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Development of Practical Data-Based Visualization Models Using the Streamlit Framework in Thermodynamics Learning

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***Abstract* – Thermodynamics is a branch of physics that explores the relationship between heat, energy, and work within systems. However, students often find it challenging to grasp due to its abstract and complex nature. This study aims to develop a data-driven visualization application to enhance students' understanding of thermodynamic concepts through interactive and visual learning. The research follows the ASSURE instructional design model, which includes analyzing learners, setting objectives, selecting appropriate methods and materials, utilizing media, encouraging active participation, and evaluating outcomes. The application was validated by experts and tested for practicality with students enrolled in thermodynamics courses. The findings indicate that the application is effective in improving engagement, ease of use, and conceptual understanding. These results highlight its potential to enhance thermodynamics education in higher learning institutions by integrating technology-driven learning tools.**

***Keywords* - Thermodynamics learning, educational technology, data visualization, streamlit, database.**

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1. Introduction

Thermodynamics studies the transfer and transformation of energy, particularly in relation to the fundamental laws that govern the behavior of thermal systems.In the field of engineering, understanding thermodynamics is crucial as its concepts are applied in various aspects such as machine design, power generation, and cooling systems [1], [2].

For mechanical engineering students, mastering the concepts of thermodynamics is fundamental to understanding and developing efficient and sustainable technologies. However, previous research has found that thermodynamics is often considered as one of the most complex and difficult subjects for many students to grasp [3], [4].

Based on research [5] on students' understanding of basic thermodynamic concepts, which involved 200 students from various engineering programs at an Indonesian university, the results showed that most students struggle to understand abstract concepts in thermodynamics, such as the laws of thermodynamics, energy changes, and thermodynamic cycles. The data indicated that only 40% of the total respondents could accurately explain the first and second laws of thermodynamics. More than 60% of the students also faced difficulties in applying these concepts to practical situations, such as in the analysis of thermal systems or heat engines.

The findings of the study suggest that a lack of effective visualization is one of the main factors making it difficult for students to understand thermodynamics. Students feel that the concepts taught tend to be too abstract and hard to grasp without clear visual representation. According to research [6], visualization can help students integrate new knowledge with prior knowledge, thus significantly improving their conceptual understanding.

Therefore, more interactive teaching methods and effective learning media are needed to visualize thermodynamic concepts.

In recent years, there has been a significant shift in students' learning styles, with a growing tendency toward the use of visualization [7]. Today's students are growing up in a media-rich environment, surrounded by educational videos, interactive graphics, and multimedia applications. This has resulted in a preference for material presented in a visual format over static text or numbers [8]. Visualization provides a more intuitive and engaging way to understand complex concepts, included in the field of thermodynamics. By viewing visual representations of data and phenomena, students can more easily identify patterns, understand relationships between variables, and apply theoretical concepts to practical situations [9]. This contrasts with traditional approaches that often rely solely on textual descriptions and mathematical calculations.

In the current digital era, there are numerous opportunities to leverage technology to enhance teaching methods. One such technology is Streamlit, an open-source framework that allows for the easy and rapid development of interactive web applications [10], [11]. Streamlit enables developers to integrate data exploration approaches such as descriptive statistics and various 2D to 3D visualization techniques using a wide range of Python libraries [12]. Research [13] has shown that Streamlit can effectively design interactive and engaging visualization models. The use of Streamlit in creating interactive dashboards, which display various types of graphs such as bar charts, line charts, scatter plots, and heatmaps, has demonstrated a significant impact on educational data analysis. These dashboards allow users to interact with data, adjust parameters, and view changes in visualizations in real-time, enhancing their understanding of the correlations between variables. Another study [14] used Streamlit to create applications with 3D spatial data visualizations, providing a more in-depth view of the geographical distribution of the analyzed data. These applications enable users to explore data from various perspectives, improving their understanding of existing patterns and trends. The use of this technology in previous research has shown its potential to provide deeper insights and facilitate the data analysis process, supporting the development of more modern and efficient teaching methods. Therefore, Streamlit is well-suited for data visualization and can be used to create applications that visualize thermodynamic concepts based on student experimental data.

Based on the issues outlined above, this research aims to integrate visualization tools based on student experimental data using the Streamlit framework.

This study is a breakthrough by utilizing data from students' independent practice tests as an interactive learning tool. Currently, the practical data from thermodynamics courses produced by mechanical engineering education students at Universitas Negeri Padang is typically used only for writing lab reports. This data is often seen merely as an academic requirement to complete assignments without further utilization. This limitation prevents the full exploration of the potential of practical data as a richer learning tool. Students tend not to gain maximal analytical and practical experience from the data they collect. With this approach, the data can be used to create more in-depth visualizations and analyses, allowing students to better understand cause-and-effect relationships in thermodynamic phenomena. The use of practical data for interactive visualization can help students directly see changes in variables and how these changes affect the system as a whole.

