IoT-based mobile data acquisition for pH and temperature monitoring as an enrichment material for high school energy transformation book

Amalia Nurul Hidayah[1], Maulana Firmansyah[1], Dwi Teguh Rahardjo[1], Anif Jamaluddin[2]*

[1]Department of Physics Education, Universitas Sebelas Maret, Ir. Sutami Street No.36A, Surakarta 57126, Indonesia

[2]Centre of Excellence for Electrical Energy Storage Technology, Universitas Sebelas Maret, Ir. Sutami Street No.36A, Surakarta 57126, Indonesia

*Corresponding author, email: elhanif@staff.uns.ac.id

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Abstract

Monitoring pH and temperature is critical in various fields, yet integrating such technical concepts into high school education remains a challenge. This study aims to develop and validate an IoT-based mobile data acquisition system as a practical case study for an enrichment book on the topic of energy transformation for high school students. Using a Research and Development (R&D) approach, an IoT device consisting of a pH sensor, a K-type thermocouple, and a NodeMCU ESP8266 was built. An accompanying enrichment book was developed using Canva and Heyzine Flipbook. The IoT system demonstrated good accuracy, achieving R^2 values for pH measurement of 0.9526 (acidic) and 0.8843 (basic). The enrichment book was validated by experts and practitioners, receiving high feasibility ratings of 92.58% and 83.01%, respectively. These findings indicate that the developed enrichment book is a highly feasible supplementary teaching resource. This study demonstrates the significant potential of integrating hands-on IoT projects into science curricula to enhance students' understanding of abstract concepts like energy transformation.

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1. Introduction

Understanding the concept of energy transformation, a fundamental process in physics where energy changes from one form to another (Ilyas et al., 2021; Yeadon & Quinn, 2021), is often challenging if learning is limited to theory. Students also need in-depth practicum experience to relate theory to practice in the real world (Bakri et al., 2023; Pölloth et al., 2023; Purwanti et al., 2024; Putri et al., 2023). One of the relevant applications of energy transformation can be found in pH and temperature monitoring systems (Sameera Fathimal & Jothiraj, 2022), where a pH and temperature monitoring system is used to display the measurement results of the acidity or alkalinity of a chemical solution (Monteiro & Koper, 2021; Pratami et al., 2020). To connect abstract concepts with real-world applications, this study developed an IoT-based pH and temperature monitoring system as a concrete and relevant case study. This tool is not only a technical device but also a learning medium that demonstrates a series of energy transformations. The integration of the Internet of Things (IoT) is key to making this tool an interactive learning medium, as it allows measurement data to be sent in real time and accessed directly by students via a smartphone application.

Technological developments have increased the demand for devices that can support all human activities (Gołąbek & Strankowski, 2024; Onggo et al., 2024; Zhang et al., 2023). One of the significant advances in the field of information technology is the Internet of Things (IoT) platform (Antonius & Saepudin, 2023; Kumari & Arowolo, 2024; Wijayanti et al., 2023). The Internet of Things (IoT) is a concept in which devices can communicate with each other over the Internet. IoT includes the use of connected smart devices and systems to access and manage data collected by sensors and driving devices integrated into machines and other physical objects (Abdel-Basset et al., 2022; Kaur & Gaandhi, 2022; Kayyali, 2022; Suresh Kumar et al., 2021). In the digital era and with the current advancements in information technology, education must continue to adapt to maximize the learning process (Listiaji et al., 2024; Morozova & Rozhnenko, 2021; Okta Riyandi et al., 2023; Saputri et al., 2023). One of the media that can be used is MIT App Inventor as a learning medium in the world of education (Kurniawan et al., 2024; Prasetyowati et al., 2024; Zakharkevich et al., 2023).

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MIT App Inventor is an Integrated Development Environment (IDE) that is useful for developing Android applications without requiring in-depth programming experience. The app is open-source and web-based (Liang et al., 2021; Muzamil et al., 2024; Tóth & Lovászová, 2021). The MIT App Inventor was used in this monitoring system to collect data from pH and temperature measurements. The results of the analysis of the pH and temperature monitoring system can be used as enrichment material for teachers in delivering material related to energy transformation to high school students in class X.

