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Flood Alarm Prototype: A STEAM Project to Study Physics and Building Students' Awareness of Natural Disasters

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ABSTRACT

Indonesia is a country with a significant portion of its territory consisting of water bodies, which makes it prone to flooding. Therefore, the development of an early warning system in the form of a flood alarm prototype is crucial. This research is designed using the Design Thinking models method. Based on the created prototype, STEAM-based learning can be implemented to enable students to learn physics through scientific steps. It also fosters critical thinking, creativity, collaboration, and communication skills in accordance with the 21st-century concept, while increasing students' awareness of natural disasters in their surroundings.

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INTRODUCTION

In terms of its topography, Indonesia predominantly consists of lowlands, basins, and a large portion of its territory is composed of sea. This makes Indonesia highly prone to experiencing floods (Wijaya et al., 2018). According to data from the National Disaster Management Agency (BNPB) for the period of 2017-2022, flood disasters consistently rank highest among natural disasters occurring in Indonesia (BNPB, 2022). These disasters also result in significant losses, ranging from infrastructure damage to loss of lives.

One of the efforts to address flood disasters and reduce the number of affected individuals is by raising awareness of disaster mitigation in Indonesia. According to UU No. 24 of 2007, disaster mitigation is defined as "a series of efforts to reduce disaster risks, both through physical development and through awareness raising and capacity building to address disaster threats". In the context of disaster mitigation, it is important to cultivate awareness among all stakeholders and take comprehensive actions to minimize the damage caused by disasters. One example of such an effort is utilizing the availability of schools or educational institutions to support disaster mitigation programs (Rahma, 2018). Through schools, students are expected to acquire knowledge and contribute to building a culture of disaster awareness in their surroundings.

In line with the 21st-century concept, the key skills that students should possess include critical thinking, creativity, collaboration, and communication skills (Lestari, 2021; González-Pérez & Ramírez-Montoya, 2022). Era of continuous scientific and technological progress, accompanied by swift societal transformations and their worldwide consequences, make the ability to think creatively become a crucial adaptive trait (Beghetto & Kaufman, 2013). More than that, creativity can ensure continuous advancements towards a more sustainable existence (Said-Metwaly et al., 2018). Aside from creativity, there are collaboration and communication skills which involve relation between students. Development of communication skills among students yields advantages for both individuals and society (Besley & Tanner, 2011; Asemanyi, 2015). It is essential for students to engage in communication in order to address scientific and social challenges effectively (Bray et al., 2012). In the realm of education, there is generally favorable support for profound and significant instructional approaches, provided that

interaction is present at a substantial level (Miyazoe & Anderson, 2010; Rodriguez and Armellini, 2015; Islam et al., 2017). Collaborative skills enhance self-efficacy, and opportunities to collaborate with other partners are beneficial for students (Hur et al., 2020). In contrast to competitive and individualistic endeavors, collaborative efforts offer numerous advantages and often lead to increased accomplishments and enhanced productivity. Collaboration fosters caring, supportive, and committed relationships while also promoting better psychological well-being, social competence, and self-esteem (Laal & Ghodsi, 2012).

Learning that aligns with the concept of the 21st century can be realized through the implementation of STEAM (Science, Technology, Engineering, Art, and Mathematics) learning (Widya et al., 2019). STEAM is a contextual learning approach where students are invited to understand phenomena that occur in their immediate surroundings (Widarti & Roshayanti, 2021). The STEAM approach encourages students to produce work that promotes their collaborative abilities, cooperation, and communication skills when done in a group format (Akçayır & Akçayır, 2017; Smith et al., 2005).

In the field of education, the STEAM approach has gained significant recognition and has been shown to have positive impacts on students' creativity, critical thinking, and problem-solving skills (Hsu & Ching, 2016; Daodu, 2017; Chen & Chang, 2018). It integrates the disciplines of science, technology, engineering, arts, and mathematics into comprehensive and context-based learning experiences. This integration not only promotes a deep understanding of these subjects but also fosters the development of communication and collaboration skills among students (Hsu & Chen, 2018; Bagiati & Evangelou, 2015).

