DESIGN AND DEVELOPMENT OF A BASIC ELECTRONICS AND SENSOR SYSTEM TRAINER KIT AS A PRACTICAL LEARNING TOOL FOR STUDENTS

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ABSTRACT

In the era of Industry 4.0, mastering electronics and sensor systems is essential for engineering and technology students. However, at Universitas Teknologi Nusantara, the lack of adequate laboratory equipment hinders students' ability to apply theoretical knowledge through hands-on practice. This study aims to design and develop a basic electronics and sensor system trainer kit to bridge this gap. Using a research and development approach, the study followed five main stages: needs identification, initial design, prototype development, testing, and validation. Components such as temperature, light, pressure, infrared, and ultrasonic sensors were integrated with Arduino Uno and ESP32 microcontrollers. The trainer kit was designed to be modular, user-friendly, and suitable for a variety of experiments. Functionality tests confirmed that all input, process, and output components worked effectively. The media and content validity were assessed by experts, yielding Aiken's V scores of 0.85 and 0.81, respectively, indicating high validity. The trainer kit not only enhances students' practical skills but also prepares them to meet industry demands by providing real-world experience in electronics and IoT systems. This development highlights the importance of practical tools in technical education to close the gap between theory and practice.

Keywords : *Electronics, Sensor, Prototype, Learning and Validation.*

INTRODUCTION

In this digital era, mastering electronics concepts and sensor systems is essential, particularly for students in technology and engineering fields. Electronics form the foundation of nearly all modern technologies, powering everything from consumer electronics to complex industrial machinery (Boltsi et al., 2024; Roy et al., 2021). Meanwhile, sensor systems are fundamental to a wide range of applications, including sensing, monitoring, and automatic control. These systems allow for the collection and interpretation of data, which is critical in sectors like healthcare, automation, the automotive industry, and environmental monitoring (Javaid et al., 2024). Given the rapid pace of technological advancements, students must gain a deep understanding of these fields to ensure they can meet the demands of the modern workforce (Demanggasa et al., 2023).

To succeed in the workforce, students not only need a solid theoretical understanding but also robust practical skills. While theoretical knowledge is the basis for academic learning, hands-on experience is equally important for students to fully comprehend how electronics and sensor systems function in real-world applications (Kumar et al., 2024; Chookaew et al., 2024). Universities like Universitas Teknologi Nusantara play a pivotal role in facilitating this learning by offering students opportunities to engage with real-world technologies. This requires providing access to laboratories equipped with the tools and materials necessary for conducting experiments and practical exercises.

Unfortunately, a significant challenge at Universitas Teknologi Nusantara is the lack of adequate laboratory equipment. While the university offers a solid theoretical curriculum in electronics and sensor systems, students face difficulties in applying this knowledge practically (Ria et al., 2025). Without sufficient practical tools and equipment, students are unable to interact directly with the components and technologies they study (Laseinde et al., 2024). This limits their ability to understand the intricacies of how electronic devices and sensors operate. Students thus miss out on the valuable experience of seeing and working with the actual systems, which is essential for their development as future professionals (Zarkasyi, 2024).

The absence of these practical tools impacts the students' ability to fully grasp the concepts of electronics and sensor systems (Mustakim et al., 2024). For example, without the opportunity to conduct experiments, students cannot observe firsthand how various components function or how sensors measure key physical phenomena such as temperature, pressure, or light. This lack of practical exposure leaves students unable to connect their theoretical learning with real-world applications (Jusoh et al., 2024). As a result, they may struggle with the implementation and troubleshooting of systems, which are crucial skills in the industry (Vennapusa et al., 2024). Furthermore, students often find it difficult to develop the technical expertise required for more complex projects without prior practical experience.

Moreover, this gap between theory and practice can lead to reduced motivation among students. When they are unable to see the real-world relevance of the concepts they study, they may find it hard to stay engaged or see the value of their coursework (O'Keefe, 2025). As a result, students may feel disconnected from their studies, which can negatively impact their academic performance and overall enthusiasm for learning. The practical application of theoretical knowledge plays a crucial role in fostering a deeper understanding of the material and can enhance students' interest in pursuing careers in technology and engineering.

