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Implementation of RShiny in Developing Interactive Learning Media for Analysis of Variance (ANOVA)

Justin Eduardo Simarmata[*1], Debora Chrisinta[2] , Miko Purnomo[3]

[1]*Program Studi Pendidikan Matematika, Universitas Timor, Kefamenanu, 85613, Indonesia*
[2]*Program Studi Teknologi Informasi, Universitas Timor, Kefamenanu, 85613, Indonesia*
[3]*Program Studi Matematika, Universitas Timor, Kefamenanu, 85613, Indonesia*

[*]Corresponding Author: justinesimarmata@unimor.ac.id

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ABSTRACT

Effective learning is significantly influenced by the methods and media used in the teaching and learning process. However, many students still struggle to understand mathematical concepts due to the limited availability of interactive learning media. Therefore, this study aims to develop and evaluate the effectiveness of a technology-based interactive learning application designed to enhance students' understanding. The development of this application follows several stages, including needs analysis, design, implementation, testing, and evaluation. The application offers various features, such as interactive materials, practice exercises, and visual simulations, to facilitate better comprehension of concepts. The data used in this study consists of pretest and posttest results from 30 students who were given a series of basic questions, including calculating the mean, standard deviation, and performing simple statistical tests. Analysis using the Paired t-Test indicates a significant increase in posttest scores compared to pretest scores (p-value = 3.522e-08). Data visualization in the form of boxplots and line charts also demonstrates a trend of improved student performance after using the application. Thus, this study confirms that the developed interactive application is effective in enhancing student learning outcomes.

Keyword: Interactive Learning, RShiny, Paired t-Test, Learning Outcomes.

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1. INTRODUCTION

Advanced Statistics is one of the courses taught in the Mathematics Education Study Program at Universitas Timor. One of the key topics in this course is One-Way and Two-Way Analysis of Variance (ANOVA), which is used to test differences in means among more than two groups. Understanding ANOVA is essential for students, as this method is widely applied in statistical research across various fields, including education, social sciences, and natural sciences [1], [2], [3], [4], [5]. However, during the learning process, students often encounter difficulties in grasping ANOVA concepts and implementing them using statistical software. Additionally, students frequently struggle to apply theoretical knowledge to problem-solving in ANOVA. One of the main challenges is the limitation of devices used, such as low-specification laptops or the unavailability of adequate statistical software. Furthermore, difficulties in understanding programming syntax in statistical software like R also pose challenges for students. As a result, students' comprehension of ANOVA concepts often remains theoretical without sufficient practical application.

A solid understanding of One-Way and Two-Way ANOVA is crucial for students, particularly in the fields of mathematics education and statistics, as it helps analyze mean differences among multiple groups [6]. One-

Way ANOVA is used to test whether there are significant differences in means among more than two groups based on a single factor, while Two-Way ANOVA allows for the simultaneous analysis of two factors and their interaction [7]. A strong grasp of ANOVA is highly beneficial in academic research [8]. Many studies utilize ANOVA to process and interpret data, enabling students who master this method to conduct deeper analyses of research findings [9]. Understanding ANOVA also aids students in making data-driven decisions, which is a crucial skill in both academic and professional settings [10]. From a statistical analysis perspective, ANOVA provides deeper insights into data variability, parameter estimation, and hypothesis testing [11]. By mastering ANOVA, students can more easily comprehend other inferential statistical methods, which are useful for various scientific studies. Moreover, data processing using statistical software such as R, SPSS, or Python is commonly employed to implement ANOVA methods, making a strong conceptual understanding of ANOVA beneficial for students in developing statistical computing skills [12].

Beyond the academic sphere, ANOVA also has extensive applications in professional fields. In areas such as education, economics, healthcare, and engineering, ANOVA is frequently used to test the effectiveness of strategies, compare different methods, and evaluate policies [13], [14]. Students with proficiency in data analysis using ANOVA will be better prepared to tackle challenges in jobs that require statistical data processing and interpretation. Overall, a solid understanding of One-Way and Two-Way ANOVA is highly valuable for students, as it not only assists in completing academic tasks but also equips them with applicable data analysis skills in various fields. By mastering this method, students can gain confidence in conducting research, interpreting statistical analysis results, and applying them in an increasingly data-driven professional environment.

