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Development of STEAM-Based Rain Alarm Prototype

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ABSTRACT

The sudden changes in weather and unpredictable rain have an impact on human life. The objective of this research is to analyze the effectiveness and sensitivity of a rain alarm prototype and its relationship with STEAM. This study employs the ADDIE model (Analysis, Design, Development or Production, Implementation or Delivery, and Evaluations). Then, the benefits will be applied in student learning by teachers through global warming education with an environmental awareness theme. From this research, the following findings were discovered: 1) The rain alarm prototype has a high effectiveness, where each component used was successfully processed and utilized; 2) the sensitivity level revealed that the water, temperature, and humidity sensors have high sensitivity; 3) the relationship between the prototype and STEAM lies in the science aspect, as measured parameters were approached scientifically, the technology aspect through the utilization of the ThingSpeak application, engineering aspect through the collaboration of three different sensors (water, temperature, humidity), and analyzing their contributions in the field of classroom learning. In terms of art, the sensor components are neatly packaged and a housing is also created as an example of installation. Mathematics is found in the coding within the Arduino application. However, a limitation of the research is the inability to utilize an automatic roof system, which means that it cannot automatically lift snacks/clothes during rainfall. Therefore, future research can further develop this prototype by incorporating an automatic roof system.

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INTRODUCTION

Indonesia is a country with a tropical climate, experiencing both dry and rainy seasons. Rainfall is a natural phenomenon greatly influenced by the climate of a region (Beuning & Balkema, 1996; Hundebøl & Nielsen, 2015; Hosseini et al., 2021; Li, 2021). The unpredictable weather patterns and global warming make it challenging to predict rain accurately (Noda et al., 2015). The understanding of unpredictable weather and climate, such as the current situation, needs to be conveyed to students as a form of environmental awareness (Tabuenca et al., 2021). The increasing extreme temperatures and the advancement of technology can facilitate measurements and data analysis of weather, temperature, and humidity in the environment where students and teachers coexist (Tabuenca et al., 2023; Kassab et al., 2020). Therefore, implementing technology in the form of a prototype product in education becomes a way to educate students about the beneficial role of technological knowledge in environmental concern.

The unpredictable climate change has impacted the weather in various regions. This factor, in turn, affects activities that rely on sunlight, such as the traditional method of sun-drying crackers commonly practiced by cracker business owners. This process significantly impacts the

continuity of cracker production (Pangestu et al., 2018). Furthermore, undetected rain can lead to crop failure for farmers in the village, as different crops have distinct characteristics, requiring appropriate planting techniques (Nugroho, 2021). Other light activities that depend on weather conditions include drying clothes, outdoor excursions, and more (Wan, 2020). If students are guided through a problem-solving process related to the environment, such as discussing the impact of crop failure, it will create a complex understanding of learning concepts.

Monitoring systems are designed to gather and obtain data and information about specific conditions in a particular location. A system is an element that consists of interconnected components to facilitate the achievement of a goal (Mabrouki et al., 2021; Mustar & Wiyagi, 2017). This system is designed using the main components: ESP8266, Raindropper sensor, and DHT-11 sensor (Katriani & Darmawan, 2021). The ESP8266 module is one type of Internet of Things (IoT) device. IoT can be defined as the ability of multiple devices or things to communicate and connect with each other, exchanging data through the internet network (Macheso et al., 2022; Msekh & Msekh, 2022; Mispan et al., 2021). The ESP8266 microcontroller module is equipped with a processor, memory, and GPIO device, with the number of pins depending on the specific type of ESP8266 used (Sutikno et al., 2021). The DHT-11 sensor (temperature and humidity) functions as a measurement tool for the surrounding air's humidity and temperature (Subastiyan et al., 2020).

In this modern era, technology is rapidly advancing, particularly in the field of physics related to global warming and climate change (Wulandari et al., 2021). Some schools incorporate STEAM in their teaching approaches (Hawari & Noor, 2020). STEAM stands for Science, Technology, Engineering, Arts, and Mathematics (Sakon & Petsangsri, 2021; Dolgopolovas & Dagienė, 2021; Topalska, 2021; Kwan & Wong, 2021; Xue, 2022). Essentially, it is an educational approach aimed at fostering early interest and love for both art and science among children (Rodríguez-Nieto & Alsina, 2022). In practice, this educational method often employs project-based learning (Arce et al., 2022). The goal is to create an inclusive learning environment where all students can engage and contribute to the learning process. Thus, the introduction of technology-based STEAM is highly beneficial for students (Wu et al., 2022).