Research related to the energy transformation material enrichment book has been developed by those who discuss the development of e-book media about Ocean Wave Power Plants as physics enrichment material in high schools (Afiah & Iswanto, 2018). The e-book discusses renewable energy materials, including a sub-material on energy transformation. The enrichment book received validation from experts, with an average percentage of 85%, with an interpretation of "Very Feasible." (Chania et al., 2020) conducted research related to the development of physics teaching materials on business and energy materials. The teaching material also contains energy transformation sub-materials. The validation results showed that the teaching materials were categorized as "Very Feasible" with a percentage of 83.25%. In a previous study, enrichment books were developed to discuss energy sources and renewable energy. Therefore, the energy transformation material is only explained in general.

To bridge the gap between abstract theory and real-world applications, this study introduces an IoT-based pH and temperature monitoring system as a practical case study for learning energy transformation. The educational relevance of the system is rooted in its clear demonstration of multiple energy conversions: the pH sensor transforms chemical energy from ion activity into an electrical signal, whereas the temperature sensor converts thermal energy into a corresponding electrical signal. The data are then processed by a microcontroller and displayed on a screen, thus converting electrical energy into light energy. The mechanism and data from this system form the core content of a digital enrichment book developed to provide students with deeper contextual learning accessible via smartphones. Accordingly, the primary objective of this research is twofold: (1) to develop and test an IoT system as an innovative learning medium and (2) to validate the effectiveness of the accompanying enrichment book as a supplementary material for enhancing students' conceptual understanding of energy transformation.

Based on the above explanation, in this study, an enrichment book was developed that specifically discusses energy transformation materials and their applications in daily life. In this study, a pH and temperature monitoring system tool was used as an example of the application of energy transformation. The energy transformation in the device, which involves converting chemical and thermal energy into electrical and light signals, results in the ability to display the pH and temperature measurement results on a monitor. This can broaden students' horizons regarding energy transformation materials. The pH and temperature monitoring system can be accessed by each student through an application on a smartphone, so that students can access it through their respective smartphones. Enrichment books can also be accessed by students through smartphones. Therefore, the primary objective of this research is twofold: first, to develop an IoT-based system as an innovative practical tool for learning, and second, to validate the effectiveness of the accompanying enrichment book in enhancing students' understanding of energy transformation concepts.

2. Method

This study uses a development method to develop new products or improve existing products (Oluwatobi et al., 2023; Opresnik, 2023). This methodology was used to produce and test the effectiveness of the developed products.

2.1. Design

The design stage in this study was carried out through the integration of a pH and temperature monitoring system. The preparation of the components used, programming the tool in the Arduino IDE, programming the application in MIT App Inventor, and initially designing the enrichment book developed through Canva, then the enrichment book was operated using a Heyzine flipbook. The design of the pH and temperature monitoring system and the design of the enrichment book are shown in Figure 1 a and b.

Figure 1. a) Design of pH and Temperature Monitoring System Equipment, b) Enrichment Book Design Development

2.2. Sensor Calibration

To ensure data accuracy, a calibration process was conducted on the pH and temperature sensors. The measurements from the developed system were compared with those of a standard Water Quality Tester PHS26C. The pH sensor was calibrated by immersing it in three standard buffer solutions: pH 4.01, 6.86, and 9.18, respectively. For the temperature sensor, calibration was performed by immersing it in water under three different conditions: cold, normal temperature, and hot. The data from this comparison were then analyzed by plotting them on a graph to perform a linear regression analysis. From this analysis, the coefficient of determination (R^2) was calculated to quantitatively assess the accuracy and correlation of the developed sensors with the standard reference tool.

2.3. Development

The development stage in this study involved the validation of enrichment books by experts and practitioners. The book was validated by two Physics Education lecturers as experts and two high school physics teachers from SMA Muhammadiyah Pontren Imam Syuhodo and SMA IT Nur Hidayah as practitioners. The validation sheet was used to obtain assessments and inputs in the form of criticism, suggestions, and responses to the enrichment book developed. In addition, the validity of the prepared enrichment book was determined. Validation sheets were provided to the lecturers and teachers. Validators assessed enrichment books by ticking the appropriate rows and columns and writing down comments and suggestions if there were any deficiencies. The assessment was carried out by looking at four aspects: feasibility of content, presentation, language, and graphics. Furthermore, the validation process was iterative, and qualitative feedback from the validators was used to revise and improve the final version of the book.

