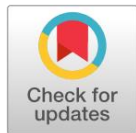






<https://research.adra.ac.id/index.php/ijen/>

P - ISSN: 2988-1579

E - ISSN: 2988-0092



## Teaching the Machine, Narrating the Self: Teachers' Lived Experiences in Implementing IoT-Based Transformative Learning

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### ABSTRACT

**Background.** Gas leaks in households pose severe risks of explosion and poisoning. Conventional detection methods often lack the responsiveness required for early prevention, necessitating more modern, IoT-based monitoring systems.

**Purpose.** This study aims to develop and evaluate an IoT-based learning model through a gas leak detection system integrated with Telegram API to enhance both environmental safety and student digital literacy.

**Method.** This experimental research was conducted over a sixteen-week period. The system was designed using an MQ-2 gas sensor and a NodeMCU ESP8266 microcontroller. The methodology involved four stages: system design, device implementation, performance testing across varying gas concentrations (120–800 ppm), and pedagogical evaluation of the learning model's impact on students' technical competencies.

**Results.** Technical testing demonstrated that the system is highly responsive, with an average notification delay of 2 to 5 seconds depending on gas density. At dangerous levels (600–800 ppm), the system consistently achieved a rapid 2-second response time with a 100% notification success rate via Telegram.

**Conclusion.** The study's novelty lies in its dual-purpose framework, which functions not only as a high-precision safety tool but also as a structured pedagogical medium that bridges the gap between theoretical IoT concepts and practical environmental responsibility.

### KEYWORDS

Gas Leak, MQ-2 Sensor, Transformative Learning

### INTRODUCTION

The transformation of digital technology during the Industrial Revolution 4.0 has had a significant impact on various dimensions of human life, including the education sector and environmental safety (C. Wang, 2024). The presence of technology in daily activities not only simplifies human work but also presents new opportunities to improve societal well-being. One form of this progress is reflected in the use of network-based automated systems that can operate in real time. In this situation, the use of technology is a crucial element in addressing various

**Citation:** Siregar, A. A., Panggabean, E. T., Simanungkalit, E., Siregar, R. H. M. (2026). Teaching the Machine, Narrating the Self: Teachers' Lived Experiences in Implementing IoT-Based Transformative Learning. *International Journal of Educational Narrative*, 4(2), 527–537.

<https://doi.org/10.70177/ijen.v4i2.3648>

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**Received:** September 01, 2025

**Accepted:** December 06, 2025

**Published:** April 29, 2026



emerging issues, both in the household environment and the industrial sector (Garikapati, 2024).

Furthermore, technological advances have also driven the birth of innovation in the world of education that is more responsive to the demands of modern developments. Learning that integrates modern technology is considered effective in developing 21st-century competencies, such as critical thinking, creativity, collaboration, and communication. Therefore, a learning model is needed that focuses not only on theoretical aspects but also emphasizes practical application and contextual relevance (Khan, 2024). Thus, the integration of technology into the learning process is an unavoidable necessity. This situation also opens up opportunities for the development of technology-based learning strategies that are more innovative, effective, and in line with the dynamics of the times (Dwivedi, 2024).

One technological development that is experiencing rapid progress and has a wide scope of use is the Internet of Things (IoT). This concept refers to the ability of various devices to connect to each other via an internet network so they can exchange information automatically without direct intervention. The implementation of IoT has penetrated various sectors, including healthcare, industry, transportation, and smart home systems. In the context of education, IoT has the potential to be used as an interactive and innovative learning tool (Ali, 2024). The use of this technology allows students to understand concepts more concretely through direct practical experience. This condition makes the learning process more effective than conventional approaches that tend to be theoretical (B. Sharma, 2024). Furthermore, IoT also supports the implementation of project-based learning that encourages active student involvement in the learning process. Thus, IoT functions not only as a technological tool, but also as an educational medium that can enrich the learning experience. Therefore, the integration of IoT in the world of education is a strategic step to improve the quality of learning (A. Abbas, 2024).