2. Methodology Section

This research employs a research and development (R&D) approach to develop a visualization application based on practical data to enhance students' understanding of thermodynamic concepts. The study subjects are 78 students enrolled in the Mechanical Engineering Education program at Universitas Negeri Padang, taking the Thermodynamics course in the 2023-2024 academic year. To achieve this goal, the ASSURE instructional design model is used, consisting of six main stages: analyzing learners, stating objectives, selecting methods, media, and materials, utilizing media and materials, requiring learner participation, and evaluating and revising [15], [16].

The Analyze Learners stage aims to assess students' needs related to media and learning outcomes by considering their characteristics and initial competencies through questionnaires and interviews to ensure the application aligns with their profile. The state objectives stage focuses on facilitating students' understanding of thermodynamics concepts through practical data visualization to enhance their ability to interpret test results and utilize practical data. The select of methods, media, and materials stage involves project-based learning using the Streamlit web application, which leverages data from steam power plant trainer tests, such as steam pressure, temperature, fuel consumption, turbine rotation, and generator power, with automatic sensors on each component.

In the Utilize Media and Materials stage, the application is developed with a user-friendly interface, interactive data visualization, data analysis, integrated guides, and tutorials within the thermodynamics curriculum to be used regularly in class.

The require learner participation stage requires students to actively use the application for practical data analysis, report or presentation creation, and feedback provision, which is expected to increase their engagement and understanding. The evaluate and revise stage employs a structured evaluation method to assess the validity and practicality of the web-based learning application developed.

Evaluation is conducted through two main stages: expert validation and practicality testing by students. This approach references evaluation models applied in previous technology-based learning research [17], [18]. An illustration of the ASSURE development model can be seen in Figure *1*.

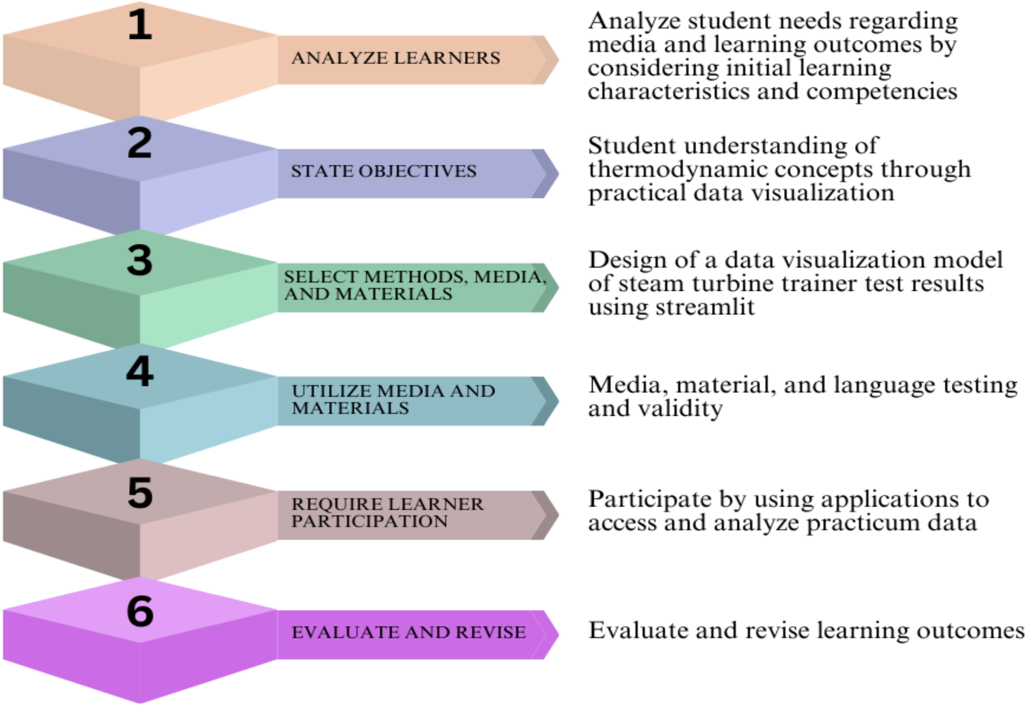


Figure 1. ASSURE development model

The data used for the application design comes from steam turbine trainer tests conducted by mechanical engineering students at Universitas Negeri Padang over the past three years, from 2020 to 2023. This data is part of the routine assignments for students taking the thermodynamics course, where the steam turbine trainer is used to simulate thermodynamic concepts occurring in steam power plants, such as energy changes, entropy, and the Rankine Cycle. During thermodynamics lessons, students are divided into small groups of 4 to 5 members. Each group is tasked with observing, collecting data from various components of the steam turbine trainer, and manually analyzing the data. This data includes steam pressure, steam temperature, fuel consumption, turbine rotation, and generator power. Data collection uses automatic sensors installed on each component of the steam turbine trainer, such as the boiler, turbine, condenser, and generator [19].

3. Results and Discussion

The active use of data in visualization allows students to conduct independent exploration. In research [20], a learning platform that integrates real-time data from the laboratory with visual analysis tools can provide a more dynamic and contextual learning experience. Furthermore, this approach reflects the current trend where data is actively used for decision-making, analysis, and innovation across various industries and disciplines. According to research [21], data can play an active role as an interactive learning tool. With the advancement of information technology and visualization tools, students can easily access and visualize steam turbine experiment data in the form of graphs, diagrams, and tables. This allows students to see and understand complex patterns, cause-and-effect relationships, and parameter changes in thermodynamic concepts more deeply.