Based on these challenges, an interactive learning medium that can be easily accessed by students without requiring high-specification devices is necessary. One potential solution is the use of RShiny as a platform for developing interactive learning media [15], [16]. RShiny allows students to perform ANOVA analyses through a web-based interface without the need to install additional software [17]. Moreover, RShiny-based applications can be accessed across various devices, including mobile phones, making them more flexible and usable anywhere. RShiny is a framework in R used to develop interactive web applications [18]. Several previous studies have demonstrated the effectiveness of RShiny in supporting statistics education and data analysis. For instance, one study developed an RShiny application for data visualization and statistical simulations, which helped students better understand statistical concepts [15]. Therefore, the implementation of RShiny in developing interactive learning media for Analysis of Variance (ANOVA) can serve as a valuable innovation in improving the quality of education at Universitas Timor.

Several prior studies have highlighted the effectiveness of RShiny in developing interactive learning media. For example, Alwi et al. developed a web-based learning medium for principal component analysis using RShiny, which significantly improved students' understanding of statistical data analysis [15]. Similarly, Maisarah et al. successfully built an interactive web application for nonparametric statistical tests using the RShiny framework, making statistical analysis more accessible for students without requiring high-specification devices [19]. Another study by Hanč et al. demonstrated that physics teachers responded positively to the use of interactive web applications based on RShiny as a teaching tool, enhancing transparency and accessibility in education [20]. These findings support the development of RShiny-based interactive learning media for the topic of Analysis of Variance (ANOVA) to address the challenges students face in understanding and applying this concept.

This study aims to design and implement an interactive learning medium based on RShiny to facilitate the learning of One-Way and Two-Way Analysis of Variance. The novelty of this research lies in the development of a web-based learning medium that can be easily accessed by students without relying on high-specification devices. With this learning medium, students are expected to gain a better understanding of ANOVA concepts and apply them to various case studies.

2. METHODS

This study is a Research and Development (R&D) study aimed at designing and implementing an interactive learning medium based on RShiny for Analysis of Variance (ANOVA) [21]. The approach used to assess the effectiveness of the developed learning medium is a quantitative approach. The data utilized in this study consists of synthetic data created as sample problems for the implementation of One-Way and Two-Way ANOVA. This data is carefully designed to reflect common cases encountered in statistical analysis. Additionally, the data used to evaluate the effectiveness of the learning medium includes students' pretest and posttest scores.

One-Way ANOVA is used to test mean differences among more than two groups based on a single factor, whereas Two-Way ANOVA is employed to examine the interaction between two factors on the dependent

variable. Analysis of Variance (ANOVA) is a statistical method used to test differences in means among two or more groups. This technique, developed by Ronald Fisher, is commonly applied in experiments to determine whether there are significant differences among the compared groups [22]. The hypothesis tested in One-Way ANOVA is:

H_0: $\mu_1 = \mu_2 = \ldots = \mu_k$ (There was no average difference between groups).

H_1: $\mu_i \neq \mu_j$ dimana $i \neq j$ (There is at least one different average).

Some of the components for calculating a single-track ANOVA are as follows:

a. Sum of Squares Total

$$SST = \sum_{i=1}^{k}\sum_{j=1}^{n_i}\left(X_{ij} - \bar{X}_T\right)^2$$

with $\bar{X}_T$ is the total average.

b. Variasi Antar Kelompok (SSB/Sum of Squares Between Groups)

$$SSB = \sum_{i=1}^{k} n_i(\bar{X}_i - \bar{X}_T)^2$$

with $\bar{X}_i$ is the average of the i-th group.

c. Sum of Squares Within Groups

$$SSW = \sum_{i=1}^{k}\sum_{j=1}^{n_i}\left(X_{ij} - \bar{X}_i\right)^2$$

d. Mean Square (MS) and F Value

$$MSB = \frac{SSB}{k-1}$$

$$MSW = \frac{SSW}{N-k}$$

$$F = \frac{MSB}{MSW}$$

with k is the number of groups and N is the total sample.

If the calculated F value is greater than the table's F value, then H_0 is rejected, which means there is a significant difference between the groups. Hypothesis tested in two-track ANOVA:

a. H_0: There is no difference in the average based on the first factor.
b. H_0: There is no difference in the average based on the second factor.
c. H_0: There is no interaction between the first and second factors.