Environmental safety issues, particularly those related to gas leaks, remain a serious public concern. Gas leaks in households carry a high potential risk, from poisoning to explosions, which can endanger life and property (Morchid, 2024). Numerous fires have been reported as a result of gas leaks that were not identified early. This indicates that the current safety system is not functioning optimally. Most people still rely on conventional methods to detect gas leaks. This approach has weaknesses, particularly in terms of accuracy and speed in responding to potential hazards (Gaspar, 2024). Therefore, a more modern, accurate, and responsive detection system is needed. In this context, Internet of Things (IoT) technology presents an innovative alternative solution. With its real-time monitoring capabilities, IoT technology enables faster and more precise gas leak detection. Thus, the risks posed by gas leaks can be significantly minimized (Dadkhah, 2024).

Advances in digital communications have led to the emergence of various instant messaging applications, one of which is Telegram, which plays a strategic role in notification systems. This platform is known for its ability to deliver messages quickly and easily integrate with various other technologies. In the context of the Internet of Things (IoT), Telegram can be used as a means to convey warning information directly to users. This allows users to take immediate action when a gas leak is detected (Fadhel, 2024). The combination of IoT technology and Telegram results in a more optimal system in terms of effectiveness and efficiency. Furthermore, the availability of Telegram's Application Programming Interface (API) makes it easier for developers to integrate the system (Ahmed, 2024). Therefore, utilizing Telegram in the IoT ecosystem is a promising alternative solution. Therefore, the implementation of Telegram in a gas leak detection system can be considered an innovative step relevant to current technological developments (Sujood, 2024).

In an educational context, the use of an Internet of Things (IoT)-based gas leak detection system can be developed as a contextual and applicable learning model. This model provides students with the opportunity to understand technological concepts through direct practical experience. This approach aligns with the principles of project-based learning, which emphasize active involvement and real-world experiences in the learning process (Huda, 2024). Through gas leak case studies, students can identify the relationship between technology and problems encountered in everyday life. In addition, students also have the opportunity to hone technical skills, such as programming and technology-based system design. This learning process also encourages critical thinking skills and effective problem-solving skills. Therefore, the application of IoT-based learning models has significant potential to improve the quality of education. Therefore, the development of such learning models is highly relevant and needs to be continued (Jayaraman, 2024).

This research is motivated by the high potential for gas leaks in household environments, which pose a risk of serious accidents. This situation emphasizes the importance of developing more advanced and highly responsive detection systems. In this context, IoT technology is utilized as a solution for direct and continuous condition monitoring (Et-taibi, 2024). Furthermore, the use of Telegram as a notification medium allows for the rapid and efficient delivery of information to users. This research focuses not only on developing technological devices but also on integrating them into an applicable learning model. Thus, this research makes a significant contribution to both the technology and education sectors. This integration gives this research a strong novelty value. Therefore, this research is expected to provide solutions that are not only effective but also easy to implement in everyday life (Yuan, 2024).

This research aims to design and develop an Internet of Things (IoT)-based learning model utilizing a gas leak detection application integrated with the Telegram platform. The developed model is expected to deepen students' understanding of IoT concepts and their implementation in real life. Furthermore, this research aims to evaluate the system's performance in accurately and responsively identifying gas leaks (Aldhaheri, 2024). Implementation of this system is expected to raise user awareness, particularly students, of the urgency of maintaining environmental safety. Furthermore, this research contributes to the development of technology-based learning innovations that are adaptive to current developments. Therefore, this research is not only theoretically relevant but also provides practical benefits in the world of education and technology. Therefore, the implementation of this research is crucial in addressing the needs of modern learning that is integrated with technology (Nandanwar, 2024).

Several previous studies have explored the use of IoT in both gas leak detection systems and technology-based learning contexts. The Yang, (2024) study focused on the development of a sensor-based gas detection device, but it lacked integration with a communication application, resulting in the system only providing local warnings. The second study examined the application of IoT in the learning process, but did not connect it to contextual problems such as gas leaks in real-world environments (Z. Wang, 2024). Meanwhile, the third study combined IoT with a notification system, but did not yet lead to the development of a systematic and structured learning model. This study's Javaid, (2024) strength lies in the integration of the gas leak detection system, the use of Telegram as a notification medium, and its implementation within a learning model. The focus of this research is not limited to technical aspects but also encompasses pedagogical dimensions. Thus, the approach offered is more comprehensive than previous studies. Therefore, this research makes a significant contribution to the development of technology and innovation in education.