A study by [22] found that the use of interactive visualization software in thermodynamics courses improves students' analytical skills in understanding the Rankine Cycle and steam turbine efficiency. Research [23] also shows that data-based simulations can help students develop a better understanding of isentropic and isobaric processes in thermodynamics. Therefore, integrating data and visualization in thermodynamics learning not only enhances the quality of education but also prepares students to face challenges in a data- and technology-driven workforce.

3.1. Analyzing Learners

In this stage, an analysis is conducted on the characteristics of students taking the thermodynamics course in the Mechanical Engineering program at Universitas Negeri Padang. Data is collected through questionnaires and interviews to identify the students' initial knowledge level of thermodynamic concepts, their learning needs and preferences, and their experience in using practical data for report writing. This information is crucial to ensuring that the developed application aligns with the students' profiles and needs [24]. Students have diverse learning styles and preferences for certain teaching methods. By identifying these preferences, the application development can be tailored to be more effective in meeting the students' needs and learning styles. If the learning application is designed according to the students' learning preferences, they will be more motivated and engaged in the learning process, which can ultimately enhance their understanding and learning outcomes [25]. The results of the initial knowledge questionnaire on thermodynamics concepts can be seen in Table 1, and the questionnaire on learning method preferences can be seen in Table 2.

Table 1. Results of the student initial knowledge questionnaire

Knowledge	Average Score	Percentage of Students with a Score > 70
Aspect	78	85%
First Law of Thermodynamics	60	45%
Rankine Cycle	55	35%

Table 2. Learning method preferences

Learning methods	Percentage of Students Voting
Interactive Learning	70%
Visual Learning	65%
Conventional Learning	20%
Project Based Learning	45%

The questionnaire results from 78 students indicate that most students have a good basic understanding of the first law of Thermodynamics, with an average score of 78 and 85% of the students scoring above 70. However, only 45% of students have an adequate understanding of the second law of Thermodynamics, with an average score of 60. Understanding of the Rankine Cycle is also low, with only 35% of students scoring above 70 and an average score of only 55. These findings suggest that students tend to struggle with more complex concepts such as the Second Law of Thermodynamics and the Rankine Cycle.

In the questionnaire regarding learning method preferences, it was found that 70% of students prefer interactive learning methods, and 65% prefer visual learning. Conversely, conventional learning methods are less favored, chosen by only 20% of students. Additionally, 45% of students showed interest in project-based learning. These results indicate that students are more interested in learning methods that involve active interaction and data visualization.

These findings demonstrate that although most students have a good basic understanding of the first law of Thermodynamics, they struggle with more complex concepts such as the second law of Thermodynamics and the Rankine Cycle. This highlights the need to place greater emphasis on these concepts in the developed learning application. The majority of students prefer interactive and visual learning methods. This suggests that the application should feature strong interactive and data visualization components to meet students' learning preferences. Project-based learning methods also attract some students, indicating that incorporating project-based learning elements could enhance student engagement.

Based on these findings, the developed learning application should focus on interactive visualizations and project-based learning elements to improve students' understanding of complex thermodynamic concepts. This aligns with previous research findings that interactive and visual learning methods can enhance student engagement and understanding of complex material [27]. Therefore, the development of a Streamlit-based thermodynamics learning application is expected to significantly improve the quality of thermodynamics education in the Mechanical Engineering program at Universitas Negeri Padang.

3.2. Stating Objectives

Based on field observations at Universitas Negeri Padang's Mechanical Engineering Education program, it was found that the thermodynamics course includes content on steam turbine operations.

Thermodynamics is typically taught face-to-face in the classroom with theoretical material delivery and practical testing using equipment such as steam turbine trainers. To date, the data from testing and experiments in the steam turbine process is only used as basic knowledge and has never been actively collected or utilized to enhance students' understanding of thermodynamic concepts. Therefore, the objective of developing this application is to facilitate students' understanding of thermodynamic concepts through the visualization of practical data. The application is expected to improve students' ability to interpret the test results from the steam power plant trainer and to use practical data more effectively in the learning process.

The steam power generation process is chosen as the data source for application development because it involves the application of complex and relevant thermodynamic concepts. In this process, the first and second laws of Thermodynamics and the Rankine Cycle work synergistically to convert the chemical energy from fuel into electrical energy [28].

The First Law of Thermodynamics ensures that energy is conserved at each conversion stage, so the energy input equals the energy output.

Meanwhile, the second law of Thermodynamics explains inefficiencies and the increase in entropy within the system, causing some energy to be lost as waste heat.

The Rankine Cycle provides an operational framework that describes the conversion of thermal energy into mechanical energy and finally into electrical energy with maximum efficiency [29], [30].

With this application, practical data from the steam power generation process can be visualized, allowing students to see how theory is applied in real practice. This is expected to deepen their understanding of thermodynamics, enhance analytical skills, and make more effective use of practical data in the learning process.