Based on previous research by Dong (2018), a wireless sensor network weather monitoring system based on a single-chip microcomputer STC chip was developed to monitor weather conditions at specific times. The system operates based on detected pH and humidity levels. However, this research did not result in a narrowed-down rain alarm device. Another study by Mufidah (2018) involved creating an information system designed using NodeMCU and Raindroper sensors, where the stored data is sent to an integrated website. However, this device was not designed as an alarm but only as a rainfall measurement tool. Another study by Chandana & Sekhar (2018) utilized an IoT-based wireless sensor network weather monitoring system to monitor weather conditions at specific times, with the system operating based on relative humidity, light intensity, and CO2 levels, providing graphical insights. However, this research did not result in a cone-shaped rain detection device. Another study conducted by Satria et al. (2018) developed a rain warning system using the Arduino Uno microcontroller, HC-SR04 ultrasonic sensor, and rain sensor, which successfully detected rainfall but has not been implemented for STEAM-based learning.

Therefore, based on the aforementioned problem of the importance of rain detection and the findings from several previous research studies, this study aims to develop a STEAM-based rain alarm prototype using water, temperature, and humidity sensors. This prototype can be taught to students and potentially provide real-world innovation in creating rain alarms, contributing to society. The contribution of the rain alarm and prototype in learning is to introduce alternative solutions during uncertain extreme weather conditions, enabling students and the community to anticipate landslides, flash floods, and other disasters that frequently occur in Indonesia. One of the causes is the high rainfall due to the impact of global warming (Wang et al., 2022). Such an introduction serves as a fundamental understanding of alternative climate change and global warming solutions among the public (Monroe et al., 2019). Moreover, the project-based learning process of developing the rain alarm prototype teaches students to actively comprehend real-life concrete problems and engage in problem-solving skill development (Tsybulsky & Sinai, 2022).

The STEAM approach, in the form of a rain alarm, is solely focused on promoting sustainable education, where students actively participate throughout the device design process. The novelty of this research lies in its STEAM-based approach and the simultaneous use of three types of sensors. This allows it to be taught to students and potentially provide real-world innovation in creating functional rain alarms, contributing to society. The research aims to achieve several objectives, including: 1) analyzing the effectiveness of the rain alarm prototype with water, temperature, and humidity sensors; 2) analyzing the sensitivity of the rain alarm prototype with water, temperature, and humidity sensors; 3) identifying the relationship between the rain alarm prototype and STEAM.

RESEARCH METHOD

The Effectiveness of Rain Alarm Prototype

This research adopts the ADDIE Development Research Model. The ADDIE model, which stands for Analysis, Design, Development or Production, Implementation or Delivery, and Evaluation, involves a five-step development process (Mayfield, 2011; Hanafi et al., 2020; Saeidnia et al., 2022). However, in this study, the implementation and evaluation stages were conducted by the researchers and physics lecturers. For further details, please refer to Table 1.

Table 1. ADDIE development research model stage

Phase	Activities
Analysis	Analyzing the interests and initial problems of product development carried out by reviewing literature on previous research and analyzing the feasibility and requirements of product development.
Design	Start designing prototypes with a systematic process that starts from designing the concept. At this stage the product design is still conceptual and underlies the development process at the next stage
Development	Activities for the realization of product designs that have previously been made. In the previous stage, a conceptual framework for implementing a new product has been developed. The conceptual framework is then realized into a product that is ready to be implemented
Implementation	The prototype made has been applied and tested by researchers. The result is a response from each sensor of water, temperature and humidity.
Evaluation	This is done to provide feedback to product users, so that revisions are made according to the results of the evaluation or needs that have not been met by the product.

In the analysis phase, a literature review was conducted using Google Scholar as the primary research database, focusing on the last five years. During the design and development process, the research was assisted and validated by two physicists who also served as validators for the prototype. In terms of product development steps, the ADDIE Development Research Model is considered to be more rational and comprehensive (Kusumastuti et al., 2020; Rizal et al., 2021). This model can be applied to various forms of product development in educational activities, such as models, learning strategies, teaching methods, media, and instructional materials (Yu et al., 2021).