Furthermore, the implementation of STEAM-based learning in specific subjects such as physics can further enhance students' skills and competencies. Physics education aims to equip students with knowledge, understanding, and high-level thinking skills in line with the concept of the 21st century (Ministry of Education and Culture, 2013; Hudha et al., 2019; Ozkan & Topsakal, 2021). By incorporating a hands-on approach to learning, students are engaged in practical applications of physics concepts, enabling them to solve everyday problems through the scientific process (Kolodner et al., 2003; An & Yang, 2020).

In this regard, the implementation of STEAM-based physics learning through the creation of a simple flood alarm prototype can provide students with a practical and interdisciplinary learning experience. This project not only enhances their critical thinking and creativity but also fosters collaboration and communication skills, which are essential in the 21st-century context (Pressick-Kilborn et al., 2021; Kay & Greenshill, 2011). Through this hands-on activity, students become more aware of natural disasters in their surroundings and develop a deeper understanding of the scientific principles involved (Maltese & Tai, 2011; Khamhaengpol et al., 2022; Kim & Park, 2012).

The significance of STEAM education and its impact on students' learning outcomes has been supported by a range of studies. For example, research by Akçayır and Akçayır (2017) emphasized the importance of integrating art and design into STEM education to foster creativity and innovation. Additionally, studies by Bagiati and Evangelou (2015) and Daodu (2017) highlighted the positive effects of STEAM education on students' engagement and motivation in learning.

Furthermore, Hudha et al. (2019) examined the impact of STEAM activities on students' conceptual understanding in physics. Their findings demonstrated that students who engaged in STEAM-based activities exhibited higher levels of conceptual understanding compared to traditional instructional approaches. An and Yang (2020) conducted a study on the implementation of STEAM education in a physics course and found that it positively influenced students' problem-solving skills and scientific process abilities.

In the context of STEAM education research, Carvalho and Goodyear (2014) discussed the architecture of productive learning networks. Halverson and Sheridan (2014) explored the maker movement in education, which is closely related to the STEAM approach. Irwanto et al. (2022) presented a systematic review of STEAM education research trends from 2011 to 2020, providing insights into the various aspects and impacts of STEAM education.

In conclusion, the integration of the STEAM approach in education, particularly in subjects like physics, offers a promising avenue for developing students' 21st-century skills. By providing students with opportunities to engage in hands-on activities, collaborate with their peers, and communicate their ideas effectively, STEAM-based learning contributes to their overall development and prepares them for the challenges of the future. It is evident that the implementation of STEAM in education is not only beneficial for individual students but also for the advancement of education as a whole. Further research and exploration of the potential of STEAM education will continue to enhance educational practices and support the growth of students' skills and competencies in the 21st century.

RESEARCH METHOD

This research utilizes a development method based on the Design Thinking model. The DT model has been widely used, including in developing STEAM-based learning. Design Thinking is a human-centered approach to innovation, derived from designer tools, that integrates people's needs, technological possibilities, and business success requirements [6]. There are four steps in this DT model, namely: (1) Define the Problem, (2) Identification of Potential Solutions, (3) Prototyping, (4) Testing and Reporting.

These four steps also help students apply scientific process skills and enhance their creativity and collaboration in designing their STEAM projects in group formats. Table 1 below is example of activities that can be carried out based on these four steps.