3.3. Selecting Methods, Media, and Materials

The chosen learning method is project-based learning, where students will use the application to analyze practical data. The media used is a web-based application developed using Streamlit. The materials prepared include practical data from testing the steam power plant trainer, as shown in Figure 2. The data used encompasses steam pressure, steam temperature, fuel consumption, turbine rotation, and generator power. Data collection is conducted using automatic sensors installed on each component of the steam turbine trainer, such as the boiler, turbine, condenser, and generator.

Figure 2. Steam power plant trainer

This application was developed to facilitate visualization-based learning, providing a more interactive and engaging learning experience.

Utilizing the Streamlit framework enables the creation of a web-based visualization tool that can be accessed anytime and anywhere.

This visualization tool integrates various Python libraries, such as Pandas profiling for automatic data characteristic analysis, Matplotlib, Plotly for 2D and 3D data visualization, and Pymongo for interacting with MongoDB databases.

Pandas profiling is used to automatically read and analyze the characteristics of the data. With Pandas profiling, students can quickly obtain an overview of data distribution, descriptive statistics, and detect anomalies in the practical data. This is very useful for understanding the data structure before conducting further analysis. Matplotlib and Plotly are used for 2D and 3D data visualization. Matplotlib provides various functions to create basic plots such as line graphs, bar charts, and scatter plots.

Meanwhile, Plotly offers more advanced and dynamic interactive visualizations, allowing students to explore data in a more intuitive manner.

These visualizations help students understand trends and patterns in the practical data, making it easier to interpret experimental results.

Pymongo is used to interact with MongoDB, a NoSQL database that stores practical data. With Pymongo, the application can efficiently access, store, and manipulate data in MongoDB. This allows students to work with large and complex datasets without worrying about performance or storage limitations. The use case of this thermodynamics concept visualization application can be seen in Figure 3.

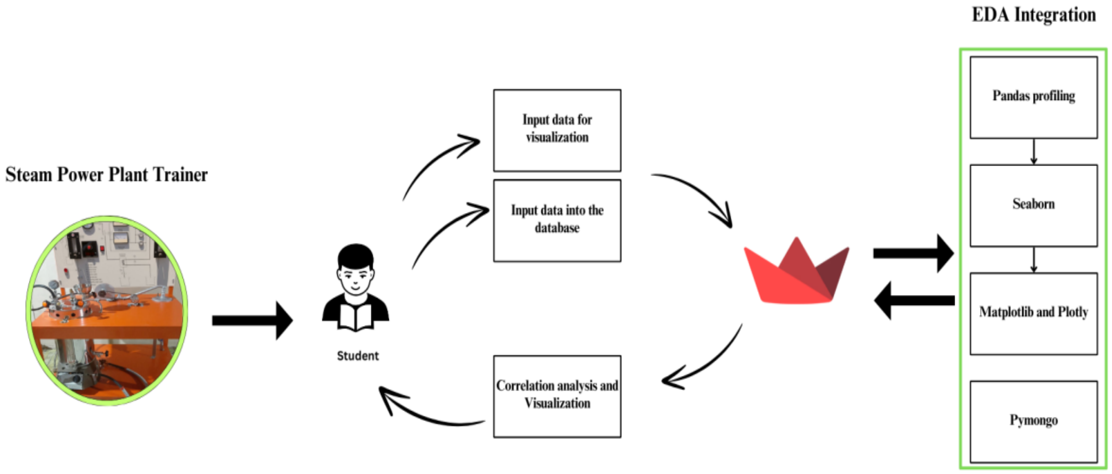


Figure 3. Usecase diagram of a thermodynamic visualization application using Streamlit