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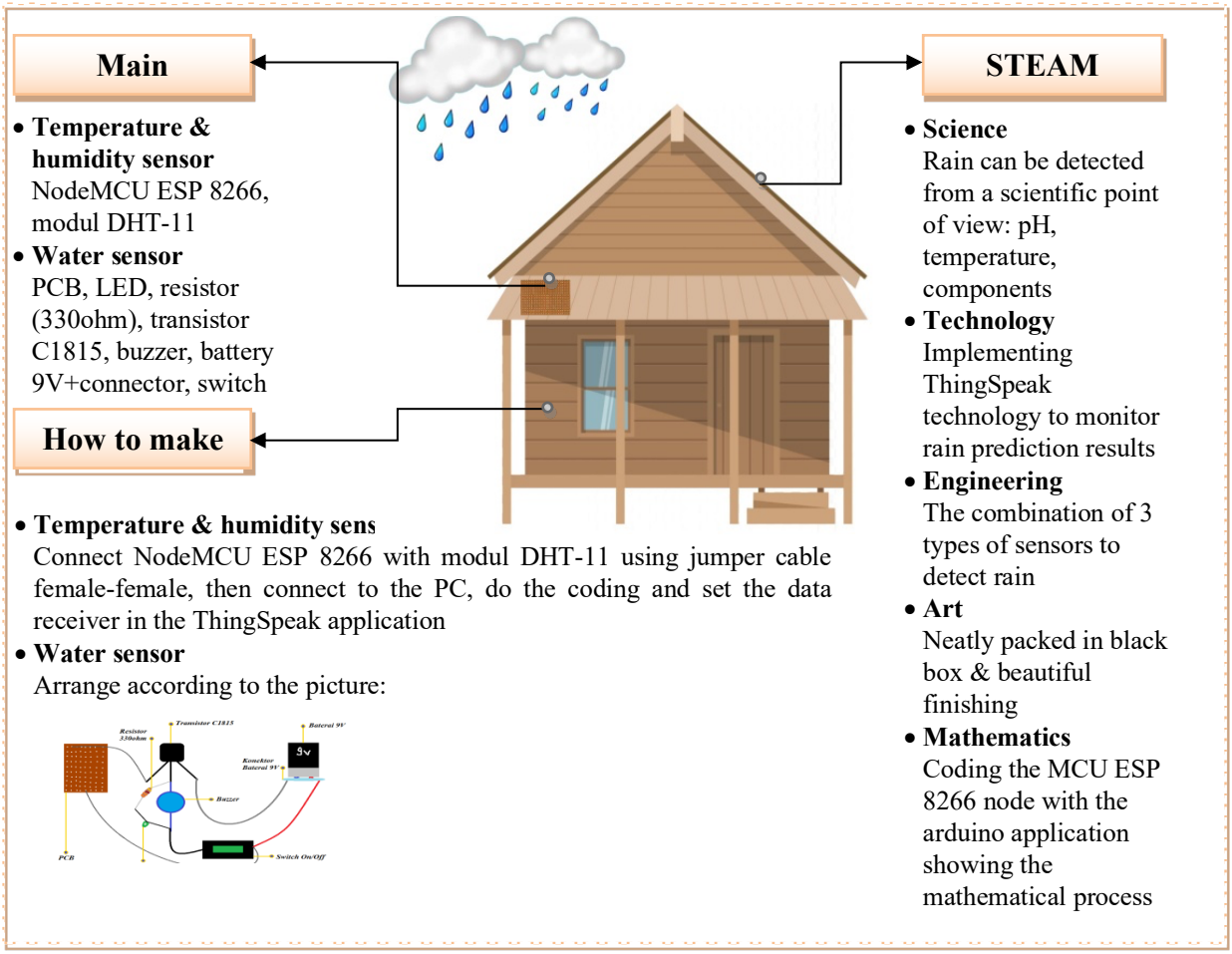


Figure 1. STEAM-based rain alarm prototype design

RESULTS AND DISCUSSION

The prototype rain alarm was tested to determine its effectiveness and success. Testing the device is necessary to minimize errors and potential user injuries resulting from the device. The rain alarm prototype circuit is designed using NodeMCU ESP8266 as the microcontroller, a rain alarm water sensor, a temperature and humidity sensor, and the ThingSpeak application (Bhaskar & Rajeshwari, 2019) to monitor temperature and humidity and receive alert notifications.

The device will notify you when the sensors detect low temperature values or an increase in humidity, indicating the possibility of rain. Having this early rain warning device can help anticipate rain during the production process of cracker.