Table 1. Activity in flood alarm prototype project

	Step	Activity
1.	Define the problem	The teacher presents the issue to the students regarding natural disasters, specifically floods. Floods are one of the most common natural disasters in Indonesia. According to data from the National Disaster Management Agency (BNPB), floods consistently rank as the top disaster in Indonesia over the past five years. The impacts caused by this disaster are extensive, ranging from infrastructure damage to loss of lives. By introducing this problem, students will become aware of the frequency of flood occurrences in their surroundings and the urgency of finding solutions to address this issue.
2.	Identification of potential solutions	One of the efforts to address floods is by creating an early warning system in the form of a flood alarm, allowing the community to be prepared in the event of a flood disaster. The teacher can ask several questions regarding the process of designing this project. Some of these questions may include: • How do we design a simple flood alarm? • What physics concepts are needed in the process of creating this flood alarm? • What tools and materials are required for this project? These questions will guide students in exploring the design process and understanding the scientific principles involved in developing a functional flood alarm system.
3.	Prototype	After completing the design phase of the project, students are directed to create a prototype within the given timeframe.
4.	Test and report	From the created prototype, testing and reporting are conducted based on the project's outcomes. • The product can be tested against the five elements of STEAM (science, technology, engineering, art, and mathematics). • Students present their project reports in front of the class, and other groups can provide comments.

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RESULTS AND DISCUSSION

Define the problem

The research begins by identifying the problem that will be the topic of the STEAM project, which is the high occurrence of flood disasters in Indonesia. In this initial stage, the researcher gathers data related to flood disasters in Indonesia. The data is collected from the website of the National Disaster Management Agency (BNPB) of Indonesia and several literature sources on floods in Indonesia obtained through Google Scholar.

Based on the search results, data on the frequency of flood disasters in Indonesia and the various impacts resulting from these natural disasters are found. The following are some infographics depicting data on natural disasters in Indonesia from 2017 to 2021.