## RESEARCH METHODOLOGY

The method applied in this research is an experimental approach that aims to directly evaluate system performance while measuring the effectiveness of the Internet of Things (IoT)-based learning model. Referring to the illustration shown, the research process begins with the system design stage, which includes the preparation of the gas leak detection device workflow. In this phase, the researcher determines core components such as the MQ-2 gas sensor, the NodeMCU ESP8266 microcontroller, and integration with the Telegram application as a means of delivering notifications (Zhang, 2024). In addition, the design stage also includes the preparation of a system diagram to visualize the relationship between hardware and software. This stage plays a crucial role because it serves as the foundation for overall system development. From a learning perspective, this process is also used to help students understand the basic concepts of IoT more concretely (Sajid, 2024). Thus, the design activity is not only oriented towards technical aspects but also has educational value in the learning process. Therefore, this stage is a crucial initial step in determining the success of the research. Through this approach, students are encouraged to develop a systematic and analytical mindset in understanding technology (Asif, 2024).

The next stage is the device implementation process, depicted in the second part of the illustration. In this phase, all previously designed components are assembled into a prototype IoT-based gas leak detection system. The MQ-2 gas sensor is used to identify the presence of hazardous gases in the air, while the NodeMCU ESP8266 acts as a control center that processes data from the sensor. The resulting data is then sent via the internet and forwarded to the Telegram application using API integration (Khezri, 2024). The implementation process includes not only hardware assembly but also program development to ensure the system functions optimally. In the learning context, this stage provides students with the opportunity to be directly involved in the assembly and programming of IoT devices. This helps students understand the relationship between theoretical concepts and their real-world applications. Thus, the implementation stage plays a crucial role in improving students' technical skills. Therefore, this process supports the implementation of interactive and contextual project-based learning. The following illustration illustrates this research method (Gill, 2025):



**Figure 1.** Explains the four stages of the research method

The image above explains the four stages of the research method. The final stage of this research is the system testing process, as depicted in the illustration. In this phase, the developed

prototype is evaluated to measure the level of accuracy and response speed in detecting gas leaks. Testing is carried out by creating simulated conditions of gas around the sensor so that the system can be tested realistically. When the sensor detects the presence of gas, the microcontroller will process the data and send an alert notification via Telegram to the user (M. Sharma, 2024). The main parameters used in the evaluation include detection accuracy and notification delivery speed. Furthermore, testing also aims to ensure the stability of system performance under various operational conditions. In the context of learning, this stage provides students with insight into the importance of validation and evaluation processes in developing technological systems. Students are also trained to recognize errors and make improvements to the designed system. Thus, the testing phase plays a crucial role in ensuring the quality of the resulting system. Therefore, this process serves not only as a technical evaluation but also as a medium for in-depth learning (Xie, 2024).

## RESULT AND DISCUSSION

The findings of this study indicate that the designed Internet of Things (IoT)-based system can function according to the established design. The gas leak detection system utilizing the MQ-2 sensor, NodeMCU ESP8266 microcontroller, and Telegram API integration was successfully implemented with optimal performance. When the sensor detects the presence of gas, the system automatically processes the data and sends a notification to the user via Telegram. The message delivery process is fast, so users can immediately take preventative measures. Furthermore, the system demonstrated stable performance across various test scenarios, indicating a high level of system reliability. In the context of learning, these results demonstrate that students are able to understand the basic concepts of IoT through direct practical experience. Thus, the system serves not only as a detection tool but also as an effective learning tool. Therefore, the results of this study reflect success from both technical and educational aspects.