Table 2. Table of component testing in the black box

Input	Hope	Result	Conclusion
Connecting artificial water sensor components using PCB	The water sensor works normally, when exposed to water, the sensor can sound a buzzer and LED	The sensor detects when the water intensity is low, only the LED lights up, while when there is a lot of water, the LED & buzzer light up. For results, see the following link: https://www.youtube.com/watch?v=-1Xa-zwfuyk	Success
Connecting DHT-11 sensor module with NodeMCU ESP8266	The DHT-11 sensor can read and transmit values of air temperature and humidity to the ThingSpeak aplikasi application	The value of temperature and humidity can be read on the gauge widget display in the ThingSpeak application. Data will be updated every 15 seconds	Success

Input	Hope	Result	Conclusion
The DHT-11 sensor reads the air temperature value below 25 degrees Celsius	When the air temperature value reaches below 25 degrees Celsius, the system will send a message to the user's ThingSpeak	When the temperature drops below 25 degrees Celsius, the graph recorded on the chart will go down and vice versa. This indicates that it will rain	Success
The DHT-11 sensor reads air humidity values above 110	When the humidity value is above 110, the system will send a message to the user's ThingSpeak	When the humidity rises above 110, the line recorded on the chart will go up and vice versa. This indicates that it will rain	Success
Air temperature and humidity widget	Displays the value of the temperature and humidity read by the DHT-11 sensor.	When temperature and humidity in the Arduino application are detected via streaming, then in ThingSpeak, the temperature and humidity widget will also display the same value.	Success

By processing temperature and humidity data from a few hours ago, we can infer the forecast for the next few hours. One limitation of this study is the absence of an automated roof system. An automated roof system would facilitate the drying process of cracker/clothes, eliminating the need for manual handling. This limitation can be considered for future system development. However, this prototype is effective for use as a rain alarm or as a learning tool for students in STEAM-related subjects and to introduce the fundamentals of coding.

Sensitivity

To determine the sensitivity of this rain alarm device, experiments were conducted. Sensitivity refers to the ability of a measuring instrument to respond to changes in the measured values (Bai et al., 2022; Ren et al., 2022). To ensure the sensitivity of the measuring instrument, it should always be used within the maximum measurement limits and scale readings (Han et al., 2022).

Table 3. The results of the water sensor sensitivity experiment

Number of Water Drops	Indicator LED	Indicator Buzzer
1	+	-
2	++	-
3	++++	+
4	+++++	+++
5	+++++	+++++
>5	+++++	+++++

Information:
- = not lit
+ = very dimly lit
++ = dimly lit
+++ = bright enough
++++ = brightly lit
+++++ = very bright/loud

From the data, it can be observed that the water sensor has a relatively high sensitivity. When a single water droplet is detected, the LED immediately lights up. However, the buzzer remains silent. This means that during low rain intensity (drizzle), only the LED lights up while the buzzer remains off. The buzzer activates after detecting the third water droplet, but the sound produced is still weak. The bell rings loudly after the fifth and subsequent water droplets. This has a positive

aspect where the rain alarm will not disturb the user when the sensor is only exposed to dew or splashes of water.

Table 4. Experimental results of temperature and humidity sensor sensitivity

Time	Places			
	Home		Ricefield	
	Temperature (˚C)	Humadity	Temperature (˚C)	Humadity
08.00	26	57	28	46
10.00	29	50	30	43
12.00	29	58	31	47
14.00	28	58	30	41
16.00	28	50	29	45

From Table 4, it can be observed that as the temperature increases, the humidity decreases. The humidity indoors is higher than in the field. This is because the house is enclosed and receives less sunlight. During the temperature and humidity sensor experiment, temperatures below 25 degrees Celsius and humidity above 110 were not detected. Therefore, it can be concluded that on the research day, June 2, 2022, there was no rain, and indeed the sky was clear and no rain occurred. This proves that the rain alarm prototype functions well, and the data it produces is accurate.

The Relation Between the Rain Alarm Prototype and STEAM

The creation of the rain alarm is based on authentic or real-life problems. Many activities depend on the weather (Laufkötter et al., 2020). However, predicting today's weather is challenging due to global warming (Saadatlu et al., 2022). Therefore, it is important to develop a STEAM-based rain alarm prototype so that it can also serve as a learning tool for students in schools.

