ETJ

(Educational Technology Journal)

Volume 5, Issue 2, October 2025, 26-34
ISSN 2797-2593 (Online)

https://journal.unesa.ac.id/index.php/etj

DEVELOPMENT OF A DETECTION SYSTEM FOR TANTRUM REAL-TIME BASED ON IoT TO SUPPORT INCLUSIVE EDUCATION IN SPECIAL SCHOOLS

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Abstract

In Special Education Schools (SLB), detecting and handling negative emotional behaviors such as tantrums in autistic students is a major challenge that directly affects the safety and quality of learning. This study aims to design a real-time tantrum detection system based on the Internet of Things (IoT), integrating a heart rate sensor and a sound sensor, processed using an ESP32 microcontroller and connected to a web-based monitoring platform as a notification medium for teachers. Through a software engineering approach and literature review of over 40 reputable scientific publications, this system is developed as an innovative and applicable early solution in the context of inclusive education. Theoretical reviews indicate that physiological and vocal behavioral indicators are key signals in detecting stress or emotional outbursts in students with Autism Spectrum Disorder (ASD). This system design is expected to contribute to creating a more adaptive, safe, and responsive learning environment in SLB.

Keywords: *autism spectrum disorder; IoT; emotion monitoring; heart rate sensor autism; sound sensor emotion detection.*

Abstract

Dalam lingkungan Sekolah Khusus (SLB), deteksi dan penanganan emosi negatif seperti tantrum pada siswa autis merupakan tantangan besar yang secara langsung berdampak pada keselamatan dan kualitas pembelajaran. Penelitian ini bertujuan untuk merancang sistem deteksi tantrum berbasis Internet of Things (IoT) secara real-time yang mengintegrasikan sensor detak jantung dan sensor suara, diproses melalui mikrokontroler ESP32, dan terhubung ke platform pemantauan berbasis web sebagai media pemberitahuan bagi guru. Dengan menggunakan pendekatan rekayasa perangkat lunak dan tinjauan literatur lebih dari 40 publikasi ilmiah terkemuka, sistem ini dikembangkan sebagai solusi awal yang inovatif dan dapat diterapkan dalam konteks pendidikan inklusif. Studi teoritis menunjukkan bahwa indikator fisiologis dan perilaku vokal merupakan sinyal kunci dalam mendeteksi stres atau ledakan emosi pada siswa dengan Gangguan Spektrum Autisme (ASD). Desain sistem ini diharapkan dapat berkontribusi pada upaya menciptakan lingkungan pembelajaran yang adaptif, aman, dan responsif di SLB.

Kata kunci: Gangguan Spektrum Autisme; IoT; Pemantauan Emosi; Sensor Detak Jantung untuk Autisme; Deteksi Emosi Menggunakan Sensor Suara

Introduction

Autism Spectrum Disorder (ASD) is a neuropsychiatric developmental disorder that impacts communication skills, social interaction, and emotional regulation. One of the main challenges in inclusive education for children with ASD is the emergence of tantrums, which are sudden, intense, and unpredictable emotional outbursts. In special education settings, this condition not only disrupts the learning process but also has the potential to endanger the safety of students and those around them. This highlights the urgency of early detection of changes in students' emotions to create a safe, responsive, and adaptive learning environment.

Along with the development of technology, the Internet *of Things* (IoT) offers numerous opportunities for real-time monitoring of human physiological and behavioral conditions. Previous research has shown that indicators such as heart rate and voice intensity can be early signals of emotional distress, including tantrums, in children with ASD. Integrating heart rate and voice sensors with microcontrollers such as the ESP32 allows for direct data transmission to a web-based monitoring platform, allowing educators to receive early, real-time notifications.

Although there have been efforts to utilize IoT in special education, most previous research is still limited to the use of a single type of sensor, does not support real-time warning systems, and is not specifically directed to the context and needs of special education schools (SLB). Therefore, this study aims to address this gap by designing an IoT-based tantrum detection system that integrates two types of sensors and supports real-time notifications to a monitoring dashboard. The novelty of this research lies in its holistic and applicable approach tailored to the inclusive learning environment in special education schools. The results are expected to make a real contribution to supporting more adaptive, safe, and technology-based education.

Research methods

This research uses an approach of research and development (R&D) to design a detection tantrum system in a real-time-based Internet of Things (IoT) environment in the Special Needs School (SLB) environment. The system was developed to detect early indicators of emotional changes in students with *Autism Spectrum Disorder (ASD)* through monitoring heart rate and sound intensity.

Research Subjects

The test plan involves three ASD students and two accompanying teachers in one of the SLBs in East Java. The subjects were selected randomly, purposive sampling based on diagnostic conditions and readiness to engage in monitoring simulation.