Some of the components to calculate a single-track ANOVA are as follows:

a. Sum Square Total

$$SST = \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{n}\left(X_{ijk} - \bar{X}_T\right)^2$$

with a is the sum of the levels of factor A, b is the sum of the levels of factor B, and n is the number of observations per combination.

b. Sum Square Factor A

$$SSA = bn\sum_{i=1}^{a}(\bar{X}_{i..} - \bar{X}_T)^2$$

c. Sum Square Factor B

$$SSA = an\sum_{j=1}^{b}\left(\bar{X}_{.j.} - \bar{X}_T\right)^2$$

d. Sum Square Interaction Factor A and B

$$SSAB = n\sum_{i=1}^{a}\sum_{j=1}^{b}\left(\bar{X}_{ij.} - \bar{X}_{i..} - \bar{X}_{.j.} + \bar{X}_T\right)^2$$

e. Sum Square Error

$$SSE = \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{n}\left(X_{ijk} - \bar{X}_{ij.}\right)^2$$

f. Mean Square (MS) and F Value

$$MSA = \frac{SSA}{a-1}$$
$$MSB = \frac{SSB}{b-1}$$
$$MSAB = \frac{SSAB}{(a-1)(b-1)}$$
$$MSE = \frac{SSE}{ab(n-1)}$$
$$F_A = \frac{MSA}{MSE}$$
$$F_B = \frac{MSB}{MSE}$$
$$F_{AB} = \frac{MSAB}{MSE}$$

If the F-value is greater than the F-table value, then the factor effect or interaction is considered significant. The stages of designing and implementing the development of the interactive learning medium are as follows:

a. Analysis of students' needs for an interactive learning medium.
b. Design of a user interface based on RShiny.
c. Development of key features in the application, including data input, selection of ANOVA type, and visualization of analysis results.
d. Testing and evaluation of the learning medium to ensure its accuracy and effectiveness in helping students understand ANOVA.
e. Implementation of the learning medium in lectures and collection of feedback from students.

3. RESULTS AND DISCUSSION

The main interface of the One-Way & Two-Way ANOVA Analysis application based on RShiny is designed to facilitate users in conducting variance analysis interactively (Figure 1). On the left side of the screen, there is an Input Data & Parameters panel that allows users to upload an Excel file containing the data to be analyzed. Additionally, users can select the type of ANOVA to be used, either One-Way ANOVA or Two-Way ANOVA, through a dropdown menu. There is also a field for entering the significance level (α), with a default value of 0.05, as well as a "Run Analysis" button that processes the input data.

Meanwhile, on the right side of the screen, there are two main tabs: Data Preview and Test Result. The Data Preview tab displays a summary of the uploaded data, allowing users to check data compatibility before proceeding with the analysis. The Test Result tab presents the ANOVA analysis results, including the F-statistic, p-value, and hypothesis test interpretation. With a simple and intuitive interface, this application is designed to help students easily understand the concept of ANOVA without requiring in-depth knowledge of statistical programming syntax. Furthermore, as a web-based application, it can be accessed from various devices without the need to install additional software, enhancing flexibility in the learning process.

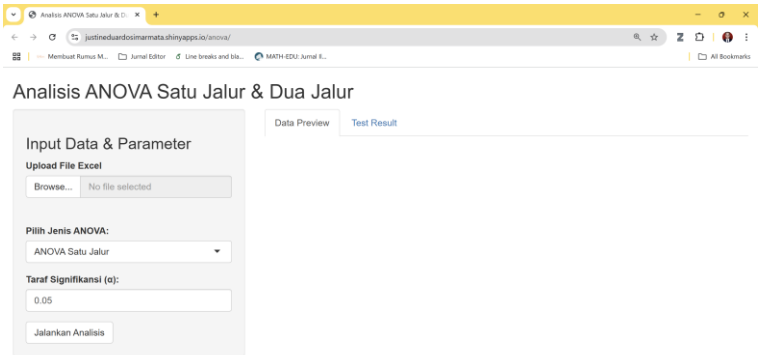
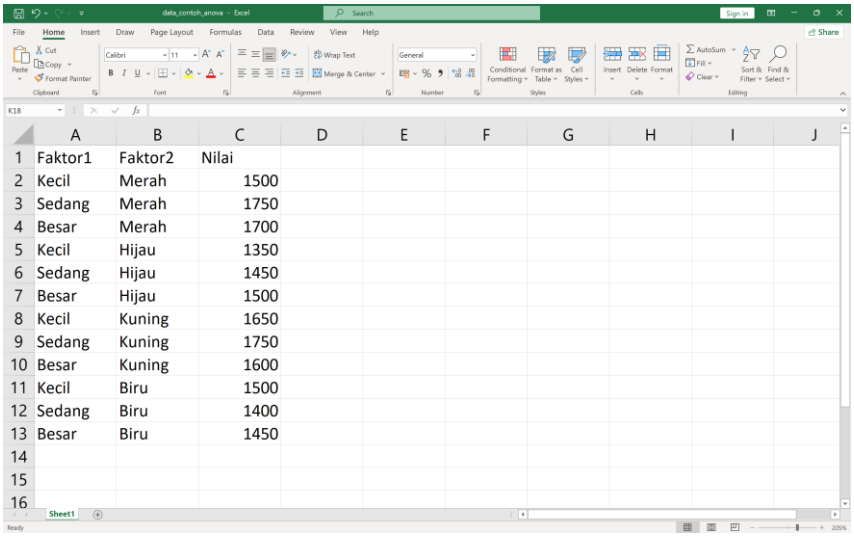