This lack of practical resources also creates a gap between the academic world and industry needs. When students are not exposed to the tools and technologies that are commonly used in the industry, they may find it difficult to adapt to the demands of the workplace (Kumi et al., 2024). In many engineering and technology fields, hands-on experience is just as important as academic credentials. Employers look for individuals who are not only knowledgeable but also capable of applying their knowledge in real-world situations (Makari et al., 2024). By neglecting the practical side of learning, Universitas Teknologi Nusantara risks producing graduates who are not fully prepared for the challenges they will face in their professional careers.

The problem is not just academic but also professional, as students who lack hands-on experience may find it difficult to enter the workforce. Electronics and sensor systems are at the core of many modern industries, and the ability to work with these systems is essential for students' employability (Supriya et al., 2024). The inability to use the right tools and technology will hinder students' development and reduce their competitive advantage in the job market. Therefore, there is an urgent need for the university to invest in practical learning tools that can bridge this gap, ensuring that students gain the experience they need to succeed in the industry.

To address this issue, it is imperative that Universitas Teknologi Nusantara provides the necessary practical tools and equipment for its students. This will not only enhance the students' learning experience but also ensure they are equipped with the skills needed to thrive in the fast-evolving technology and engineering sectors. Practical tools such as laboratory kits, sensors, and electronic components will allow students to apply theoretical concepts in a real-world context, helping them develop the competence and confidence required for their future careers. By bridging the gap between theory and practice, the university can better prepare its students for the demands of the modern industrial landscape.

METHOD

Research Design

This research uses a design and development approach to develop a basic electronics trainer kit and sensor systems. The focus of the study is on the process of creating a device that can be used by students to understand the basic concepts of electronics through hands-on practice. The stages of this research are outlined in the Figure 1, following the diagram.

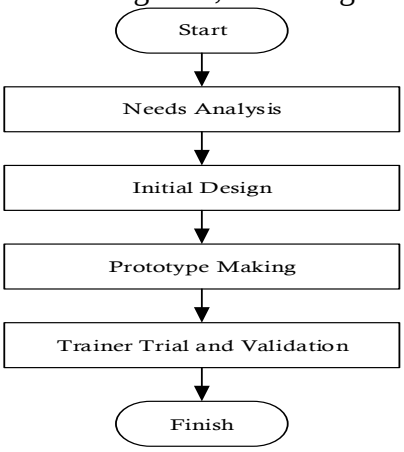


Figure 1. Research Flow

Needs Identification

The needs identification stage is a crucial first step in the development of the basic electronics trainer kit and sensor systems at Universitas Teknologi Nusantara. This stage aims to gain a detailed understanding of the practical needs of students and lecturers, considering that initial observations revealed that the current laboratory facilities are insufficient, which makes it difficult for students to grasp the basic concepts of electronics and sensor systems.

Interviews with lecturers and students highlighted several key issues, including the lack of interactive and flexible practical tools for various experiments, and the need for integrating sensor systems with microcontrollers such as Arduino or Raspberry Pi. In the era of Industry 4.0, programming skills and sensor data processing are becoming increasingly important. Therefore, the proposed trainer kit is expected to meet these needs with a modular, cost-effective, and easy-to-use design for various experiments, without requiring much maintenance.

Initial Design

The sensor system design stage is an essential step in the development of the basic electronics trainer kit and sensor systems, with the goal of designing a system that allows students to learn how sensors work and their real-life applications. The designed sensor system will include temperature, light, and pressure sensors, chosen based on their relevance to the course material and ease of programming and operation. The initial component requirements are listed in Table 1 below.

Table 1. Trainer Kit Component Requirements

Component	Specification
Temperature Sensor	Temperature range: -40°C to 125°C, accuracy: ±1°C.
Light Sensor	Measurement range: 0 to 1000 lux, analog output.
Pressure Sensor	Pressure range: 0 to 100 kPa, accuracy: ±1%.
Infrared Sensor	Wavelength: 850-950 nm, operating voltage: 3.3V-5V.
Ultrasonic Sensor	2 cm to 400 cm, accuracy: ±1 cm, frequency: 40 kHz.
Breadboard	400 points
Connectors	JST, 2.54 mm header
Power Supply	5V DC, 1A
Microcontroller	Arduino Uno and ESP 32
LED Traffic Light	Red, yellow, and green LEDs; 5V operation
Relay Module	Operating voltage: 5V; Control current: 10A (AC) or 30V DC
LCD 16x2 I2C	16 characters x 2 rows; I2C communication interface (2-wire)

Prototype Development

The prototype development stage is a key step in the development of the basic electronics trainer kit and sensor systems, where the initial version of the kit is assembled and tested before

mass production. This process begins with the collection of components such as sensors, microcontrollers, and other supporting devices. These components are assembled on a breadboard to allow circuit testing without soldering, involving students to provide them with hands-on experience in assembling and understanding the function of each part. After that, the microcontroller is programmed using platforms like Arduino IDE to initialize the sensors and process data.