Tools and materials

The system is designed using:

- Microcontroller ESP32 as a control center and data sender;
- Heart rate sensor MAX30100, chosen for its accuracy and low power consumption, is suitable for wearable devices.
- Sound sensor KY-037, which can sensitively detect fluctuations in sound intensity.
- Interface dashboard *web* or application mobile as a notification and monitoring medium

System and Procedure Plans

The system is designed with the following flow:

1) **Sensor Initialization**– *ESP32* activates and connects sensors to the network*IoT*.
2) **Data Acquisition**– The system reads heart rate and sound intensity every 30-60 seconds (*sampling rate* 1 Hz).
3) **Data analysis** – Data is compared with the initial calibration threshold (heart rate > 100 bpm; sound > 70 dB).
4) **Detection Decision**– If the threshold is exceeded, the system flags a potential tantrum and proceeds to the notification.
5) **Notification Delivery**– Information sent to dashboard network IoTo or website teacher real-time.
6) **Teacher Action**– The teacher receives the notification and immediately intervenes.
7) **Advanced Monitoring**– The system continues to monitor or is turned off if not needed.

Research Variables

The physiological response is operationalized through the measurement of Heart Rate (HR), recorded in beats per minute (bpm). This variable serves as a proxy for the participants' physical exertion and autonomic nervous system arousal during the experimental sessions. Behavioral responses are quantified by monitoring Sound Intensity Levels, measured in decibels (d*B*). This variable is utilized to evaluate vocal engagement, providing data on the intensity of the participants' behavioral interaction with the stimuli. The technical performance of the evaluated system is defined by two primary variables: Notification Speed (quantified by system latency) and Device Convenience. The latter is an ergonomic construct assessing the user's perceived comfort and ease of use during device operation.

Data Collection Techniques

Data was collected through automatic monitoring by the system and manual observations by teachers for comparison. Analysis was carried out systematically. Quantitative descriptive methods *to* evaluate the effectiveness of the system in detecting early signs of starvation. The threshold was established based on initial observations and WHO standards regarding heart rate in children aged 6–12 years (Kildal et al., 2023; Riaz et al., 2025).

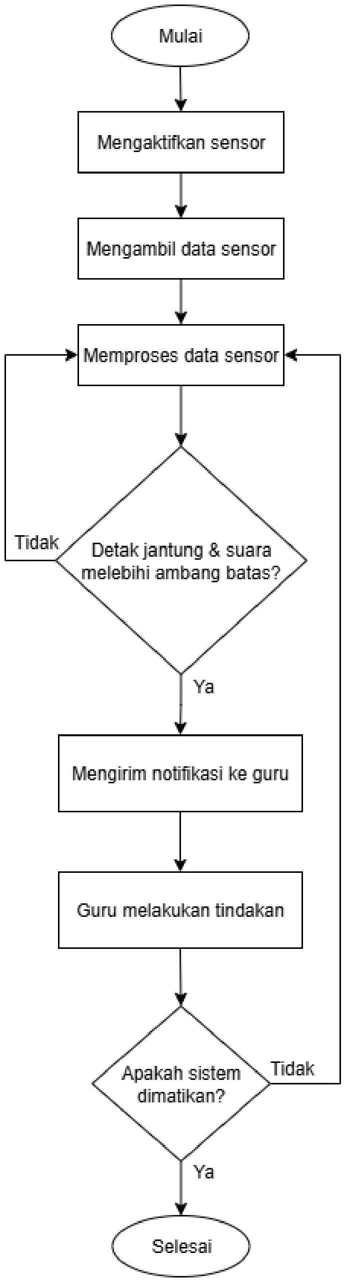

Figure 1. System Flowchart

Research Results and Discussion

This research is still in the system development stage and has not yet been tested directly in the field. Therefore, the results and discussion presented are preliminary. Simulative and literature-based, and refers to initial observations of real needs in the Special School (SLB) environment.

The system developed consists of a microcontroller *ESP32* as a control and data processing center, a heart rate sensor, MAX30100, and a sound sensor *KY-037*. Based on the results of laboratory simulations, the system can read physiological and vocal signals stably, with a response time the average time for sending notifications is 5–10 seconds, depending on local network conditions. This is below the system's target of 30 seconds.

