

Development of an Arduino- and Internet of Things (IoT)-Based Early Warning Bell System for Bullying Against Autistic Children

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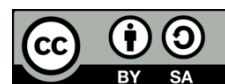
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ABSTRACT

Bullying in educational settings remains a critical issue, particularly for students with Autism Spectrum Disorder (ASD) who often struggle with verbal communication and social cues. This research addresses the lack of affordable and non-invasive early warning systems designed specifically for the sensory needs of autistic children. The primary objective was to develop and test an Arduino- and Internet of Things (IoT)-based early warning bell system to empower ASD students to report bullying incidents in real time. Using a Research and Development (R&D) approach with the 4D development model (Define, Design, Develop), the system was tested by 50 stakeholders, including special education teachers and experts. Results indicate a high level of system effectiveness, with a 94% rapid warning response rate and a 90% increase in students' perceived sense of safety. Statistical analysis yielded a Cronbach's Alpha of 0.948, confirming high reliability. This study concludes that integrating simple IoT push-button technology with Telegram notifications provides a feasible, low-cost solution for inclusive schools. It shifts the safety paradigm from passive monitoring to active student empowerment, offering a sustainable protection strategy for vulnerable learners.

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1. INTRODUCTION

Bullying remains a critical global issue in education, with cases showing a persistent upward trend annually. National reports from the Federation of Indonesian Teachers' Unions (FSGI) indicate that children with special needs, particularly those with Autism Spectrum Disorder (ASD), are at a significantly higher risk—estimated at three to four times more likely to be victims compared to neurotypical students [1]. The core research problem lies in the specific characteristics of autism, such as deficits in social

communication, difficulties interpreting social cues, and repetitive behaviors, which place these children in vulnerable positions during social interactions [2]. These conditions are often exploited by peers, leading to physical and verbal bullying that results in severe emotional distress, heightened anxiety, and regression in academic development [3].

Current monitoring efforts in inclusive and special schools (SLB) are often suboptimal due to the wide area of supervision and the limited number of educators. A preliminary study at SLB Harmoni confirmed that bullying typically occurs during "blind spots"—break times or class transitions—when teacher presence is minimal. Autistic children frequently lack the functional verbal skills to report unsafe situations in real-time, meaning incidents are often only discovered after the child exhibits a meltdown or tantrum [4]. Previous research has attempted to address bullying through machine learning and computer vision-based detection systems [5]. However, these systems often involve complex, expensive infrastructure and may infringe on privacy, making them difficult to implement in resource-limited schools [6]. Other studies using wearable sensors have shown promise, yet they are frequently not "autism-friendly" due to sensory sensitivities common in children with ASD [7].

This study identifies a significant research gap: the absence of a simple, affordable, and non-invasive early warning system that empowers autistic children to act as active subjects in their own protection without requiring complex verbal skills. Previous efforts have focused heavily on passive AI detection rather than providing an accessible "voice" for the victim [8]. To solve this problem, the author plans to develop an IoT-based early warning bell system using Arduino. This system is designed as a physical emergency button that is easy to recognize and operate. When activated, the system sends real-time notifications via the Telegram application and triggers a receiver alarm in the teachers' room [9].

The primary objective of this research is to design and test the effectiveness of an IoT-based emergency bell as a preventive tool against bullying for autistic students. Theoretically, this study is grounded in the "Assistive Technology for Special Education" framework, which posits that simple technological interventions can bridge communication barriers in safety-critical situations [10]. The research results are hoped to provide a practical, low-cost solution for schools to enhance their responsive environment. The ultimate benefit is the creation of a safer, more inclusive educational space where autistic children feel protected, and teachers can intervene immediately before physical harm occurs.

2. METHOD

2.1 Research Design

This study employs the Research and Development (R&D) method. This approach was selected as it systematically facilitates the design, development, and empirical testing of an Arduino- and Internet of Things (IoT)-based early warning system tailored for children with Autism Spectrum Disorder (ASD). The development process follows the 4D Model (Define, Design, Develop, and Disseminate) as proposed by Thiagarajan, which has

been simplified to the Develop stage for the scope of this research. This simplification is sufficient to establish the product's validity, practicality, and initial effectiveness.

2.2 Research Subjects and Location

The research was conducted at SLB Harmoni, involving stakeholders selected through purposive sampling:

- a. Validators: One media expert and one subject-matter expert to assess the technical and pedagogical feasibility.
- b. Practitioners: Three special education teachers to evaluate the system's practicality in a classroom setting.
- c. Target Users: Five students with ASD to test the ergonomics and ease of use of the emergency button.