System testing is conducted to evaluate the overall performance of the trainer kit, including the stability and accuracy of sensor data, as well as providing students with the opportunity to give feedback regarding the effectiveness of the tool.

Testing and Validation

The testing begins with functional testing, where each component of the trainer kit will be individually tested to ensure proper functionality. This includes verifying the performance of sensors, microcontrollers, and the user interface. The functionality test will be followed by a performance test, which assesses the overall system's performance, focusing on parameters like response time, sensor data accuracy, and system stability during use. This step is essential to identify any malfunctions or areas for improvement in the trainer kit before it is used in practical exercises.

The next stage is the user satisfaction test, where students, as primary users, will provide feedback on their experience with the trainer kit. Their input is crucial for evaluating the tool's usability and effectiveness in understanding electronics and sensor systems. Finally, a media validity test will be carried out to assess the trainer kit's overall performance and reliability. If all criteria are met and the feedback is positive, the trainer kit will be validated and deemed ready for widespread use in educational settings.

RESULTS AND DISCUSSIONS

Trainer Design

The design of the basic electronics trainer kit and sensor system was created with consideration of the students' learning needs in understanding basic electronics concepts through practical applications. This trainer is designed with several main components, including a power supply, sensor module circuits, and interfaces that allow users to conduct various experiments directly. The trainer design can be seen in Figure 2 below.

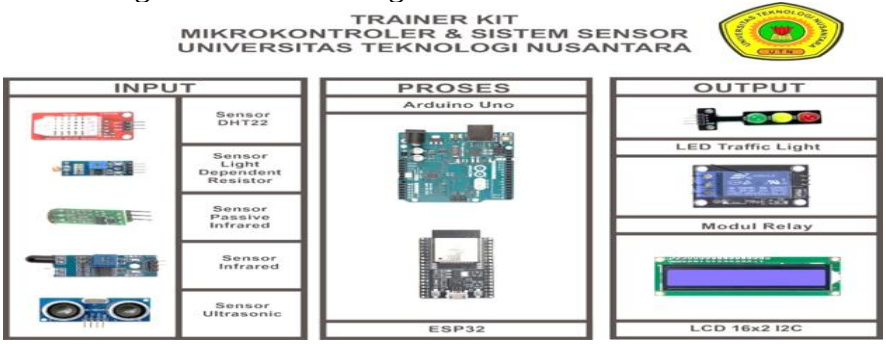


Figure 2. Trainer Design

This trainer design emphasizes flexibility and modularity, allowing students to perform various experiments easily. The available modules can be installed and removed as needed, enabling users to explore various electronics circuit configurations without requiring additional equipment. Furthermore, this design also takes safety into account by protecting against overcurrent and short circuits.

In addition to technical aspects, aesthetics and ergonomics were also considered in the trainer design. The neat layout and easily accessible components aim to enhance user comfort during practical exercises. The trainer is also equipped with comprehensive documentation, including user guides and experiment examples, to help students better understand the operation of each module.

Trainer Development Results

The results of the development process show that the trainer developed has met the technical specifications designed previously. The trainer consists of several modules that can be used independently or integrated, allowing students to use it for various experiments. Moreover, the materials used were selected to ensure high durability and ease of maintenance. The results of the trainer development can be seen in Figure 3 below.



Figure 3. Trainer Development Results

Initial testing of the trainer showed that all basic functions work well, including sensors that respond according to the environmental parameters being measured. Each module has been tested to ensure compatibility with the main system, allowing users to easily connect and configure the devices without encountering technical difficulties. The performance of the power supply was also tested to ensure voltage stability in various usage scenarios. The functionality test of the trainer is shown in Table 2.