The system is successfully marking potential tantrums when the heart rate parameter exceeds 100 bpm, and the sound volume is above 70 dB. The graph displayed on the interface dashboard shows significant BPM fluctuations under certain conditions. As shown in Figure *2*, when the heart rate increases drastically, the system automatically sends an alert with a notification *"ALERT: Potential tantrum detected!"*

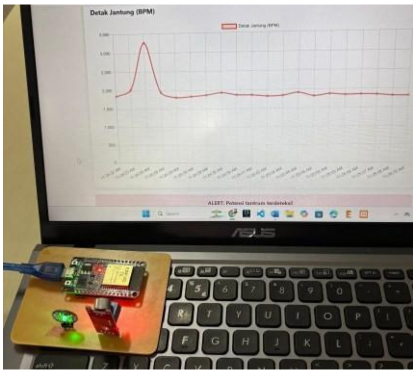

Figure 2. Monitoring Dashboard Display and ESP32 Components Connected to Laptop

Likewise, the dashboard web-based interface are accessed via mobile devices shows two main graphs in real-time: heart rate and sound volume. Figure 3 is shows a visualization of the system when detecting a high heart rate, which is marked with a yellow warning.

In simulation testing, the system's detection results showed initial validity against the tantrum indicator. This is supported by literature stating that physiological indicators (*heart rate*) and vocals (*voice intensity*) have a strong correlation with children's emotional reactivity with *Autism Spectrum Disorder (ASD)*. Utilization of technology*Internet of Things* (IoT), in this context has also shown effectiveness for real-time monitoring in various previous studies.

Figure 3. Real-time Visualization of Voice Volume and Heart Rate via Mobile Device

Table 1. Simulation Results of the Tantrum Detection System
(All data are the results of internal system testing in the class)

Parameter	Simulation Results	Reference Standard
Heart rate (bpm)	102-125	> 100 bpm (WHO, anak 6–12 th)
Sound intensity (dB)	72-88	> 70 dB
Notification time (seconds)	5-10	< 30 seconds (system target)
Simulation detection accuracy	±95%	-

This system is also designed with consideration of ergonomic aspects, such as ease of use for special needs students and ease of interface access for teachers. The use of lightweight wearable devices that do not interfere with the activities of children with ASD also aligns with approaches widely recommended in current literature.

*Figure 4*shows the hardware configuration assembled on a PCB board for efficiency and portability.

Although it has not been tested directly on students, the system has demonstrated early detection functionality that works logically and meets field requirements. The next step in this research will focus on validating the system in a real-life special needs environment**,** including tests of accuracy, sensitivity, user comfort, and its impact on the learning process and student safety in inclusive classes.

Conclusions and Recommendations

Based on the results of the system design and simulation, it can be concluded that the development of a real-time tantrum detection system based on...*Internet of Things (IoT)* has the potential to be an applicable solution to support the inclusive learning process in Special Schools (SLB), especially in dealing with students with *Autism Spectrum Disorder (ASD)*. This system utilizes the integration of heart rate and sound sensors controlled by a microcontroller.*ESP32*, equipped with an interface dashboard, is a web-based system that allows teachers to receive notifications quickly and efficiently.

Although the system is still in the laboratory simulation stage, initial results indicate that the detection of physiological and vocal indicators can be done accurately and responsively, providing early warning of potential tantrums. The use of this system in inclusive learning strategies is fundamental. Early notification on*dashboard* changing teachers from a reactive to a proactive approach; teachers can immediately intervene and de-escalate before a full-blown tantrum ensues. Furthermore, on the dashboard*, there* is a system that can serve as a decision-making tool, where teachers can use historical student data to identify stress triggers and implement more effective personalized learning. In addition to technical excellence, the system design also considers user convenience and ease of access to information by educators.

Therefore, this system is expected to reduce the burden of manual supervision and create a learning environment that is more adaptive, safe, and responsive to the needs of students with special needs. This research opens up opportunities for further development through direct field testing, validation on a wider user sample, and integration with artificial intelligence technology to improve the accuracy and personalization of the detection system.

Although this IoT-based tantrum detection system shows great potential, the research still has several important limitations. First, the testing was limited to laboratory simulations, thus not reflecting the more complex and dynamic conditions of special needs classrooms. Second, the system was tested on a limited user sample, so the detection accuracy cannot be generalized to the full range of behaviors of students with ASD. Third, the system is not equipped with an artificial intelligence algorithm capable of distinguishing between increased heart rate or vocalizations due to stress, physical activity, or other emotional states, so the risk of false alarms remains. Furthermore, the user experience aspect of students' use of wearable sensors has not yet been tested in a real-world context. Future development can focus on direct field testing in special needs classrooms involving more students to strengthen the system's validity. Machine learning can be added to enhance the system's ability to recognize emotional and behavioral patterns more accurately and personally. Furthermore, the dashboard interface can be developed with behavioral analytics features, intervention recommendations, and automated reports to help teachers make faster and more informed decisions. Improvements to the wearable design should also be considered to make it more comfortable, discreet, and safe for children. These steps are expected to make the system more comprehensive, adaptive, and ready for implementation in inclusive learning in the future.

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