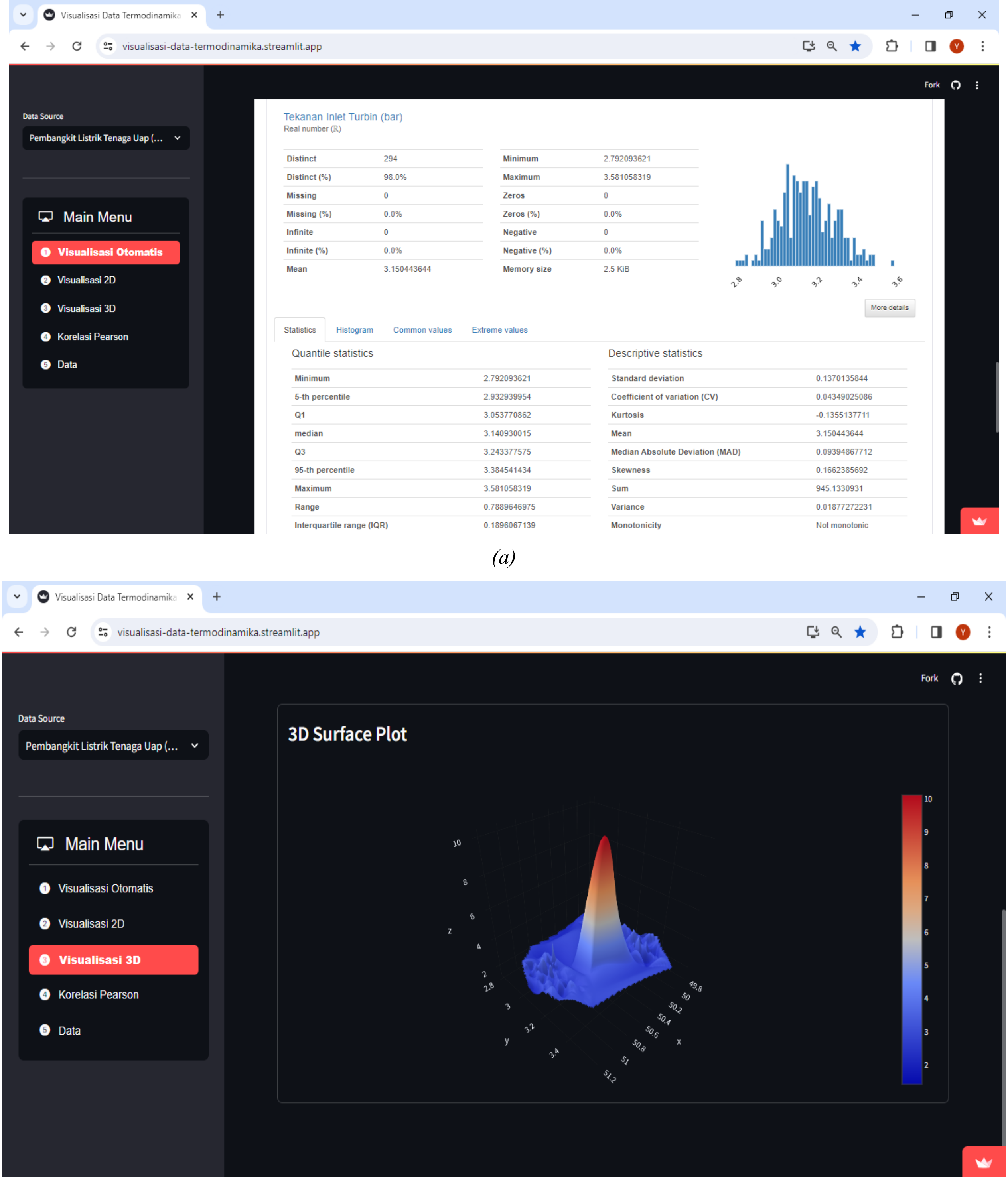
The use of the Streamlit framework in conjunction with these libraries allows the creation of a robust and flexible application capable of providing rich and interactive data visualizations. Students can observe trends and patterns in the data, compare experimental results, and directly connect theory with practice. This visualization-based learning approach is expected to enhance students' understanding of complex thermodynamic concepts, such as the second law of Thermodynamics and the Rankine Cycle, in a more comprehensible and applicable manner.

3.4. Utilizing Media and Materials

This application features several functionalities designed to facilitate students in understanding and analyzing the practical data from the steam power plant. The first feature is automatic data visualization using Pandas profiling, which allows students to quickly obtain an overview of data distribution and descriptive statistics and detect anomalies in the practical data. This aligns with research [31], indicating that the use of interactive data visualization tools can accelerate students' understanding of complex concepts in data science.

With Pandas profiling, students can automatically obtain detailed analyses such as data distribution, descriptive statistics, and anomaly detection without needing to master complex statistical analysis techniques beforehand.

The second feature is 2D and 3D visualization using Matplotlib and Plotly, which helps students explore data in a more intuitive way. The 3D visualizations implemented in this application, such as contour plots and surface areas, are particularly useful for displaying optimal values in the operation of the steam power plant. The use of Pandas profiling and 2D as well as 3D visualizations assists students in interpreting the practical data from the steam power plant more efficiently and effectively. This feature does not only provide a comprehensive view of the dataset but also prepares students for further analysis by providing a strong foundation for their initial understanding of the data. This can develop relevant data analysis skills for the technology and information sectors. The display of automatic data visualization and 2D as well as 3D visualizations can be seen in Figure 4.



Tekanan Inlet Turbin (bar)
Real number (ℝ)

Distinct	294	Minimum	2.792093621
Distinct (%)	98.0%	Maximum	3.581058319
Missing	0	Zeros	0
Missing (%)	0.0%	Zeros (%)	0.0%
Infinite	0	Negative	0
Infinite (%)	0.0%	Negative (%)	0.0%
Mean	3.150443644	Memory size	2.5 KiB

Quantile statistics

Minimum	2.792093621
5-th percentile	2.932939954
Q1	3.053770862
median	3.140930015
Q3	3.243377575
95-th percentile	3.384541434
Maximum	3.581058319
Range	0.7889646975
Interquartile range (IQR)	0.1896067139

Descriptive statistics

Standard deviation	0.1370135844
Coefficient of variation (CV)	0.04349025086
Kurtosis	-0.1355137711
Mean	3.150443644
Median Absolute Deviation (MAD)	0.09394867712
Skewness	0.1662385692
Sum	945.1330931
Variance	0.01877272231
Monotonicity	Not monotonic

(a)

(b)

Figure 4. Display of the practical data-based thermodynamic visualization application: (a) automatic data visualization feature; (b) 2D and 3D visualization features

The next feature is Pearson correlation analysis, which allows students to observe the relationships between various variables in the practical data. This analysis is displayed using a correlation heatmap created with the Seaborn library, facilitating students' understanding of data interrelationships. Correlation analysis with a heatmap is a data visualization method that shows the relationships between two or more variables in a dataset.