Table 2. Trainer Functionality Test

Component Block	Component	Description
Input Block	Temperature Sensor	Functioning
	Light Sensor	Functioning
	Pressure Sensor	Functioning
	Infrared Sensor	Functioning
	Ultrasonic Sensor	Functioning
Process Block	Microcontroller	Functioning
Output Block	LED Traffic Light	Functioning
	Relay Module	Functioning
	LCD 16x2 I2C	Functioning

The results of the trainer functionality test showed that all components in each block are functioning well. In the input block, all sensors used, namely the DHT22, LDR, PIR, and Photodiode, work as expected in detecting the environmental parameters being measured. The DHT22 sensor functions to measure temperature and humidity, the LDR sensor detects light intensity, the PIR sensor captures motion, and the Photodiode sensor responds to light in a specific spectrum. The performance of these sensors ensures that the data sent to the microcontroller is accurate and can be used for further processing.

In the process block, the Arduino Uno and ESP32 microcontrollers also show optimal performance. Both microcontrollers are able to process the data received from the sensors and execute the necessary instructions to control the output components. The Arduino Uno is used as the main controller in the system, while the ESP32 plays a role in network connectivity and Internet of Things (IoT)-based communication. With these two microcontrollers, the trainer can function as a learning tool that provides hands-on experience in programming and implementing IoT systems.

The output block consists of a relay, an LCD 16x2, and a Traffic Lamp LED, all of which have been tested and confirmed to function properly. The relay is used as an electronic switch that can control other devices based on signals from the microcontroller, while the LCD 16x2 is used to display important information such as sensor reading results. The Traffic Lamp LED simulates a traffic light system, which can be controlled through the program in the microcontroller. These test results show that the trainer can be effectively used in learning electronics and IoT systems, as each component has been verified to function well.

Trainer Evaluation

The next step in this study is to validate the media and materials in the trainer kit. A media validation questionnaire was given to two validators, one media expert and one content expert, who evaluated the content and objectives, instructional aspects, and technical components of the trainer kit. The evaluation results of each aspect assessed by the validators were analyzed using Aiken's V statistical formula. These findings contribute to the validation score of the trainer kit, and a summary of the validation results from various aspects is presented in Table 3.

Table 3. Trainer Validity Test

Validator	Validation Results	Category
Media Expert	0.85	Valid
Content Expert	0.81	Valid

Based on the findings presented in Table 3, the validity test analysis conducted by the media expert yielded an average score of 0.85. This indicates that the trainer kit is categorized as valid. Additionally, the content expert's validation results obtained an average score of 0.81, confirming the validity of the content in the supporting modules of the trainer kit. Overall, the evaluations from the content expert and the media expert confirm the validity of the developed trainer. Therefore, it can be concluded that the trainer kit meets the quality criteria for content, objectives, instructional aspects, and technical aspects, making it suitable for use in academic settings to achieve learning objectives.

Although the developed trainer has been validated, this product is not without its shortcomings. Some of these include the supporting module that does not fully explain the step-by-step usage of the tool. Additionally, the trainer kit developed has not yet been equipped with a complete integrated circuit specification, and there are still some shortcomings in long-term implementation.

Practicality test data for the trainer kit were collected through a questionnaire distributed to sixth-semester students from the Electrical Engineering Study Program. The practicality evaluation results of the trainer kit are summarized in Table 4 below.

Table 4. Trainer Validity Test

Respondent	Practicality Result (%)	Category
Students	85.08	Very Practical

Based on the findings presented in Table 4, the practicality test results of the trainer kit from student data show a score of 85.08%. Therefore, the trainer is categorized as "very practical" for use in learning. Overall, the evaluations from students show that the developed trainer kit is practical for use in the classroom and meets the four practicality criteria. This indicates that this practical trainer can facilitate learning for students effectively.

CONCLUSIONS

The development of the basic electronics trainer kit and sensor systems at Universitas Teknologi Nusantara is a significant step toward addressing the lack of practical tools that hinder students from gaining hands-on experience. By integrating commonly used sensors such as temperature, light, pressure, and motion sensors, along with microcontrollers like Arduino and ESP32, the trainer enables students to bridge the gap between theory and practice. This learning device empowers students to explore real-world applications of electronics and sensor systems, thereby fostering both competence and confidence in working with technological tools relevant to Industry 4.0.

The results of the trainer development and testing show that all functional blocks—including input, processing, and output—perform reliably, and the trainer meets its design specifications. The sensors and components operate effectively, and the modular structure ensures flexibility in conducting various experiments. Furthermore, the system validation through media

and content experts confirms the kit's appropriateness for educational use, with high validity scores indicating its reliability as a teaching aid. The success of this trainer validates its potential as a scalable solution for similar educational challenges in other institutions.