The data used in the energy transformation material enrichment book are in the form of quantitative data based on a Likert scale as follows: score 1, if the assessment is not good; score 2, if the assessment is good enough; score 3, if the assessment is good; and score 4, if the assessment is very good. The data obtained using data collection instruments were analyzed using analysis techniques and percentages according to a predetermined formula. The percentage of the average score of each aspect assessed was calculated using Equation (1).

$$P = \frac{\sum X}{N} \times 100 \tag{1}$$

Where P is the percentage of validity of the enrichment book. $\sum X$ denotes the sum of the scores for each aspect of the assessment. N is the ideal score. The average score percentage from the enrichment book assessment was then obtained. If the P value is 76% - 100%, then the enrichment book is categorized as very good or very decent quality. If the P value is 51%–75%, then the enrichment book is categorized as good or worthy. If the P value is 26%–50%, then the enrichment book is categorized as good enough or quite feasible. If the P value is 0%–25%, then the enrichment book is categorized as poor or unqualified (Sugiyono, 2022). The stages of this research are shown in Figure 2.

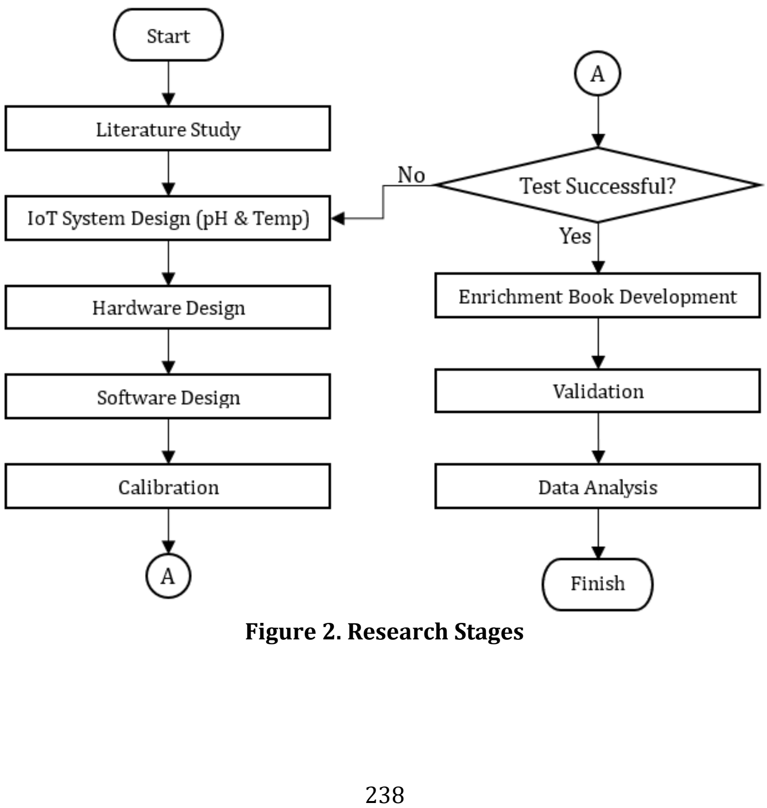

Figure 2. Research Stages

3. Results and Discussion

Data were collected by providing validation sheets to high school lecturers and teachers. The resulting product is in the form of an enrichment book for energy transformation material in the form of an e-book, which is used as enrichment material in learning. The enrichment book was developed using the R&D model. The first stage was the design of the pH and temperature monitoring system, as shown in Figure 3.

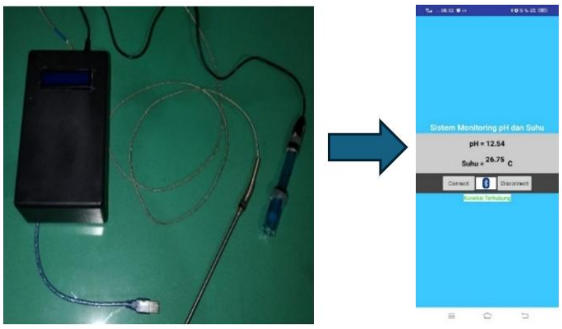

Figure 3. Display of pH and Temperature Monitoring System Tools

3.1. Results of pH and Temperature Measurement in Acid and Base Solutions

3.1.1. Acid Solution

The acid solution used is ammonium sulfate, where the pH value is less than 7. In this measurement, ammonium sulfate was used as much as 3.3 g. The measurements were carried out at different volumes ranging from 50 to 250 ml. The measurement results are presented in Table 1.