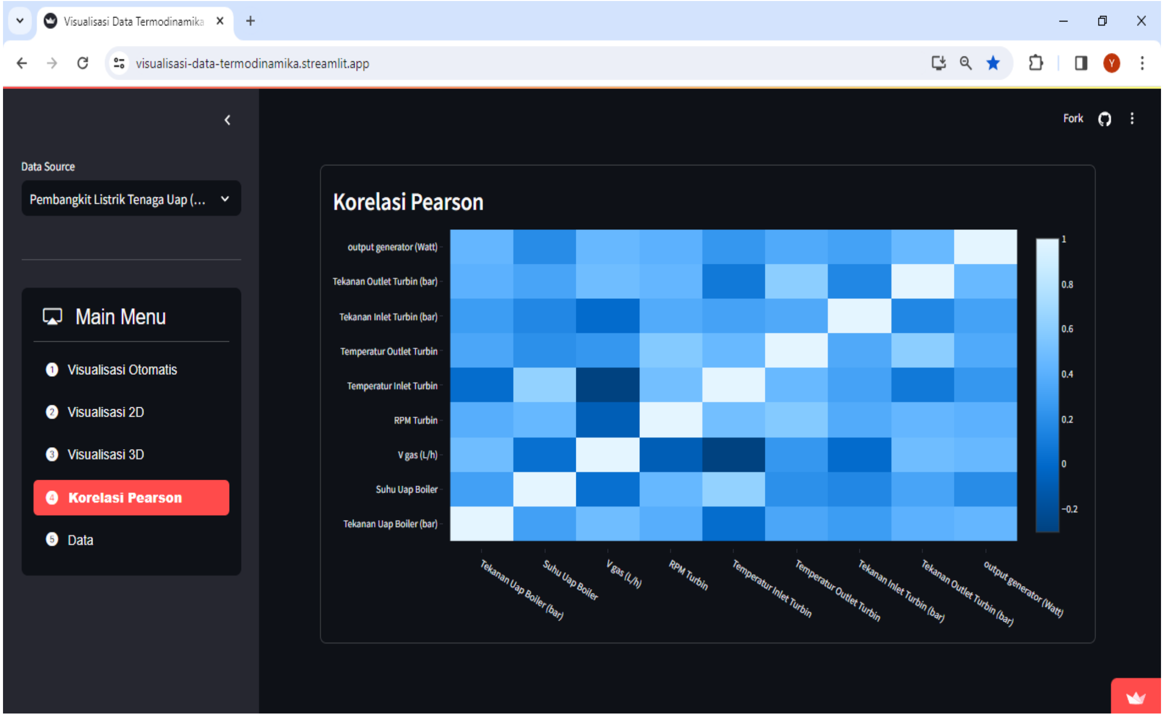
The correlation heatmap displays a matrix that uses colors to indicate the degree of relationship between these variables. Correlation values range from -1 to 1, where a value of 1 indicates that as one variable increases, the other variable also increases. A value of -1 indicates that as one variable decreases, the other variable also decreases, while a value of 0 indicates no linear relationship between the variables [33], [32], [34].

The correlation heatmap simplifies identifying patterns and relationships between variables in the practical steam power plant data. For example, students can easily see whether there is a strong relationship between steam pressure and steam temperature or between fuel consumption and generator power.

