels of education and various types of subjects with different levels of depth of analysis [14], [18], [19].

The flexibility of data that different students can read allows teachers to develop various alternative learning activities that encourage the exploration of real conditions. Students can be confronted with environmental problems and perform analyzes of varying degrees of complexity. This choice is adjusted to the student's level of thinking. This learning strategy was developed concerning the theory of learning connectivity, social learning, and others [20]–[22]. Implementation of this strategy with various approaches has also been carried out by other researchers with significant results [6], [13].

Users of these IoT devices are not only teachers but also the public for various purposes. Data read from sensors can trigger other devices to perform certain actions. This means that IoT devices can be combined with other devices to provide a wider range of performance. As an example of use in fisheries, the pH sensor can be connected to other devices that can change the pH of the liquid. So that the sensor reads a change in pH, the pH regulator will be activated to pour certain substances at a certain level so that the pH is as expected. Thus, this tool can be used in various sectors in education and other fields, especially in agriculture, fisheries, and livestock [23]–[27].

V. Conclusion

This research attempts to develop an IoT-based Smart Water Quality application prototype that can be used to monitor water quality in real-time from a smartphone. The IoT-based prototype is equipped with sensors that read pH levels, temperature, and turbidity. Teachers in elementary schools use the IoT-based prototype as part of the student's learning activities on the topic of the natural environment. The IoT-based prototype provides opportunities for students to collaborate within an integrative learning model such as problem-based learning. The TDS sensors are used to measure the water quality. Nonetheless, it is also widely used in agriculture, such as fish farming, shrimp, rice fields, etc. This provides opportunities for students to experience contextual learning related to problems that exist in society. The application of this prototype can be extended by integrating it with other tools for water quality regulation. There is also an opportunity to incorporate other relevant sensors to cater to potential future applications.

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Declarations

Author contribution	**:**	Dwi Sulisworo took overall responsibility for the research project. Meita Fitrianawati authored the manuscript draft, while Arsyad Cahya Subrata played a role in the prototype design. Meita Fitrianawati and Khairul Shafee Kalid contributed to data collection, transcription, and analysis. Wan Fatimah Wan Ahmad meticulously revised and proofread the manuscript. Finally, all authors approved the final version of the manuscript.
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Additional information	**:**	No additional information is available for this paper.