From the rain alarm, we can conclude that from a scientific perspective, it relies on measuring the humidity of the air as a parameter for rainfall. Additionally, in the field of science, temperature is commonly measured in Celsius. With the water sensor, students can learn about components such as resistors in ohms, color bands, and more. From a technological standpoint, we can see the implementation of Thingspeak technology in this rain alarm prototype. The temperature and humidity sensors can be monitored and controlled through the ThingSpeak application on a PC or laptop.



Figure 2. The series of components in the black box

In Figure 2, several components can be seen for the water sensor, NodeMCU ESP 8266, humidity sensor (DHT-11), and others. This relates to the engineering aspect, which involves combining three types of sensors to create a rain alarm. The packaging, using a black box made of sturdy materials, ensures the safety of the components, making them less prone to damage or getting wet. The neat packaging, coupled with the house example shown in Figure 3, is part of the artistic aspect.



Figure 3. An example of a rain alarm prototype

In addition to science, technology, engineering, and art, this prototype also incorporates mathematics. This can be seen in the process of creating the temperature and humidity sensors, which involve the combination of NodeMCU ESP8266 with the DHT-11 sensor module, coded using the Arduino application. As for receiving the data, it is done through the ThingSpeak application. For the coding details, please refer to Figure 4.

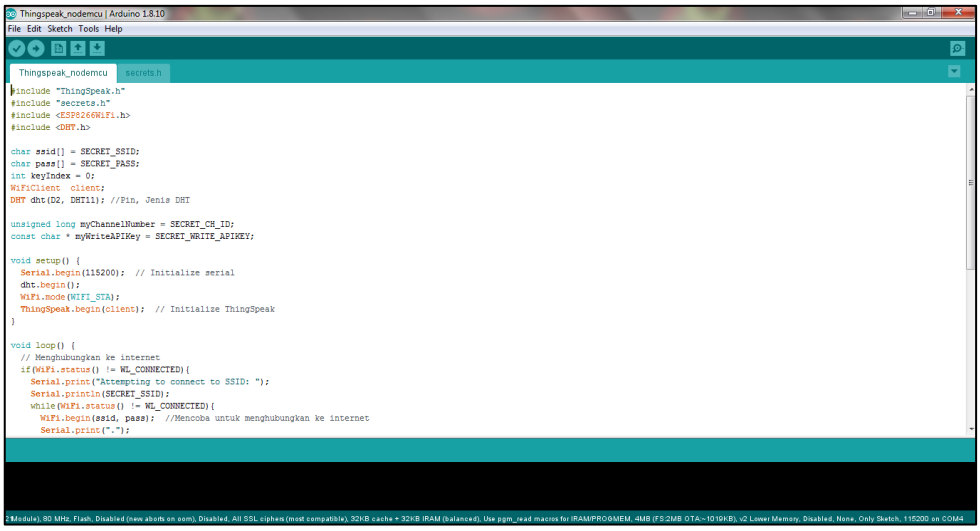


Figure 4. Coding via the Arduino application

The results of coding in the Arduino application will be displayed on charts and widgets in the ThingSpeak application. The data received by ThingSpeak is in the form of live streaming which is updated every 15 seconds.