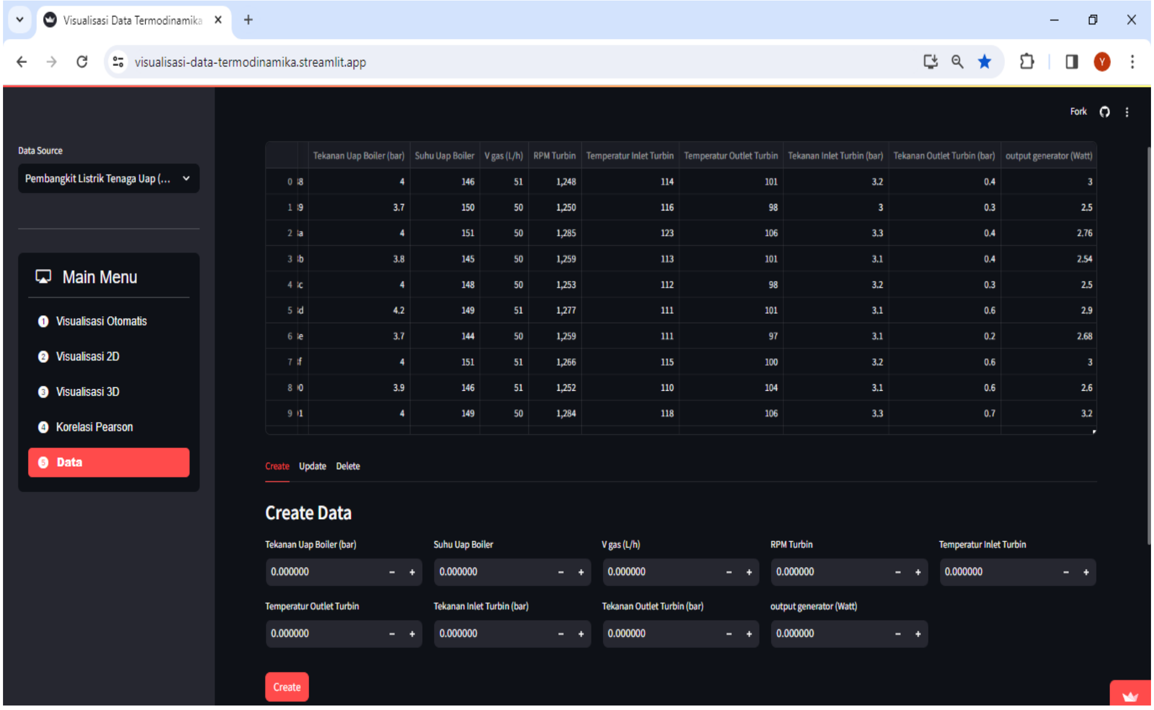
This helps them understand how these variables influence each other within the power plant system.

The final feature is the database, which allows students to store, access, and manage the test data from the steam power plant trainer.

This feature enables CRUD (Create, Read, Update, Delete) operations on the database using Pymongo, providing flexibility in managing complex practical data. The display of the automatic data visualization and 2D as well as 3D visualization features can be seen in Figure 5.



(a)



		Tekanan Uap Boiler (bar)	Suhu Uap Boiler	V gas (L/h)	RPM Turbin	Temperatur Inlet Turbin	Temperatur Outlet Turbin	Tekanan Inlet Turbin (bar)	Tekanan Outlet Turbin (bar)	output generator (Watt)
0	8	4	146	51	1,248	114	101	3.2	0.4	3
1	9	3.7	150	50	1,250	116	98	3	0.3	2.5
2	a	4	151	50	1,285	123	106	3.3	0.4	2.76
3	b	3.8	145	50	1,259	113	101	3.1	0.4	2.54
4	c	4	148	50	1,253	112	98	3.2	0.3	2.5
5	d	4.2	149	51	1,277	111	101	3.1	0.6	2.9
6	e	3.7	144	50	1,259	111	97	3.1	0.2	2.68
7	f	4	151	51	1,266	115	100	3.2	0.6	3
8	0	3.9	146	51	1,252	110	104	3.1	0.6	2.6
9	1	4	149	50	1,284	118	106	3.3	0.7	3.2

Create Data

Tekanan Uap Boiler (bar): 0.000000
Suhu Uap Boiler: 0.000000
V gas (L/h): 0.000000
RPM Turbin: 0.000000
Temperatur Inlet Turbin: 0.000000
Temperatur Outlet Turbin: 0.000000
Tekanan Inlet Turbin (bar): 0.000000
Tekanan Outlet Turbin (bar): 0.000000
output generator (Watt): 0.000000

Create

(b)

Figure 5. Display of the practical data-based thermodynamic visualization application: a. automatic data visualization feature; b. 2D and 3D visualization features

This application provides highly useful features to assist students in understanding and analyzing practical steam power plant data. Features such as automatic data visualization, 2D and 3D visualization, correlation analysis with a heatmap, and database management lay a strong foundation for students to develop relevant data analysis skills for the professional world. Visual-based learning, which uses students' experimental data as a source, enables them to observe and understand complex patterns and cause--effect relationships in power plant systems. By using real data from their own experiments, students can more easily connect theory with practice, thereby enhancing their engagement with and understanding of thermodynamic concepts.

In future research, further integration of AI and machine learning technologies into this application could open opportunities for more advanced predictive analysis and pattern recognition. This would enable students not only to understand historical data but also to predict trends and outcomes in the future, providing them with valuable skills across various professional fields. Thus, this application serves not only as a learning tool but also as a platform for developing the analytical and technical competencies required in today's digital era. Through data-driven and visual-based learning, students can be prepared to become competent and adaptable professionals facing the evolving technologies and data challenges of the future.

3.5. Requiring Learner Participation

Students are encouraged to actively participate by using the application to access and analyze practical data. This visualization tool is designed to help students understand that data is not just the result of experiments but also a valuable learning resource. Through the use of this visualization tool, it is expected that students will understand that data plays a more significant role than just being an output of an experiment. Data also serves as a foundation for students to gather information, clean and analyze it, and use it as a basis for decision-making. Thus, this visualization tool encourages students to take an active role in their learning process, build analytical skills, and understand the importance of data as a dynamic and interactive learning tool. Specifically, integrating data from tests and simulations of thermodynamics learning devices, such as steam turbine trainers, with web-based thermodynamics concept visualization tools creates a robust connection with previous research. This method enables students not only to understand concepts theoretically but also to experience their practical applications through data visualization, bridging the gap between theory and practical experience.