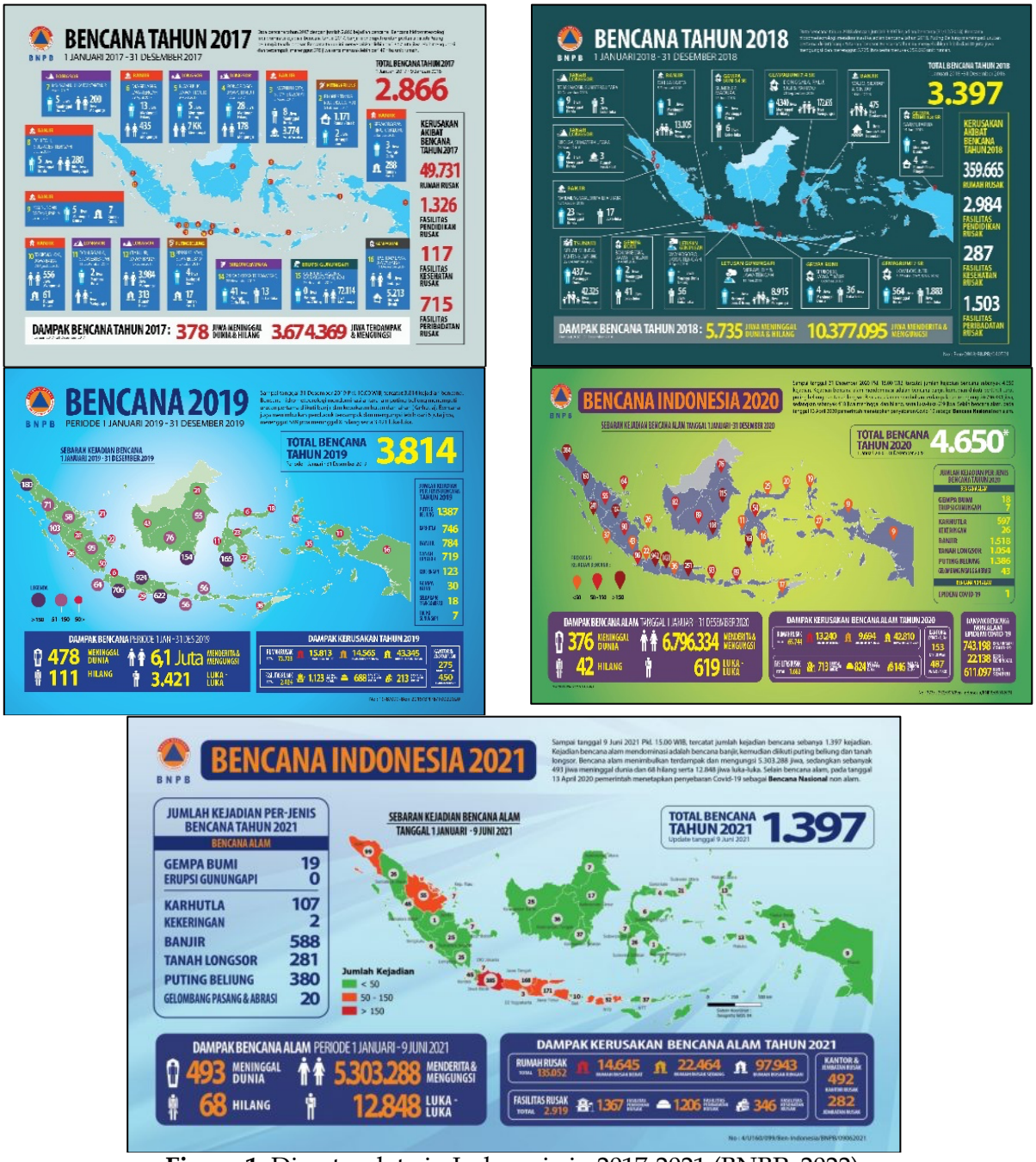


Figure 1. Disaster data in Indonesia in 2017-2021 (BNBP, 2022)

In the above infographic, it can be observed that floods are the top-ranked natural disaster throughout the year 2017, with a total of 980 flood disasters occurring. In the years 2018-2019, floods ranked second as a natural disaster, with 883 and 790 respective incidents. Furthermore,

from 2020 to mid-2021, floods regained the top position as the most prevalent disaster in Indonesia, with 1,518 and 588 respective incidents. As of the year 2022, there have been 73 recorded flood disasters in Indonesia, with South Sumatra being the province most affected by floods, as depicted in the table 2.

Table 2. Data of flood disaster in 2022

Province	Amount Disaster
North Sumatra	2
South Sumatra	33
Lampung	1
Bangka Belitung Islands	3
West Java	6
Central Java	17
East Java	6
West Kalimantan	1
North Kalimantan	1
North Sulawesi	1
Central Sulawesi	2

From the previous infographic data, it is evident that floods have significant impacts, including damage to public facilities, homes of residents, government offices, and even loss of lives. In the early months of 2022 until mid-2022 alone, the number of affected individuals reached 60,183 people. The most affected structures were residential houses, with a total of 1,767 houses damaged (BNBP, 2022). Based on the obtained data, the flood issue in Indonesia is chosen as the problem to be addressed in the subsequent stages.

Identification of potential solutions

The next stage is to identify solutions to the selected problem. One of the efforts to address the flood issue in Indonesia is by creating an early warning system in the form of a flood alarm, which allows the community to be prepared when a flood disaster occurs. Here is a proposed design for creating a prototype of a flood alarm, presented in the form of a poster.