Figure 1. Main Interface of the One-Way & Two-Way ANOVA Analysis Application

The website that users can freely access is available at the following address: https://justineduardosimarmata.shinyapps.io/anova/ . The upload file format used in the One-Way & Two-Way ANOVA Analysis application must be structured as a table with three main columns: Factor1, Factor2, and Value (Figure 2). The Factor1 column contains the main categories analyzed, such as size (Small, Medium, Large). The Factor2 column contains additional categories used in two-way analysis, such as color (Red, Green, Yellow, Blue). Meanwhile, the Value column contains numerical data used in ANOVA calculations. This format allows the application to read and categorize the data correctly according to the selected ANOVA type. If the user selects One-Way ANOVA, only one factor will be used in the analysis, whereas if Two-Way ANOVA is chosen, both factors will be analyzed to observe their effects and interaction on the response variable. With this well-organized structure, users can easily upload and process data without requiring significant adjustments.



	A	B	C
1	Faktor1	Faktor2	Nilai
2	Kecil	Merah	1500
3	Sedang	Merah	1750
4	Besar	Merah	1700
5	Kecil	Hijau	1350
6	Sedang	Hijau	1450
7	Besar	Hijau	1500
8	Kecil	Kuning	1650
9	Sedang	Kuning	1750
10	Besar	Kuning	1600
11	Kecil	Biru	1500
12	Sedang	Biru	1400
13	Besar	Biru	1450

Figure 2. Upload File Format

After successfully uploading data into the One-Way & Two-Way ANOVA Analysis application, users can view the data preview on the Data Preview tab (Figure 3). In this view, the uploaded data is displayed in table format with three main columns: Factor1, Factor2, and Value. The Factor1 and Factor2 columns contain the categories used for ANOVA analysis, while the Value column contains the numerical data to be analyzed. Additionally, the application provides a search feature that enables users to quickly find specific data. The number of entries displayed can also be adjusted through a dropdown menu, allowing users to select how many rows of data they want to view per page. If the uploaded data is large, users can navigate between pages using the Previous and Next buttons at the bottom of the table.

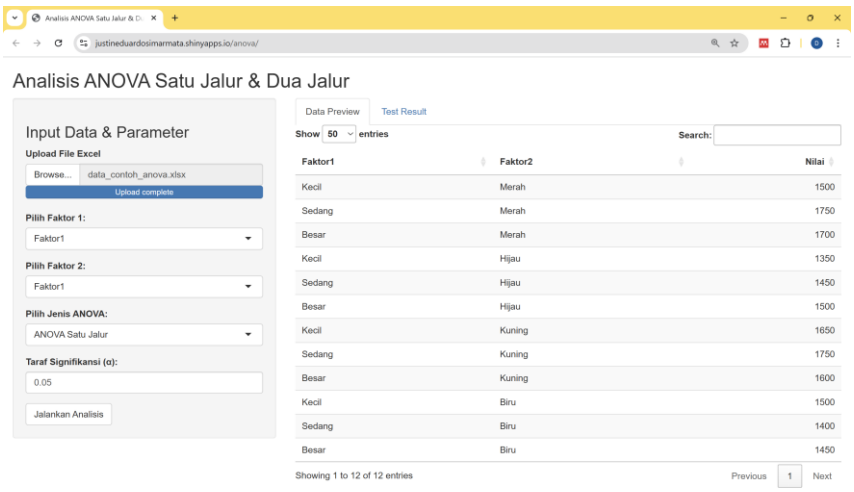


Figure 3. Data Preview in the Data Preview Tab

After users upload the data and select the One-Way ANOVA method, the analysis results are displayed in the Test Result tab (Figure 4). The result table shows the degrees of freedom (DF), sum of squares (Sum Sq),