Table 1. Results of pH and Temperature Measurement of Acid Solution

Sensor	Volume (mL)	Sensor Reading	σ_{sensor}	Reference Reading	σ_{ref}	Error (%)
pH	250	5.67	0.06	5.64	0.005	0.56
	200	5.75	0.02	5.82	0.010	1.15
	150	5.92	0.02	5.94	0.005	0.42
	100	6.03	0.02	6.01	0.005	0.31
	50	6.10	0.03	6.10	0.005	0.08
Temperature (°C)	250	29.6	0.23	27.2	0.05	8.86
	200	29.6	0.23	27.4	0.05	7.70
	150	29.3	0.15	27.5	0.05	6.35
	100	29.2	0.11	27.6	0.04	6.24
	50	29.2	0.07	27.5	0.04	6.19

The measurements showed that the pH sensor produced high accuracy and consistency. The pH sensor can detect changes in the increase in the pH value of the ammonium sulfate solution. To further analyze the accuracy and linearity of the sensor, a linear regression analysis was performed by comparing the sensor data with the reference tool. Figure 4 shows the correlation between the pH measured by the sensor and the reference pH in the ammonium sulfate solution, yielding a coefficient of determination (R^2) of 0.9526. This value indicates a very strong correlation and high accuracy of the pH sensor in an acidic environment. This also indicates that the sensor was well calibrated and operated under stable conditions.

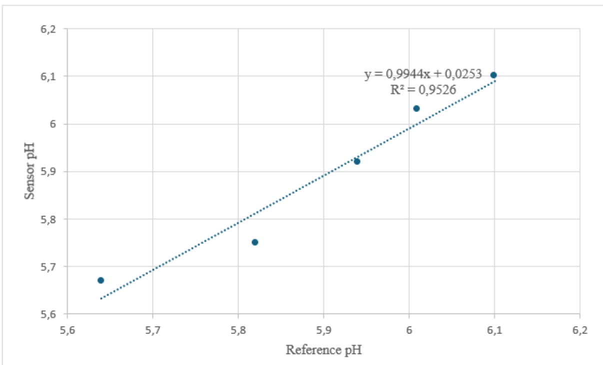

Figure 4. Acid Solution Sensor vs Reference pH Value Relationship

In contrast, temperature sensors showed a higher percentage of errors, indicating lower accuracy and consistency. The regression for the temperature sensor, as shown in Figure 5, resulted in an R^2 value of 0.727, suggesting a moderate correlation and lower reliability in this particular solution, which may be due to improper calibration, lower sensor quality, or less stable measurement conditions. Specifically, in acidic environments, the solution can act as an aggressive electrolyte that attacks the K-type thermocouple junction. This direct exposure can trigger corrosion, oxidation, and galvanic reactions that degrade the thermocouple Seebeck coefficient, leading to inaccurate readings (Abdelaziz et al., 2022; Kumar et al., 2025; El Arouji et al. 2015). Therefore, additional calibration and monitoring of environmental conditions are required to improve the accuracy and consistency of the temperature measurements.

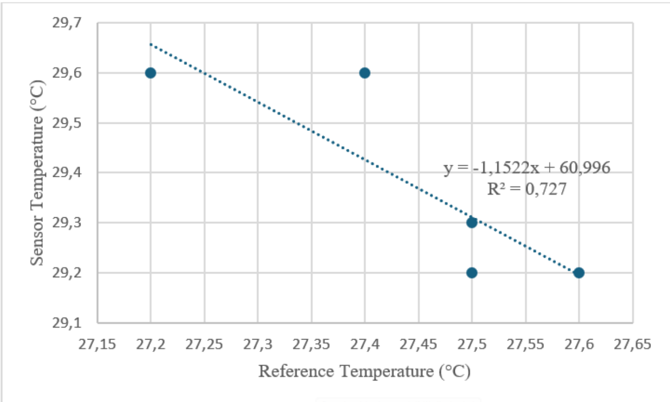

Figure 5. Acid Solution Sensor vs Reference Temperature Value Relationship

3.1.2. Base Solution

The base solution used was KOH. KOH is an alkaline chemical solution with a pH value greater than 7. In this measurement, KOH was used as much as 3.3 g. The measurements were carried out at different volumes ranging from 50 to 250 ml. The results of the pH and temperature measurements in the KOH solution are presented in Table 2.