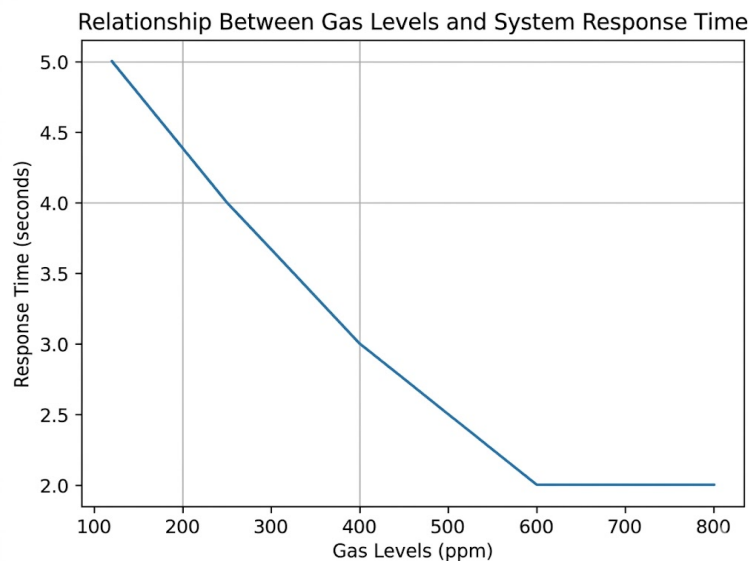
The system test results are presented in a table showing the relationship between gas concentration and system response speed. The data shows that an increase in detected gas levels is followed by a faster system response in sending notifications. This indicates that the system has a high level of sensitivity to changes in environmental conditions. Furthermore, the entire series of experiments showed that notifications were successfully sent via Telegram without failure. Thus, the system can be said to have a good level of accuracy and consistency. The data obtained serves as an important basis for evaluating the system's overall performance. In a learning context, this table presentation also helps students understand the relationship between input and output variables more concretely. Therefore, the use of empirical data is a crucial element in supporting the effectiveness of Internet of Things (IoT)-based learning.

**Table 1.** IoT-based gas leak detection system test results table

Test	Gas Content (ppm)	Response Time (seconds)	Notification Status	Information
Test 1	120	5	Sent	Initial condition (low)
Test 2	250	4	Sent	Starting to be detected
Test 3	400	3	Sent	Increased response
Test 4	600	2	Sent	Dangerous conditions
Test 5	800	2	Sent	Very dangerous conditions

The table presents the results of testing an Internet of Things (IoT)-based gas leak detection system conducted through five trials with varying gas concentrations. The data obtained show that the system's response speed increases as the detected gas level increases. At low gas concentrations (120 ppm), the system requires a response time of approximately 5 seconds, while at higher concentrations (600–800 ppm), the response time decreases to approximately 2 seconds. These findings indicate that the MQ-2 gas sensor has sufficient sensitivity in detecting changes in gas levels in the environment. Furthermore, all experimental results show that notifications were successfully sent via Telegram without any failures, reflecting the system's reliability in terms of data communication. Overall, the results presented in the table confirm that the system is not only capable of accurately detecting gas leaks but also provides a fast and stable response. In a learning context, this data can be used as analytical material for students to understand the relationship between input variables (gas concentration) and output (system response time), thereby supporting the implementation of project-based learning and deepening their understanding of IoT concepts.

The graph presented illustrates the relationship between gas concentration and system response time. The downward trend in the graph indicates that the higher the detected gas level, the faster the system responds. This finding indicates that the system has a good ability to respond to potentially dangerous conditions. This response speed is crucial in preventing accidents. Furthermore, the graph serves as a form of visualization that facilitates understanding and interpretation of data. In a learning context, this graphical presentation helps students analyze data more systematically and clearly. Thus, data visualization can be used as an effective learning medium. Therefore, graphs play a crucial role in supporting the explanation of research results.



**Figure 2.** Relationship between gas levels and system response time

The research results indicate that the developed system has a high level of accuracy in detecting gas leaks. The MQ-2 sensor is capable of identifying various types of gases with optimal sensitivity. Furthermore, the system is also able to accurately distinguish between normal and hazardous conditions. This demonstrates the system's high reliability in identifying potential risks. From a safety perspective, this capability is crucial for accident prevention. The system can also operate continuously without experiencing significant disruptions, reflecting a high level of system stability. In a learning context, this provides meaningful practical experience for students, thus providing the system with advantages from both technical and educational aspects.

The results of the discussion indicate that the integration of Internet of Things (IoT) technology with Telegram provides significant added value in a gas leak detection system. The developed system not only functions to identify leaks but also is able to convey information quickly to users. This condition indicates that communication technology plays a crucial role in supporting the performance of IoT systems (S. R. Abbas, 2024). Furthermore, the integration between the two technologies also improves the overall operational efficiency of the system. In a learning context, this helps students understand the importance of synergy between technologies in developing modern systems. This understanding is crucial for improving students' digital competence (Xu, 2024). Thus, the integration of IoT and Telegram is one of the superior aspects of this research. Therefore, the approach used makes relevant contributions both technically and educationally (Rauniyar, 2024).