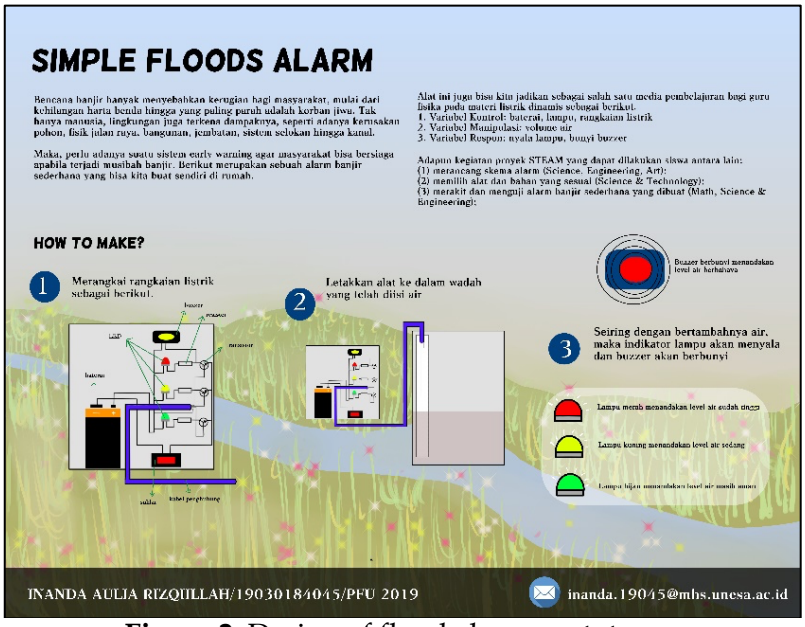


Figure 2. Design of flood alarm prototypes

As this research is related to STEAM-based learning, the creation of this flood alarm will also be designed with a STEAM approach (science, technology, engineering, art, and mathematics), as follows:

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- Science, Engineering, Art - designing the alarm scheme
- Science & Technology - selecting appropriate tools and materials
- Math, Science & Engineering - assembling and testing the created flood alarm prototype

The circuitry used in the creation of this flood alarm prototype is an implementation of the dynamic electricity concept. The following is the circuitry design used in the flood alarm prototype.

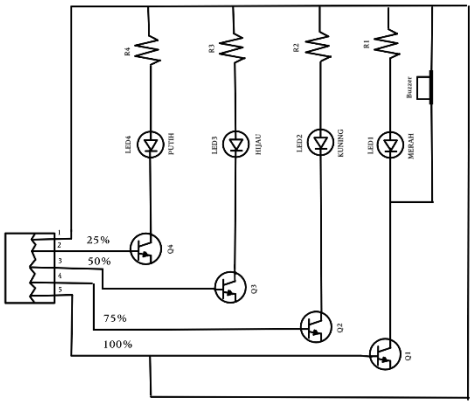


Figure 3. Design of flood alarm prototype circuit

Prototype

Based on the design that has been made, the next step is to create the flood alarm prototype. The tools and materials needed to create the flood alarm are relatively simple, consisting of circuit components: resistors, LEDs, transistors, cables, and buzzers; solder, scissors, pliers, wires, plywood board, plastic bottle, and circuit box. The created flood alarm prototype is shown in figure 4.

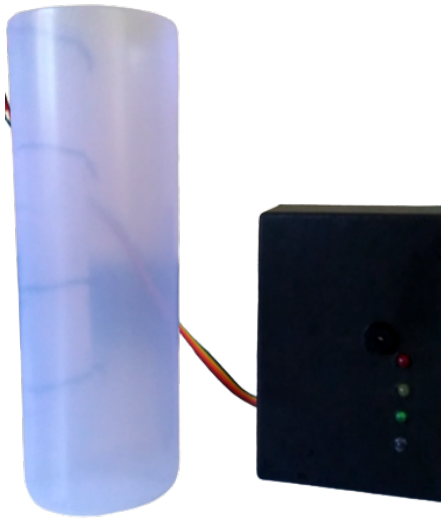


Figure 4. Flood alarm prototype

Test and Report

The created flood alarm prototype was then tested by filling water into the bottle. Based on the test results, it was found that as the water level in the bottle increased, the indicator lights would turn on, and the buzzer would sound. The white light indicates that the water fills the bottle by 25%, the green light indicates that the water fills the bottle by 50%, the yellow light indicates that the water fills the bottle by 75%, and the red light along with the buzzer indicates that the water fills the bottle by 100%. The testing results are presented in a video format that can be accessed through the following link: https://unesa.me/UjiFloodAlarm.

CONCLUSION

This research has developed a STEAM-based (Science, Technology, Engineering, Art, and Mathematics) learning approach through the creation of a flood alarm prototype project. Through this project, it is hoped that students can easily learn physics through a scientific approach within the five elements of STEAM while also increasing their awareness of natural disasters.

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