Table 2. Results of pH and Temperature Measurement of base Solution

Sensor	Volume (mL)	Sensor Reading	σ_{sensor}	Reference Reading	σ_{ref}	Error (%)
pH	250	13.80	0.14	14.14	0.008	2.37
	200	13.63	0.03	14.11	0.007	3.40
	150	13.33	0.05	13.98	0.050	4.68
	100	13.25	0.01	13.86	0.008	4.38
	50	13.18	0.01	13.75	0.005	4.31
Temperature (°C)	250	29.67	0.12	29.55	0.05	0.42
	200	28.57	0.20	28.87	0.04	1.02
	150	28.27	0.20	28.45	0.05	0.61
	100	27.62	0.33	28.16	0.05	1.89
	50	27.62	0.31	28.17	0.04	1.93

The measurement results for the basic solution (KOH), summarized in Table 2, provide further insight into the performance of the sensors. The pH sensor continued to demonstrate robust performance, achieving a coefficient of determination (R^2) of 0.8843, as shown in Figure 6. While this indicates a strong correlation, it is slightly lower than the R^2 value of 0.9526 observed in the acidic solution (Figure 4), suggesting that the sensor was marginally more linear in the acidic environment. Nevertheless, with R^2 values above 0.88 in both conditions, the pH sensor can be considered reliable across the tested ranges. The most significant finding, however, was the dramatic improvement in the temperature sensor's performance, which achieved an excellent R^2 value of 0.9811, indicating very high accuracy and reliability in the basic solution, as shown in Figure 7.

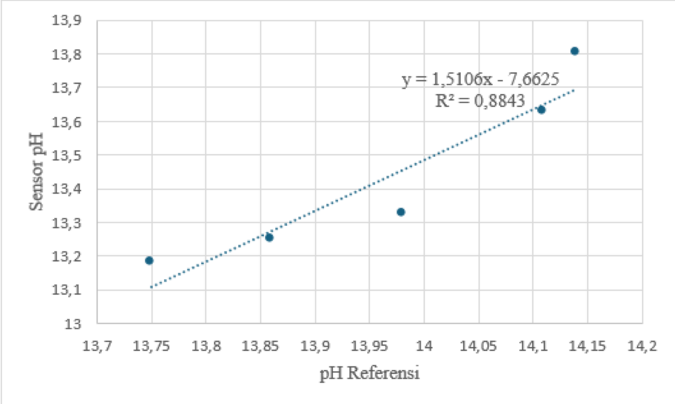

Figure 6. Base Solution Sensor vs Reference pH Value Relationship

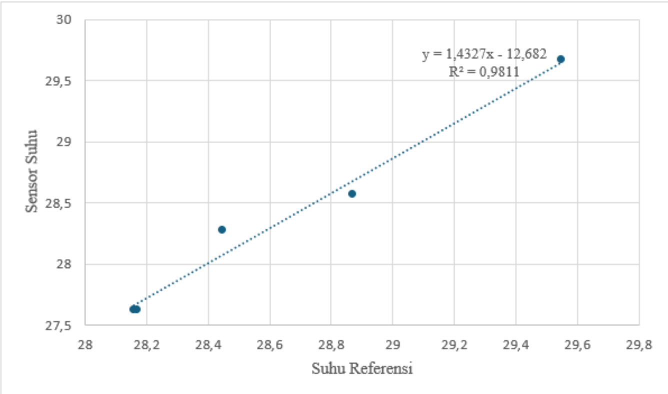

Figure 7. Base Solution Sensor vs Reference Temperature Value Relationship

The different R^2 values between the acidic and basic solutions, particularly for the temperature sensor, have several important implications. This demonstrates that the reliability of the temperature sensor is highly dependent on its chemical environment. The excellent performance of the sensor in the basic solution (R^2 = 0.9811) compared to its moderate performance in the acidic solution (R^2 = 0.727) implies that its reliability is not universal across all conditions. The practical implication is that for high-precision applications, the current IoT system is significantly more suitable for monitoring the temperature in basic solutions than in acidic solutions.

Based on the data, the measurement results showed that the pH and temperature sensors could work with high accuracy. This highlights the need to increase the accuracy of temperature sensors, one of which is recalibration (Azharul et al., 2021). Kurniawan et al (2022) conducted research related to the analysis and design of Aquascape using the MQTT protocol for temperature and pH data transmission media. In this study, the NodeMCU microcontroller ESP8266 was used. In addition, the system uses the MQTT protocol via a mobile application. The application is used to monitor water temperature and pH quality, and data are sent in real time by connecting to a Wi-Fi or Internet connection. The system uses a pH PH4502C sensor and a DS18B20 temperature sensor. Based on the results of the calibration test of the accuracy of the pH sensor with a pH meter in this study, the average error percentage was 3.03% at pH 6.86 and 1.05% at pH 4.00. Meanwhile, the calibration of the accuracy of the temperature sensor with a thermometer resulted in an average error of 11.73% in cold water and 3.05% in warm water. The research also shows the need to improve the performance of the tool, one of which is through calibration. Therefore, in this case, calibration is important to obtain more accurate measurement results.