3.6. Evaluation and Revision

This research employs a structured evaluation method to assess the validity and practicality of the developed web-based learning application. Evaluation is conducted through two main stages: validation by experts and practicality testing by students. This approach refers to evaluation models previously applied in technology-based learning research.

This application was validated by nine experts, consisting of three experts in thermodynamics, three experts in instructional media, and three experts in information technology. The validation process involved a focus group discussion (FGD) and questionnaires were distributed via Google Forms. The purpose of this validation was to evaluate the application in terms of media, content, and language used. In the first stage, an FGD was conducted with experts to obtain direct feedback on the application. The experts provided input on the user interface, the quality of the content, and the appropriateness of the language used. After the FGD, a questionnaire was distributed to the experts to collect more structured quantitative data. The validation results indicate that this application has a high level of validity, with an average score above 4.5 in all aspects. The experts agreed that the application is easy to use, contains content aligned with the curriculum, uses comprehensible language, and effectively aids in understanding thermodynamics concepts. The details of the validation results are shown in Table 3.

Table 3. Results of expert questionnaires

Aspect	Question	Average Score
Media	Is the application interface easy to use?	4.7
Material	Is the content of the thermodynamics material in the application in accordance with the curriculum?	4.6
Language	Is the language used in the application easy for students to understand?	4.8
Visualization	Does the data visualization in the application help in understanding thermodynamic concepts?	4.7
Interactivity	Can interactive features in applications increase student engagement?	4.5

In addition to expert validation, a practicality test was conducted by implementing the application with 78 students enrolled in a thermodynamics course during the 2023-2024 academic year.

After using the application during learning sessions, students were asked to complete a practicality questionnaire covering aspects of ease of use, engagement, and effectiveness in aiding conceptual understanding. The practicality test results indicate that students found the application easy to use, engaging, and effective in improving their understanding of thermodynamics concepts. The high average scores in all aspects suggest that the application was well received by students. The details of the practicality test results are shown in Table 4.

Table 4. Results of the practicality questionnaire

Aspect	Question	Average Score
Ease of Use	Is the application easy to use for learning?	4.5
Involvement	Do interactive features in the application make learning more interesting?	4.6
Effectiveness	Does the app help you understand thermodynamic concepts better?	4.7
Visualization	Does data visualization in the application help in understanding practical data?	4.6
Data Management	Are the data storage and management features in the application easy to use?	4.5

The results of the validation and practicality tests indicate that the developed application has high potential to enhance the quality of thermodynamics education. The high validity level from experts, along with positive student responses, demonstrates that this application can serve as an effective learning aid in higher education settings.

3.7. Discussion

Based on the results of validation and practicality testing, this web-based learning application has proven to be valid and practical for use in higher education contexts. Automatic data visualization using Pandas profiling, along with 2D and 3D visualization through Matplotlib and Plotly, assists students in analyzing experimental data more efficiently and effectively. Correlation analysis with a heatmap generated using Seaborn also aids students in understanding relationships between various variables in experimental data, which is crucial for interpreting test results. The feature of data storage and management using Pymongo allows students to store, access, and manage experimental data efficiently, supporting continuous learning processes.

The evaluation conducted indicates that this application not only enhances students' understanding of thermodynamic concepts but also prepares them with relevant data analysis skills for careers in technology and information fields. Revisions based on feedback from further evaluation have improved the functionality and user-friendliness of the application, making it more effective tool for supporting teaching and learning processes in thermodynamics.

Thus, the web-based learning application developed in this study has significant potential to enhance the quality of thermodynamics education in higher education, aligning with previous research findings that integrating technology in learning can enhance the effectiveness and efficiency of teaching and learning processes [35], [26].

4. Conclusion

This study aims to develop and evaluate a web-based learning application designed to help students understand thermodynamics concepts through the visualization of experimental data. The application was built using the Streamlit framework integrating various Python libraries to provide features that support the learning process, including automated data visualization, 2D and 3D graphics, correlation analysis, as well as data storage and management.

Based on validation conducted by nine experts, the application was assessed to have a high level of validity in terms of media, content, and language. The experts agreed that the application is easy to use, contains content aligned with the curriculum, and employs clear and comprehensible language. Meanwhile, a practicality test involving students from the 2023–2024 academic year indicated that the application is not only easy to use but also effective in enhancing their understanding of thermodynamics concepts.

In addition to improving students' comprehension of thermodynamics, this application also equips them with relevant data analysis skills applicable to the workforce, particularly in the fields of technology and information.

However, this study has some limitations, including a restricted user scope limited to a single institution and the absence of a long-term evaluation of the application's impact on learning. Therefore, future research is recommended to expand the implementation of this application to various educational institutions and explore the integration of artificial intelligence to enhance the learning experience. Consequently, this application has significant potential to improve the quality of thermodynamics education in higher education and drive innovation in data-driven learning.

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