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How to conduct paired-t-test SPSS: comprehension in adsorption with bibliometric

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ABSTRACT

The purpose of this study was to provide an example of how to calculate, measure, and interpret a paired t-test analysis using Statistical Package for the Social Sciences (SPSS). This study explained a step-by-step process to understand how t-test analysis can be used. To support this study, bibliometric research was added for showing the research trend in the use of t-test in a wide range of applications in the medical and educational fields. The analysis was carried out in two stages, namely prerequisite testing and hypothesis testing. In the prerequisite test, we did the normality (the Shapiro-Wilk) and the homogeneity test (Levene). Both tests were used for understanding what a significant impact happens on student learning outcomes from the statistical data gained during the teaching and learning process. Since this study provided step by step on conducting the t-test using SPSS and also how to interpret the results, this study is applicable for users to use in various research fields.

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1. INTRODUCTION

There are two types of statistical inference, namely parametric and non-parametric methods. The parametric method refers to a statistical technique with several requirements: probability distributions can be determined, probability variables can be defined, and distribution parameters can be inferred. In contrast, nonparametric methods are used if the probability distribution cannot be determined [1]. One of the important statistical techniques is the t-test. The t-test belongs to the parametric method. It aims to determine the significant impact gained from the average difference in the two compared data [2]. This test can be used when the sample satisfies the conditions of measured values on an interval scale or ratio scale, simple random extraction, homogeneity of variance, normality data distribution, and appropriate sample size [3]. The t-test can be used although the samples are extremely small ($n \leq 5$) [4]. In the calculation, the t-test analysis is divided into two types: independent and paired t-test, depending on the type of dependency of the data [5]. Both types of t-tests can be analyzed using manual or computational analysis.

Several studies are available relating to the t-test analysis. From a brief description of the t-test [6], an analysis of the misuse of the t-test and the operation of the Statistical Package for the Social Sciences (SPSS) in medical research [7], statistical records of the sample t-test independent for clinical researchers [8], the use of Welch t-test to compare differences between two groups of samples [9], and equivalent statistical test for one-sample t-test [10]. However, there is no paper yet discussing the explanation and visualization of t-test analysis. To support this analysis, bibliometrics is added to analyze the direction and trends of the research [11]–[30]. This study aims to provide a step-by-step process to understand how to calculate and interpret a paired t-test analysis using SPSS. As an example, the analysis was taken from data from the teaching and learning results on students' understanding of the concept of adsorption isotherm using a video with an experimental demonstration learning method. A detailed explanation of the adsorption isotherm is explained in previous studies [31]–[40].

2. RESEARCH METHOD
2.1. Bibliometric analysis
This study consists of four stages as described in the flowchart. This research was fully carried out using a computer starting from collecting data to analyzing the mapping result. This research involves three software namely Publish or Perish, Microsoft Excel, and VOSviewer. The detailed information for the use of bibliometric analysis is shown in previous study [41].

2.2. Calculating t-test using SPSS
Some experimental data were used as a model in Table 1. Detailed explanation for the use of t-test is explained in previous literature [42]. The data is classified as independent and paired. Thus, we conduct the paired t-test. The data was obtained from pre-test and post-test conducted on two classes of vocational students around Bandung, Indonesia. Pre and post-tests were used to analyze students' comprehension on the concept of adsorption isotherm by using a video with an experimental demonstration learning method.

Table 1. Some experimental data for a model of analysis

Question number	Score (%)					
	Control class			Experimental class		
	Pre-test	Post-test	Gain control class	Pre-test	Post-test	Gain experimental class
1	90	70	-20	90	90	0
2	40	70	30	80	95	15
3	30	30	0	30	55	25
4	100	90	-10	85	95	10
5	80	50	-30	70	90	20
6	20	40	20	35	65	30
7	40	90	50	60	90	30
8	40	50	10	75	80	5
9	40	60	20	35	70	35
10	40	60	20	50	45	-5
11	80	80	0	70	85	15
12	40	60	20	50	75	25
13	60	60	30	75	85	10
14	20	70	50	30	60	30
15	70	75	5	75	95	20
Average	50.67	67.67	15.00	50.67	78.33	17.67

3. RESULTS AND DISCUSSION
3.1. Trend research on t-test: bibliometric analysis
The top 10 articles with the most citations are shown in Table 2. The most often used t-test are medical, animal, and education [43]–[47]. This is confirmed by the terms most related shown in Figure 1.