The work system in the pH and temperature monitoring system was used as material for the enrichment book of energy transformation material. Each component used in this monitoring system experiences energy changes that cause all components to work and display the results of the pH and temperature measurements. In pH and temperature monitoring systems, several energy transformations involve the conversion of chemical, thermal, and electrical energy. The pH sensor converts chemical energy, which comes from the change in the concentration of hydrogen ions (H^+) in the solution into electrical energy in the form of a voltage signal. Then, the temperature sensor on the Amplifier MAX6675 converts the thermal energy from the temperature change into an electrical signal by detecting a change in resistance or voltage. The electrical signals from the two sensors were then processed by microcontrollers, such as the NodeMCU ESP8266, which converts an analog signal into digital information. Furthermore, the data from the pH and temperature measurements can be sent over a wireless network, where electrical energy is converted into electromagnetic waves for data transmission using Wi-Fi. If the data are displayed on the screen, the electrical energy is converted into optical energy (light) to display the measurement result information. This energy transformation allows the conversion of physical or chemical parameters into digital data that can be monitored and analyzed. The discussion was used as material for energy transformation in the enrichment book developed.

Enrichment books contain additional material and aim to complement the content of textbooks (Mulyana & Desnita, 2023; Ulfa, 2025). The characteristics of knowledge enrichment books are as follows: (1) the material/content of the book is reality, (2) the development of writing content is not bound to the curriculum, (3) the development of material relies on the development of related science, (4) the form of presentation is descriptive and can be accompanied by images, and (5) the presentation of book content is done popularly (Asrizal et al., 2020). Therefore, this enrichment book aims to provide students with insights regarding the application of energy transformation in a measuring instrument. Students can directly observe how pH and temperature monitoring system tools can work. In addition, students can experiment directly with the tool, and the measurement results can be seen by students in the application made through MIT App Inventor. The application can be accessed by students through their smartphones.

3.2. Content of the Enrichment Book

This monitoring system is used as the main topic in the creation of enrichment books for students, which are used as additional teaching materials on energy transformation materials. The enrichment book developed is titled "Application of Energy Transformation in pH and Temperature Monitoring Systems." With this enrichment book, students can increase their knowledge of the mechanisms of the tools used as one of the applications of energy transformation. Students can view the results of the pH and temperature measurements through an application that can be accessed through their respective smartphones. The following is a view of the enrichment book, as shown in Figure 8. Furthermore, the detailed enrichment book can be accessed in the website (https://heyzine.com/flip-book/215e61d479.html).

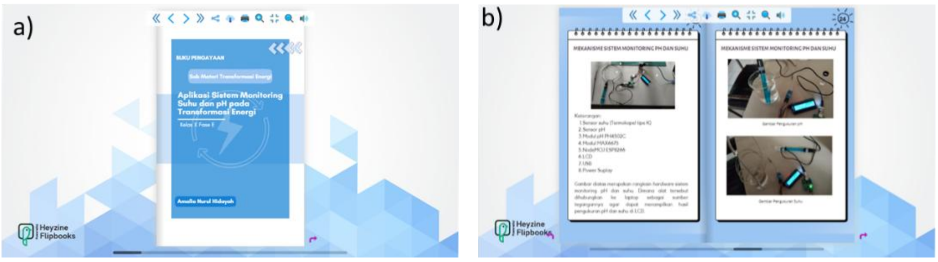

Figure 8. Enrichment Book Cover Display and content

To demonstrate how the scientific concepts were translated into learning material, the enrichment book was structured into three main parts with an additional practice question to systematically guide students from foundational theory to practical application of the theory. Part 1, "Forms of Energy and Transformation," begins by explaining the fundamental concepts of various energy forms, such as chemical, thermal, and electrical energy, supported by clear illustrations and real-world examples. This section builds the theoretical groundwork necessary for students to understand the subsequent case study, with Figure 9 providing an example of how chemical and electrical energy are explained.

Figure 9. Forms of Energy and Transformation Section

The next section, "Sensors," introduces the core components of the IoT device. It explains the basic working principles of sensors in general before detailing the specific mechanisms of the pH sensor and K-type thermocouple. This section serves as a bridge between the abstract principles of physics and the tangible hardware used in the experiment. This section introduces the core components of the IoT device, explaining the basic working principles of the sensors and transducers before detailing the specific mechanisms of the pH and temperature sensors shown in Figure 10.