Ultimately, the implementation of this trainer kit not only enhances student engagement but also aligns academic instruction with industry standards, thereby improving graduate readiness for the workforce. This innovation reflects the institution's commitment to producing skilled graduates capable of contributing to the evolving technological landscape. For sustained impact, it is essential for the university to continue investing in tools and learning innovations that promote practical skills and experiential learning.

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REFERENCES

Boltsi, A., Kalovrektis, K., Xenakis, A., Chatzimisios, P., & Chaikalis, C. (2024). Digital tools, technologies, and learning methodologies for education 4.0 frameworks: A stem oriented survey. *Ieee Access*, *12*, 12883-12901.

Chookaew, S., Kitcharoen, P., Howimanporn, S., & Panjaburee, P. (2024). Fostering student competencies and perceptions through an artificial intelligence of things educational platform. *Computers and Education: Artificial Intelligence*, *7*, 100308.

Demmanggasa, Y., Sabilaturrizqi, M., Kasnawati, K., Mardikawati, B., Ramli, A., & Arifin, N. Y. (2023). Digitalisasi pendidikan: akselerasi literasi digital pelajar melalui eksplorasi teknologi pendidikan. Community Development Journal: Jurnal Pengabdian Masyarakat, 4(5), 11158-11167.

Javaid, M., Haleem, A., Khan, I. H., Singh, R. P., & Khan, A. A. (2024). Industry 4.0 and circular economy for bolstering the healthcare sector: A comprehensive view on challenges, implementation, and futuristic aspects. *Biomedical Analysis*, *1*(2), 174-198.

Jusoh, M. N. H., & Hadibarata, T. (2024). Bridging Theory and Practice: The Role of Site Visits in Environmental Engineering Learning. *Acta Pedagogia Asiana*, *3*(1), 13-22.

Kumar, S., Bharathi, S. H., & Castro, M. (2024, December). Bridging Theory and Practice: Innovative Approaches in Contemporary Engineering Education. In *2024 IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE)* (pp. 1-8). IEEE.

Kumi, E., Osei, H. V., Asumah, S., & Yeboah, A. (2024). The impact of technology readiness and adapting behaviours in the workplace: a mediating effect of career adaptability. *Future Business Journal*, *10*(1), 63.

Laseinde, O. T., & Dada, D. (2024). Enhancing teaching and learning in STEM Labs: The development of an android-based virtual reality platform. *Materials Today: Proceedings*, *105*, 240-246.

Makari, Z. A. M., & Ahamed, A. A. (2024). Exploring Innovations in Curriculum Design for Technical Vocational Education and Training. المجلة الأفروآسيوية للبحث العلمي (AAJSR), 385-397.

Mustakim, W., Effendi, H., Giatman, M., & Wulandari, D. P. (2024). Development of Internet of Things Trainer Kit as a Learning Media for Digital Circuit Subjects in Higher Education. *International Journal of Online & Biomedical Engineering*, *20*(9).

O'Keefe, J. G. (2025). Project Based Learning (PBL): enhancing student motivation to promote real world accomplishment. *福岡女学院大学教職支援センター教育実践研究*, *9*, 26-47.

Ria, A., Dini, P., & Bucchi, F. (2025). Prototyping of Automated Guided Vehicle for Teaching Practical Mechatronics. *Education Sciences*, *15*(3), 294.

Roy, M., & Roy, A. (2021). The rise of interdisciplinarity in engineering education in the era of industry 4.0: Implications for management practice. *IEEE Engineering Management Review*, *49*(3), 56-70.

Supriya, Y., Bhulakshmi, D., Bhattacharya, S., Gadekallu, T. R., Vyas, P., Kaluri, R., ... & Mahmud, M. (2024). Industry 5.0 in smart education: Concepts, applications, challenges, opportunities, and future directions. *IEEE Access*.

Vennapusa, S. C. R., Tejani, J. G., Mohammed, M. A., & Yarlagadda, V. K. (2024). Automated Robotics Solutions for Precision Molding in Rubber Manufacturing. *NEXG AI Review of America*, *5*(1), 1-18.

Zarkasyi, M. (2024). Perancangan Trainer Dan Modul Internet Of Things (IOT) Pada Mata Kuliah Praktikum Sensor Dan Tranduser (Doctoral dissertation, Universitas Islam Negeri Ar-Raniry).