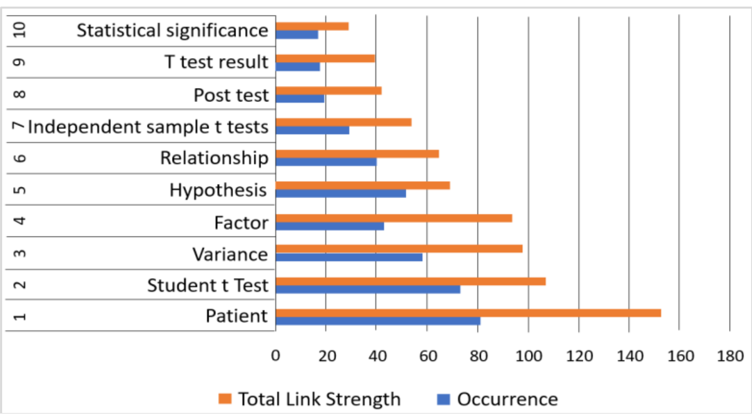

Figure 1. The most related term to the t-test analysis

Table 2. Publication on the t-test analysis research with the highest number of citations

Cited	Title	Year	Ref
15689	lmerTest package: tests in linear mixed effects models	2017	[48]
2150	The impact of covid-19 epidemic declaration on psychological consequences: a study on active Weibo users	2020	[49]
1662	A prospective study of the accuracy and concordance between in-situ and postfixation measurements of colorectal polyp size and their potential impact upon surveillance	2013	[50]
1561	The effect of using educational multimedia in dictation on students' listening comprehension at MA Darul Hikmah Pekanbaru	2018	[51]
1508	Bayesian estimation supersedes the t test.	2013	[52]
1275	How to calculate sample size in animal studies?	2013	[53]
1254	T test as a parametric statistic	2015	[1]
1243	Analysis of factors associated with disease outcomes in hospitalized patients with 2019 novel coronavirus disease	2020	[54]
1163	Experimental design and analysis and their reporting II: Updated and simplified guidance for authors and peer reviewers	2018	[55]
1105	Diagnostic utility of clinical laboratory data determinations for patients with the severe COVID-19	2020	[56]

3.2. Step-by-step calculating t-test

Before conducting the t-test, the data must meet the requirements, namely normal and homogeneous. Thus, before testing the hypothesis in the form of a t-test, we must carry out a prerequisite test, namely the normality test and homogeneity test. If the data is not normal and not homogeneous, the t-test cannot be done.

3.2.1. Normality test

Statistical tests that can be employed include the Chi-square test, Kolmogorov Smirnov, Lilliefors, Shapiro Wilk, or Jarque Bera. The Chi-square or X2 method for the Normal Distribution Goodness of fit test utilizes the sum approach of the data for each class with the expected value. The requirements for the Chi-square method are that the data are arranged in groups or grouped in a frequency distribution table, the amount of data is large (>30). The Kolmogorov-Smirnov test can be used for both large and small data. The requirements for the Lilliefors test are interval or ratio (quantitative) data, single data, or not yet grouped in the frequency distribution table. The data normality test with Lilliefors is almost the same as the Kolmogorov-Smirnov test, except that the Lilliefors test uses the Lilliefors table. The requirements for the Lilliefors test are the same as for the Kolmogorov-Smirnov test. The Shapiro-Wilk test is an effective and valid normality test method used for small samples. The requirements for the Shapiro-Wilk test are interval or ratio (quantitative) data, single data, not yet grouped into a frequency distribution table, and data from random samples. The Jarque Bera test is based on the fact that the skewness and kurtosis values of the normal distribution are equal to zero. Thus, the absolute value from this parameter is measured by the deviation of the distribution from normal condition. However, the Jarque Bera test is not yet available in statistical test software such as SPSS, Minitab or STATA.