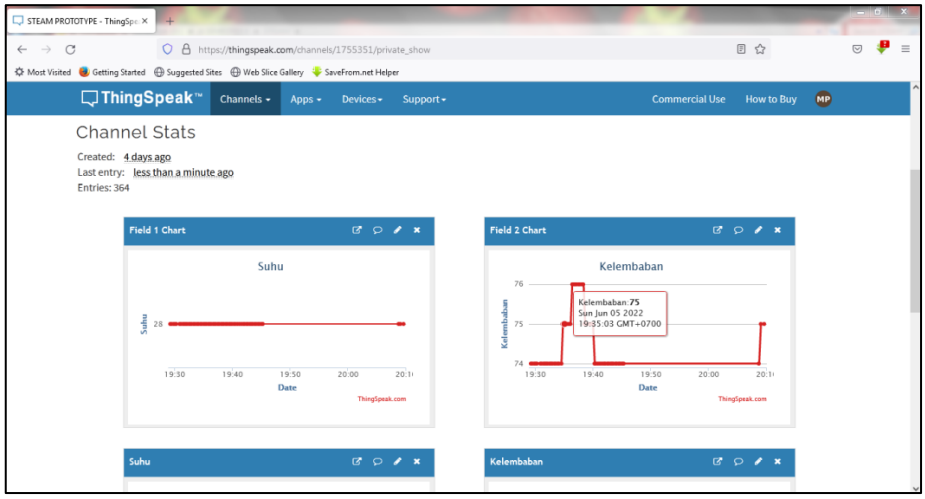


Figure 5. Real time data received on ThingSpeak

Based on the above explanation, the rain alarm prototype has been successfully created and meets the criteria of STEAM. In general, the science aspect involves scientific approaches in measuring parameters, the technology aspect involves the use of the ThingSpeak application, and the engineering aspect is achieved through the collaboration of three different sensors: water, temperature, and humidity. In terms of art, the sensor components are neatly packaged and a house example is provided for installation demonstration. Mathematics can be found in the coding process using the Arduino application. For further details on the final result of the rain alarm prototype, please refer to the following video upload: https://www.youtube.com/watch?v=Y2IX4CdTeb0.

The implementation of activities integrated into education using the rain alarm prototype aims primarily at raising awareness among the community. The success of these activities depends on proper guidance and support during the teaching and application of the rain alarm, both from community leaders and within the academic structure of Education. If this integration is supported by stakeholders and receives positive feedback from specific communities, the effectiveness of this tool will be highly beneficial. However, it is important to emphasize that the primary goal of the developed tool is education and learning. The combination of technology, art, science, and learning is suitable for various teaching models. Based on the results and discussions obtained, the researchers believe that problem-based learning and inquiry are suitable approaches for implementing the rain alarm, with an emphasis on active student involvement from problem formulation to the design process of an IoT-based device. Creating awareness of the environment, which is essential for students and teachers, can be achieved through direct practice in creating a rain alarm, thereby fostering an understanding of technological advancements in the era of Industry 4.0 through inquiry-based learning or projects. Future research using this prototype can create concrete learning scenarios for environmental awareness to address the current global climate crisis.

The activity implemented in the learning process using the rain alarm prototype aims to raise awareness among the community. This activity will be successful if the teaching and implementation of the rain alarm are well supported both by community leaders and the academic structure of education. If this integration is supported by stakeholders and receives positive feedback from specific communities, the effectiveness of this tool will be greatly beneficial. However, it should be noted that the primary goal of the developed tool is education and learning. The combination of technology, art, science, and learning is suitable for various learning models. Based on the results and discussions obtained, the researchers believe that problem-based learning and inquiry (Kusmin, 2019) are suitable approaches for implementing the rain alarm, with an emphasis on active student involvement from problem formulation to IoT-based device design (Davies et al., 2020). Understanding environmental awareness that needs to be instilled in students and teachers can be achieved through hands-on practice in creating the rain alarm, fostering awareness of technological advancements in the era of Industry 4.0 through inquiry-based learning or projects (Wulandari et al., 2022; Tsybulsky & Sinai, 2022). Future research using this prototype can create concrete learning scenarios for environmental awareness in addressing the current global climate crisis (Thor & Karlsudd, 2020).

CONCLUSION

From the experiments and presentation of the results above, it can be concluded that the rain alarm prototype with three sensors, namely water, temperature, and humidity, has high effectiveness, where each component used has been successfully processed and utilized. This prototype is portable, so you can take it anywhere. Based on the sensitivity level results, it is known that the water sensor has high sensitivity, where the LED can light up with just one water droplet, while the buzzer will gradually sound on the third droplet. This means that the prototype will not disturb users because of the buzzer, as the buzzer will not sound when the sensor is exposed to dew/drizzle.

The relationship between the prototype and STEAM lies in the science aspect, as the measured parameters are approached scientifically, the technology aspect, as the Thingspeak

application is utilized, the engineering aspect, as it involves the collaboration of three different sensors (water, temperature, and humidity), and the art aspect, as the sensor components are neatly packaged and a sample housing is provided for installation. Mathematics is found in the coding process within the Arduino application.

The implications of this research are focused on learning, where students need to actively participate in the development of rain alarm projects, enabling them to create environmental awareness effectively. And secondly, it can provide benefits to the crackers manufacturing company by enabling them to anticipate sudden rain with this rain alarm system. However, a limitation of the research is the lack of an automatic roof system, which means that the drying of crackers or clothes cannot be done automatically during rainfall. Therefore, future research can focus on developing this prototype with an automatic roof system.

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