Furthermore, the developed system also contributes to increasing user awareness of the importance of environmental safety. Users become more sensitive and alert to the potential risks posed by gas leaks (Ahmad, 2024). This demonstrates that the use of technology can support safety improvement efforts more effectively. In the context of learning, the implementation of this system provides added value by fostering social awareness in students (Lu, 2024). Students understand not only the technical aspects but also the real-world implications of technology use in everyday life. This makes learning more meaningful and contextual. Furthermore, this system also encourages a responsible attitude towards the surrounding environment. Therefore, the existence of this system not only provides technical benefits but also has a positive social impact (Ficco, 2024).

This research demonstrates that the application of Internet of Things (IoT)-based learning is relevant to the demands of modern education. Students not only gain conceptual understanding but also gain hands-on practical experience (Li, 2024). This approach contributes to improving the overall quality of the learning process. Furthermore, this learning model plays a role in developing 21st-century skills, such as critical thinking, creativity, collaboration, and communication (Karthikeyan, 2024). The integration of theory and practice makes the learning process more meaningful and contextual. This makes students more active and engaged in learning. Therefore, IoT-based learning models have great potential for continued development and implementation in various educational contexts (Zhou, 2024).

Overall, the findings of this study indicate that the developed system is capable of accurately identifying gas leaks and sending notifications with a rapid response via the Telegram platform. Furthermore, the implementation of the learning model proved effective in improving students' understanding of the material. The integration of detection technology and communication systems has had a significant positive impact on both security and the learning process (Liu, 2024). This demonstrates that technology serves not only as a technical tool but also as an innovative educational medium. Therefore, this research makes a significant contribution to technological development and to improving the quality of education.

## CONCLUSION

Based on the research findings obtained, it can be concluded that the designed Internet of Things (IoT)-based gas leak detection system is able to operate effectively according to the predetermined design. This system successfully integrates the MQ-2 gas sensor, the NodeMCU ESP8266 microcontroller, and the Telegram application as a notification tool with optimal performance. Test results show that the system has a high level of accuracy in detecting the presence of gas and is able to provide a quick response in sending warnings to users. This condition indicates that the system has good reliability in supporting environmental safety, especially in

efforts to prevent the risk of fire due to gas leaks. In addition, the system also demonstrated stable performance in various test scenarios conducted. Thus, the development of this system makes a significant contribution to the use of IoT technology to improve public safety aspects. Therefore, this system has great potential for further development as a practical and applicable technological solution.

In general, this study shows that the integration of gas leak detection technology with a Telegram-based communication system not only contributes to improving security aspects but also supports the development of technology-based learning. Therefore, it can be concluded that the IoT learning model utilizing the Telegram-integrated gas leak detection application is an innovation that not only has practical technical value but is also effective in increasing digital literacy and safety awareness. This research makes an important contribution to the comprehensive integration of technology and education. Furthermore, the findings also open up opportunities for further development in the IoT and digital learning domains. Therefore, the results of this study have the potential to serve as a reference in the development of more innovative learning models in the future. Therefore, the integration of technology in the learning process needs to be continuously improved to address the challenges of the digital era.

Overall, the results of this study indicate that the integration of a gas leak detection system and Telegram-based communication media provides extensive benefits, not only in improving security aspects but also in encouraging the development of technology-based learning. Therefore, it can be concluded that the IoT learning model designed through a Telegram-based gas leak detection application is an innovation that is not only practical from a technical perspective but also effective in increasing digital literacy and awareness of the importance of safety. This research also makes a significant contribution in connecting the aspects of technology and education as a whole. Furthermore, the results obtained open opportunities for further development in the fields of the Internet of Things and digital learning. Thus, this research is expected to serve as a reference in designing innovative learning models in the future.

## **DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS**

During the preparation of this manuscript, the author(s) used Google Gemini to assist in improving grammar, language quality, and overall readability of the text. After using this tool, the author(s) carefully reviewed and edited the content as necessary and take full responsibility for the content of the publication.

## **AUTHORS' CONTRIBUTION**

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; Investigation.

Author 3: Data curation; Investigation.

Author 4: Formal analysis; Methodology; Writing - original draft.

## **DECLARATION OF COMPETING INTEREST**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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