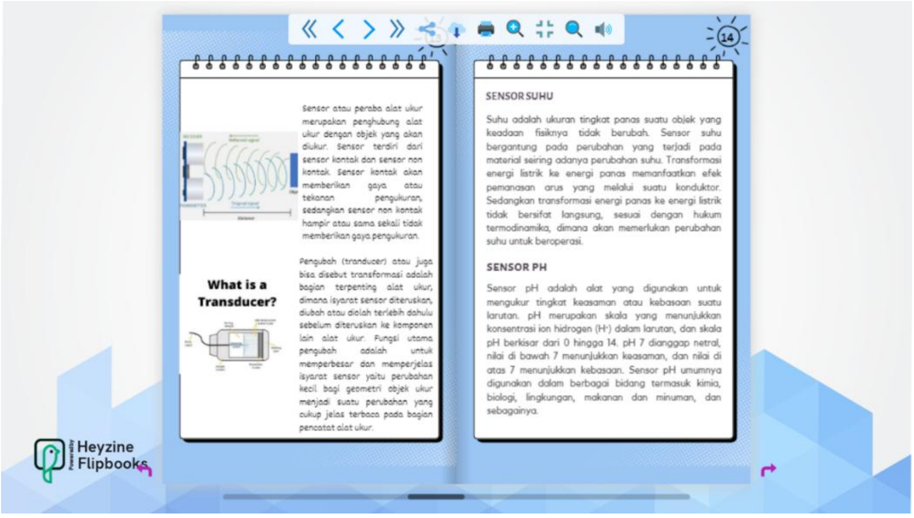

Figure 10. Sensors Section

The final section, "Application of the Monitoring System in Energy Transformation," is the core of the book. This section explicitly connects the operation of the device to the energy transformation concepts discussed in Part 1. Supported by diagrams and photographs of the actual device, it breaks down the energy conversion chain step-by-step, detailing the conversion of chemical and thermal energy into electrical signals by the sensors, and finally, the conversion of electrical energy into light on the LCD screen. This approach allows students to deconstruct a complex technology and see how multiple physics principles are applied in a single real-world application. This section explicitly connects the device operation to the energy transformation concepts discussed in the first part. Supported by diagrams and photographs of the actual device components, as shown in Figure 11, it breaks down the energy conversion chain step-by-step. This approach allows students to deconstruct a complex technology and see how multiple physics principles are applied in a single real-world application.

Figure 11. Application of the Monitoring System in Energy Transformation Section

3.3. Results of Enrichment Book Validation

Expert validation was performed by two Physics Education Lecturers. The practitioner validator was carried out by teachers at Muhammadiyah Islamic Boarding Imam Syuhada High School and Nur Hidayah IT High School. Enrichment books are assessed from several aspects, including content suitability, presentation, language, and graphics (Dewi & Arty, 2021). The assessment for each aspect was in the range of 1-4. The validators conducted assessments by filling out the provided assessment instruments. After conducting the assessment, the validator provided comments on the enrichment book and decided whether the enrichment book was suitable for use as enrichment material in learning energy transformation material. The following are the results of the expert validation of the enrichment book that was developed. The results of the validation by experts and practitioners are shown in the graph in Figure 12 below.