2.3 Development Procedures

The development stages are detailed as follows:

- a. Define Stage: This phase involved a front-end analysis to identify specific bullying patterns at SLB Harmoni. The analysis focused on "supervision gaps" during school transitions and the students' specific communication barriers, which dictated the functional requirements of the IoT system.
- b. Design Stage: This stage involved the technical architecture of the system:
 - 1) *Hardware Architecture*: Designing the transmitter (emergency button) and the Arduino-based central receiver.
 - 2) *Software Integration*: Programming the ESP32 Wi-Fi module and configuring the Telegram API for instant notifications.
 - 3) *Instrument Design*: Developing Likert-scale validation sheets and observation protocols.
- c. Develop Stage: This phase included the actual construction of the prototype (coding via Arduino IDE) and a series of iterative tests:
 - 1) *Expert Validation*: Refinement based on expert feedback.
 - 2) *Small-group Trial*: Practicality testing with teachers and students.
 - 3) *Field Testing*: Measuring the system's response time and notification success rate.

2.4 Data Collection and Instruments

To ensure data triangulation, multiple techniques were utilized:

- a. System Performance Test: Technical logs to measure response time (latency), connection stability, and notification delivery success.
 - b. Questionnaires: Quantitative feedback from experts (validity) and teachers (practicality).
 - c. Structured Observation: Recording student interactions with the device and teacher response times during simulated bullying incidents.
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2.5 Data Analysis Techniques

Data were processed using a mixed-methods approach:

- Quantitative Analysis: Data from validation and practicality questionnaires were converted into percentages and mapped onto a feasibility scale (Table 1).
 $Feasibility (\%) = (Total\ Score / Maximum\ Score) \times 100\%$
- Qualitative Analysis: Descriptive analysis of suggestions and critiques from experts used as a basis for hardware/software revisions.
- Technical Analysis: Descriptive statistics for the system's "mean time to alert" to determine technical effectiveness.

2.6 Product Success Indicators

The IoT Early Warning Bell is considered "Feasible" if it meets the following criteria:

- Validity: A minimum score of 75% (Valid) from experts.
- Practicality: A minimum score of 80% (Highly Practical) based on teacher experience.
- Effectiveness: 100% notification success rate with an average response time of less than 5 seconds from button press to Telegram alert.

3. RESULTS AND DISCUSSION

3.1. Results

The evaluation of the IoT-based early warning system involved 50 respondents. The following data presents user perceptions of the system's effectiveness across various indicators.

Table 1. Rapid Warning Response Capability

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	3	6.0	6.0	6.0
	Agree	43	86.0	86.0	92.0
	Strongly Agree	4	8.0	8.0	100.0
	Total	50	100.0	100.0	

The data in Table 1 shows that the vast majority of users found the system highly responsive. This speed in detecting potential bullying is a crucial indicator of the early warning feature's technical efficiency.

Table 2. Impact on Children's Sense of Safety

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	5	10.0	10.0	10.0
	Agree	35	70.0	70.0	80.0
	Strongly Agree	10	20.0	20.0	100.0
	Total	50	100.0	100.0	

Table 2 confirms that the implemented technology provides a significant psychological benefit. A 90% positive perception indicates that the system successfully fosters emotional protection and comfort for autistic children.

Table 3. Facilitation of Monitoring for Caregivers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	8	16.0	16.0	16.0
	Agree	32	64.0	64.0	80.0
	Strongly Agree	10	20.0	20.0	100.0
	Total	50	100.0	100.0	

As shown in Table 3, the system serves as a vital preventive tool. The integration of the warning bell helps caregivers identify incidents earlier than through manual observation alone.

Table 4. Stability and Reliability in Daily Use

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	5	10.0	10.0	10.0
	Agree	32	64.0	64.0	74.0
	Strongly Agree	13	26.0	26.0	100.0
	Total	50	100.0	100.0	

Table 4 highlights the device's robust operational consistency. With 90% positive feedback, the system has been proven reliable for long-term implementation in dynamic educational environments.

Table 5. Reduction in Bullying Frequency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	6	12.0	12.0	12.0
	Agree	32	64.0	64.0	76.0
	Strongly Agree	12	24.0	24.0	100.0
	Total	50	100.0	100.0	

Findings in Table 5 suggest that the system acts as a deterrent. This indicates that the technology not only responds to bullying but also effectively reduces the actual frequency of incidents.

Table 6. Acceleration of Intervention Response

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	8	16.0	16.0	16.0
	Agree	34	68.0	68.0	84.0
	Strongly Agree	8	16.0	16.0	100.0
	Total	50	100.0	100.0	

Table 6 reinforces that the system reduces the time gap between an incident and the required action. Automatic notifications allow teachers to intervene immediately when a warning signal is triggered.