mean squares (Mean Sq), calculated F-value, and p-value for the tested factor and residuals. In this example, the tested factor has an F-value = 0.39 and a p-value = 0.69. With a significance level (α) of 0.05, a p-value greater than 0.05 indicates no significant difference among groups based on the tested factor. Additionally, since the calculated F-value (0.39) < F-table (4.256), the null hypothesis (H_0) cannot be rejected, meaning there is no significant difference among the groups analyzed.

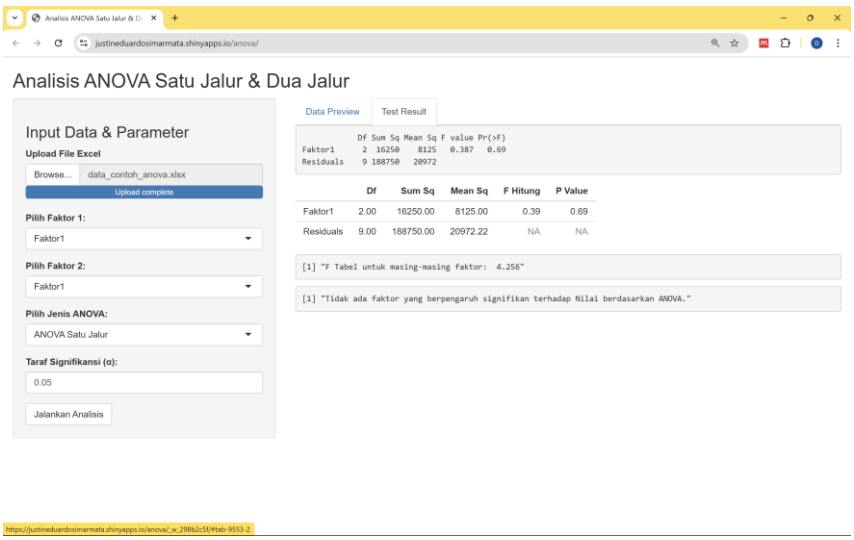


Figure 4. Analysis Results Displayed in the Test Result Tab

For Two-Way ANOVA analysis (Figure 5), the results show that the second factor (Factor2) significantly affects the observed values, while the first factor (Factor1) and the interaction between the two factors do not show significant effects.

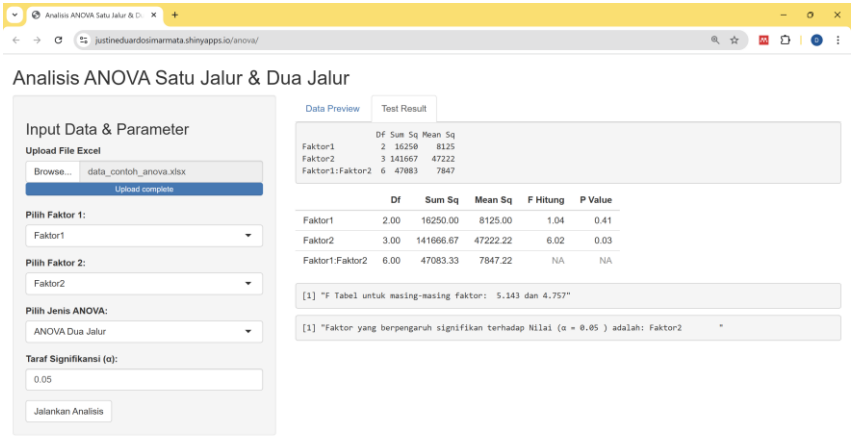


Figure 5. Two-Way ANOVA Analysis Results

The visualization of students' pretest and posttest scores after using the interactive media shows an improvement in learning outcomes (Figure 6). In the boxplot diagram, pretest scores (red box) are mainly between 50-70, while posttest scores (blue box) increase with most above 70. The higher median posttest score indicates improvement in learning outcomes after using the interactive media.