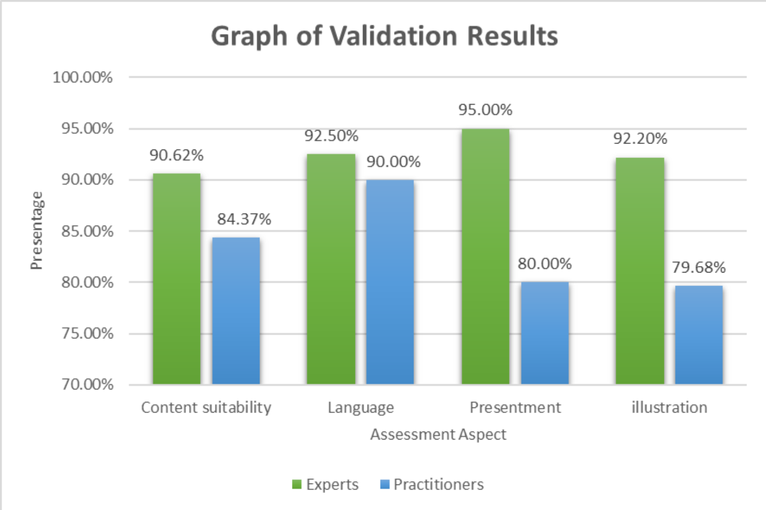

Figure 12. Graph of Validation Results by Experts and Practitioners

Based on Figure 12, the assessment graph by expert validators showed that the presentation aspect received the highest score of 95.00%, indicating that the method of conveying information was considered very good and adequate. The Language aspect had a percentage of 92.50%, indicating that the language used was clear and easy to understand, although there was still room for improvement in grammar and sentence structure. Graphics received a score of 92.18%, indicating that the visual elements are quite supportive in conveying information but can be improved to provide a stronger impact. Finally, the Content Suitability aspect received a percentage of 90.62%, meaning that although the content is quite relevant, there is an opportunity to further improve the quality of the content to align with the assessor's expectations. Meanwhile, the assessment by the validator practitioner showed that the language aspect received a score of 90.00%, indicating that the use of language in delivering the material was considered very good by the majority of assessors. The Eligibility of Content was 84.37%, indicating that the content was considered quite relevant and appropriate, although some improvements could still be made. The Presentation received a percentage of 80.00%, indicating that the delivery of the material was quite good but needed improvement to be more interesting or structured. The Graphics aspect received a score of 79.68%, indicating that visuals or graphic displays are still the areas that need the most attention for improvement. It can be seen that the assessment aspects, which include the feasibility of content, presentation, language, and graphics, received a high percentage, so that all aspects of the assessment can be said to be "Very Good." The results of the recapitulation of the validation results by experts and practitioners are presented in Table 3.

Table 3. Recapitulation of the Results of Validation of the Enrichment Book

No	Validators	Percentage	Criterion
1	Expert	92.58%	Very Good
2	Practitioners	83.01%	Very Good
Average		87.79%	Very Good

The results of validation by experts and practitioners showed a high average percentage; therefore, this enrichment book can be categorized as "Very Good." This is because the percentage obtained was 87.79%, which was still in the range of 76%–100%. Therefore, in this range, the enrichment book is categorized as "Very Good or "Very Worthy" (Sugiyono, 2022). Therefore, enrichment books can be used by students as enrichment material. In addition, enrichment books can add insight and develop students' skills (Saputri & Qohar, 2020). This enrichment book can increase insight and improve students' skills. In this enrichment book, students are taught about the direct application of energy transformation material from a measuring instrument, namely the pH and temperature monitoring system. The enrichment book explains the working mechanism of the pH and temperature monitoring system, where each component experiences an energy change that causes the instrument to work and display pH and temperature measurement data.

Beyond the quantitative scores, qualitative feedback from the validators guided an iterative revision process to refine the enrichment books. Several of the most significant suggestions that were acted upon included redesigning the cover to better reflect the topic, adding a summary chapter and a user guide to improve usability and navigation, and adjusting the book's format to align with the 'Kurikulum Merdeka' (Merdeka Curriculum) standards. This process of making concrete improvements based on validator feedback was crucial for enhancing the quality and pedagogical suitability of the final product.

The development of an enrichment book on energy transformation materials has also been developed by (Desniarsyah, 2016) which discusses the development of an enrichment book on physics studies in forest fire events. The material covered in the book includes heat material, energy changes, and dynamic electricity. The enrichment book received a percentage of 85.4% with an interpretation of "Very Good.". The development of an enrichment book has also been carried out, discussing micro hydro power plants, where the discussion also contains energy transformation material. The enrichment book was validated by material and graphic experts with decent and good predicates. The two studies on the development of the enrichment book discuss energy sources in more detail; therefore, the energy transformation material is only explained in general. Therefore, in this study, an enrichment book was developed that only discusses energy transformation and its applications. A pH and temperature monitoring system tool was used as an example of the application of energy transformation.

4. Conclusion

The IoT system achieved good accuracy, with R^2 values of 0.9526 for pH and 0.727 for temperature in ammonium sulfate solutions, and 0.8843 for pH and 0.9811 for temperature in KOH solutions. Furthermore, an enrichment book on energy transformation materials was successfully designed and validated by experts and practitioners, with average validation scores of 92.58% and 83.01%, respectively. These findings suggest that the enrichment book is a viable and useful supplementary resource for teaching energy transformation. This study highlights the potential of integrating IoT-based data-collecting devices into instructional content, thus improving students' grasp of scientific principles through real-world applications.

Author Contributions

Amalia Nurul Hidayah: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Visualization; Software, Writing – original draft. Maulana Firmansyah: Writing - review & editing. Dwi Teguh Rahardjo: Project Administration; Validation. Anif Jamaluddin: Funding acquisition; Resources; Supervision; Validation. All authors have read and approved the final manuscript.

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Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript. AI were used only to improve readability and language under strict human oversight; no content, ideas, analyses, or conclusions were generated by AI.

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