The study presents an example of calculating normality in the pre and post-test data of students who have carried out learning with the demonstration experimental method. In this study, the type of normality test used was the Shapiro-Wilk test. The Shapiro-Wilk test was chosen because it is suitable for use with small samples (<100), according to the sample of the study (less than 50 students per test class). The results of the normality test are presented in Table 3. To determine whether data is normally distributed using the Shapiro-Wilk, it is sufficient to get at the sig. on the Shapiro-Wilk column, meaning significance, called as the p-value, or probability value. If the p-value>0.05, H0 is accepted meaning the data is normally distributed. However, if the p-value <0.05, H0 is rejected, meaning that the data is not normally distributed. However, the hypothesis in this study are: i) Students' pre and post-test results are normally distributed (H0); ii) The pre and post-test results of students are not normally distributed (H1).

Table 3. The result of the normality test

	Respondent	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	1	0.290	15	0.001	0.894	15	0.077
	2	0.207	15	0.084	0.902	15	0.103
Post-test	1	0.148	15	0.200*	0.964	15	0.763
	2	0.195	15	0.130	0.895	15	0.081

*This is a lower bound of the true significance.
a. Lilliefors Significance Correction

As shown in Table 3, since the significance value of all data is more than 0.05, the data receive H0 or which means the data are normally distributed. The value of degrees of freedom (df) is the number of samples or the amount of data used in the research. The statistical value is the result of calculating the Shapiro-Wilk (W) coefficient. This value correlates with the sample distribution. The greater value of this coefficient indicates the more likely the sample data normally distributed, and vice versa. The Shapiro-Wilk coefficient can be calculated using (1).

$$W = \sum_{i=1}^{n}(X_i - \bar{X})^2 \quad (1)$$

For determining normality using the Shapiro-Wilk test manually, it can be determined by (2).

$$T_3 = \frac{1}{W}\left[\sum_{i=1}^{k} a_i(X_{n-i+1} - X_i)\right]^2 \quad (2)$$

where, W is the coefficient of Shapiro-Wilk, n is the total data, Xi is data number i, $\bar{X}$ is the average, $T3$ is the Shapiro-Wilk statistical equation for determination of normal data, and $Xn\text{-}i\text{+}1$ is the data number $n\text{-}i\text{+}1$. Manual calculations are not widely used because it takes longer and the chances of calculation errors are greater. After confirming that the data is normally distributed, the calculation is continued to the homogeneity test.

3.2.2. Homogeneity test

To do the homogeneity test we can use Levene’s test or Barlett’s test. Levene’s test has the main objective to determine the homogeneity of the two groups of data with different variances [2]. The data tested using Levene’s test does not have to be normally distributed, but the data must be continuous. The Barlett test is used to test the homogeneity of the variance of more than two data groups. The study presents an example of calculating homogeneity using the Levene test. Levene’s test was used because it is suitable for testing homogeneity between two data. The results of the homogeneity test are presented in Table 4.

Table 4. The result of the homogeneity test

		Levene statistic	df1	df2	Sig.
Pre-test	Based on mean	1.027	1	28	0.320
	Based on median	0.096	1	28	0.759
	Based on median and with adjusted df	0.096	1	24.958	0.759
	Based on trimmed mean	0.911	1	28	0.348
Post-test	Based on mean	0.001	1	28	0.979
	Based on median	0.007	1	28	0.936
	Based on median and with adjusted df	0.007	1	27.947	0.936
	Based on trimmed mean	0.001	1	28	0.971

To determine whether data is homogenous using Levene’s test, it is sufficient to look at the Sig. in the based on mean column. The sig value means significance or may be called the p-value or probability value. If the p-value>0.05 then H0 is accepted meaning the data is homogenous. However, if the p-value<0.05 then H0 is rejected, meaning that the data is not homogenous. However, the hypotheses in this study are: i) Students’ pre and post-test results come from populations that have the same population variance (H0); ii) The pre and post-test results of students come from populations that did not have the same population variance (H1).