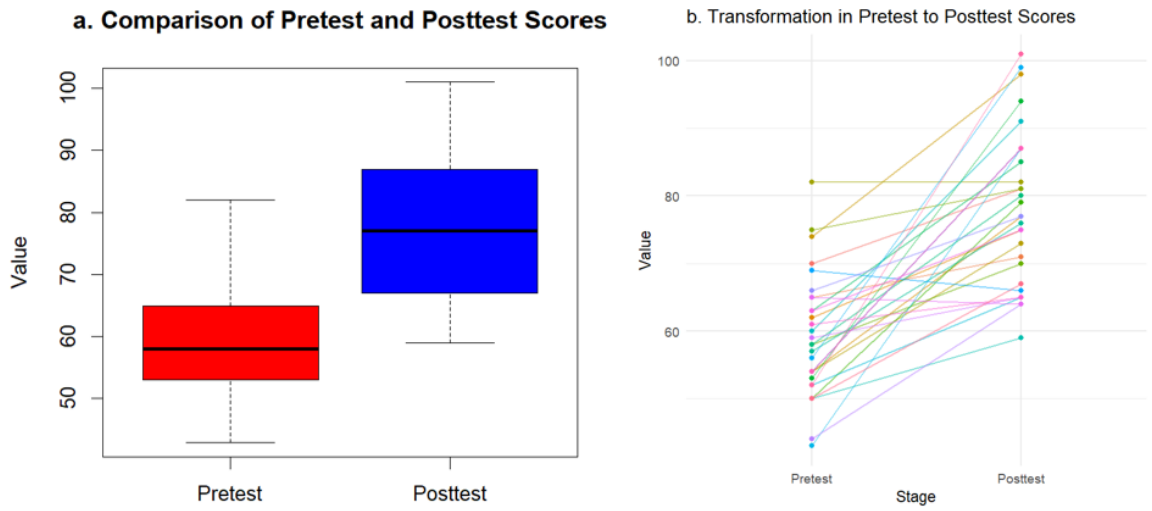


Figure 6. Visualization of (a) Pretest and Posttest Score Distribution; (b) Changes in Pretest and Posttest Scores

```
        Paired t-test

data:  pretest and posttest
t = -7.4231, df = 29, p-value = 3.522e-08
alternative hypothesis: true mean difference is not equal to 0
95 percent confidence interval:
 -24.14991 -13.71676
sample estimates:
mean difference
      -18.93333
```

Figure 7. Paired t-Test Results

Based on the results of the Paired t-Test in Figure 7, the obtained t-value is -7.4231, with df = 29, and a p-value of 3.522e-08. The very small p-value (less than 0.05) indicates a significant difference between students' pretest and posttest scores. The 95% confidence interval for the mean difference ranges from -24.14991 to -13.71676, meaning that the posttest scores are significantly higher than the pretest scores. The obtained mean difference is -18.93333, indicating that after using the interactive media, there is a significant improvement in students' learning outcomes. Thus, it can be concluded that the use of interactive media has a positive effect on students' learning outcomes and is effective in enhancing their understanding of the material.

The findings of this study align with the research conducted by Kurniawati (2018), which found that the use of interactive technology-based learning media can improve students' conceptual understanding [23]. Additionally, the study by Islamiyah & Widayanti (2016) showed that digital technology-based learning methods can enhance students' academic performance compared to conventional methods [24]. These findings are further supported by the research of Worang et al. (2021), which stated that interactive multimedia-based learning can increase students' motivation and understanding of lecture materials [25]. Thus, this study confirms that the use of interactive media in learning can significantly improve students' academic performance, as also found in previous research. Therefore, integrating technology into learning is highly recommended to enhance the effectiveness of the teaching and learning process.

4. CONCLUSIONS

Based on the findings of this study, it can be concluded that the use of technology-based interactive learning media has a positive impact on improving students' learning outcomes. The results of the Paired t-Test indicate a significant difference between pretest and posttest scores, with a p-value of 3.522e-08, demonstrating that the developed application is effective in enhancing students' understanding of the material. Data visualization through boxplots and line charts also reveals an upward trend in scores following the use of the application, further reinforcing these findings. Additionally, this study is supported by previous research, which has shown that the integration of technology in education significantly enhances conceptual understanding. Therefore, the development and implementation of technology-based interactive learning media should be continuously pursued to improve the quality of education, particularly in quantitative subjects such as mathematics and statistics.

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