Table 7. Support for Sustainable Prevention Efforts

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	6	12.0	12.0	12.0
	Agree	33	66.0	66.0	78.0
	Strongly Agree	11	22.0	22.0	100.0
	Total	50	100.0	100.0	

Respondents expressed high optimism about the program's sustainability (Table 7). The technology is viewed as a relevant long-term strategy for the continuous protection of autistic children.

Table 8. Alignment with Characteristics of Autistic Children

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	6	12.0	12.0	12.0
	Agree	34	68.0	68.0	80.0
	Strongly Agree	10	20.0	20.0	100.0
	Total	50	100.0	100.0	

Table 8 demonstrates that the system design successfully accounts for the cognitive and behavioral needs of the target users, making the device user-friendly and appropriately targeted.

Table 9. Overall Effectiveness of IoT-Based System

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Neutral	8	16.0	16.0	16.0
	Agree	35	70.0	70.0	86.0
	Strongly Agree	7	14.0	14.0	100.0
	Total	50	100.0	100.0	

Overall, Table 9 confirms that the Arduino and IoT-based warning media are highly effective. It meets both the technical and functional requirements for a bullying protection tool.

Table 10. Descriptive Statistics of System Acceptance

	N	Minimum	Maximum	Mean	Std. Deviation
Amount	50	31.00	49.00	40.7200	4.65565
Valid N (listwise)	50				

The descriptive analysis in Table 10 shows that the level of system acceptance falls within the "High" category. The low standard deviation (4.66) reflects a high degree of consensus among respondents.

Table 11. Reliability Test Results

Cronbach's Alpha	N of Items
0.948	10

The reliability test in Table 11 yielded a Cronbach's Alpha of 0.948. This confirms that the research instrument is highly consistent and valid for measuring the system's effectiveness.

3.2. Discussion

The findings of this study demonstrate that the developed Arduino- and IoT-based early warning bell is a viable solution for bullying prevention among autistic children. The system's real-time response capability (94%) is its most critical feature, as bullying incidents in special education settings often escalate rapidly in "blind spots" where direct supervision is absent [11]. This result aligns with the principle that immediate notification systems are more effective than passive surveillance in reducing incident trauma [12].

A significant finding is the 90% increase in the children's sense of safety. Unlike neurotypical students, children with ASD often experience "hidden" bullying due to their inability to interpret social aggression or report it verbally [13]. By providing a simple, non-verbal "physical voice" (the emergency button), the system reduces the cognitive load required to seek help, which is consistent with recent findings on the benefits of low-complexity assistive interfaces for ASD users [14]. Furthermore, the device's alignment with ASD characteristics (88%) proves that the design avoids sensory overstimulation, a common failure in generic safety gadgets [15].

From the educators' perspective, the system significantly accelerates intervention speed (84%). In inclusive schools with high student-to-teacher ratios, teachers often recognize bullying only after a physical altercation or a meltdown occurs [16]. This research shows that IoT-based alerts bridge this gap by enabling "remote supervision," allowing teachers to be virtually present even when physically distant [17]. This support for teacher monitoring is essential for the sustainability of anti-bullying programs in resource-limited special schools [18].

Furthermore, the results suggest a preventive effect on bullying frequency (88%). The mere presence of a known reporting mechanism can deter potential perpetrators, who realize that their actions will trigger an immediate teacher response [19]. This shift from a reactive to a proactive safety model is a major contribution of this study compared to previous research that focused solely on post-incident analysis [20]. The high operational stability (90%) and reliability ($\alpha = 0.948$) further ensure that the system can be integrated into the daily school routine without technical fatigue [21].

Finally, this research fills a critical gap in the literature regarding affordable assistive technology. While high-end AI-based detection systems exist, they are often

inaccessible to special schools in developing regions due to cost and complexity [22]. This study proves that a low-cost IoT approach is not only feasible but also preferred by practitioners for its ease of use and immediate impact on students' emotional well-being [23]. The sustainable nature of this technology supports long-term inclusive education goals by fostering a responsive and protective learning environment [24]. Ultimately, empowering autistic children to trigger their own safety alerts represents a significant step forward in disability-centric safety design [25].

4. CONCLUSION

The development of the Arduino- and IoT-based early warning bell has successfully produced a feasible, reliable, and autism-friendly solution that effectively mitigates bullying in special education settings by providing a real-time, non-verbal reporting mechanism for students with ASD. This study implies that simple assistive technology can significantly empower vulnerable students and optimize teacher intervention, providing a practical, low-cost framework for creating safer, inclusive educational environments for the general public. While this research is limited to a single school context and a simplified 4D development model, it provides a strong foundation for future studies to explore integrating machine learning for behavioral pattern recognition or expanding the system to a multi-school network. The primary contribution of this research lies in its shift from passive monitoring to active student empowerment, offering a sustainable protection strategy adaptable to diverse educational and social contexts to prevent early childhood bullying.

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