In Table 4, the significance value of all data is more than 0.05, the data receives H0 or which means the data come from populations that have the same population variance or the variance of data is homogenous. The value of df1 is the number of independent variables, and df2 is the number of samples minus the number of independent variables minus 1. Levene’s statistic value is the result of calculating Levene’s (L) test. Manually, Levene’s test can be calculated using (3).

$$\frac{(N-k)\sum_{i=1}^{k} n_i(\bar{z}_i - \bar{z}_{..})^2}{(k-1)\sum_{i=1}^{k}\sum_{j=1}^{n_i}(z_{ij}-\bar{z}_{i.})^2} \quad (3)$$

where, n is the number of observations, k is the number of groups, $Z_{ij}=|Y_{ij} - \bar{Y}|$, $\bar{Y}_i$ is the average of the i-group, $\bar{z}_i$ is the group average of Z_i, $\bar{z}$ is the overall average of Z_{ij}.

3.2.3. T-test calculation

The prerequisite for conducting the t-test is that the data is normally distributed and the variance is homogeneous. If the data is not normal and not homogeneous, the t-test cannot be carried out. If the prerequisites are not met, non-parametric mean difference tests such as the Mann-Whitney, Kruskal-Wallis, Wilcoxon, or ANOVA tests can be performed. In this test, we have to separate the control class and the experimental class. The paired t-test cannot be carried out simultaneously between the control class and the experimental class. Thus, we removed the experimental class data from the data view and perform the paired t-test separately. Table 5 shows the results of the descriptive analysis of the data obtained after the t-test was performed. The mean value shows the average value of the data. After the t-test is carried out, the average value shows the average value of the data. in both classes, the pretest score was lower than the posttest average. In both classes, there are differences in student learning outcomes descriptively. Bigger differences were found in the experimental class. The N value indicates the amount of data for each variable.

Table 5. Paired sample descriptive analysis result

		Mean	N	Std. Deviation	Std. Error mean
Control class	Pre-test	52.67	15	25.486	6.580
	Post-test	63.67	15	16.952	4.377
Experimental class	Pre-test	60.67	15	20.777	5.364
	Post-test	78.33	15	15.999	4.131

In Table 5, all of the calculated data groups show a deviation value that is smaller than the mean value. All mean values show a good representation. Equation (4) can be used manually to determine the standard deviation.

$$s = \sqrt{\frac{\sum(X_i - \bar{x})^2}{n-1}} \quad (4)$$

where, S is the standard deviation, X_i is the data to i, $\bar{X}$ is the average value of the data, and n is the number of data.

The mean standard error can be used to determine how accurately the average data sample can approach the population means for each variable. The known standard error can explain how the average data from the sample data for each variable can predict the population means if the data is regularly distributed (satisfies the normality test). The standard error mean (sx) can be calculated manually using (5).

$$S_{\bar{X}} = \frac{s}{\sqrt{n}} \quad (5)$$

where, $S_{\bar{X}}$ is the standard error mean, s is the standard deviation, and n is the amount of data.

The results of the paired sample t-test are shown in Table 6. The mean value represents the average difference and is used to calculate the value of pairwise differences. The test's findings indicate that the average difference is -11.000 and -17.667. The sample standard deviation on the column is the pairwise difference. The test findings reveal a difference with a standard deviation of 22.694 and 11.932. The sample mean distribution (of differences) standard deviation is estimated using the standard error mean for an infinite population. The confidence bounds of the confidence interval for the mean difference are the upper and lower confidence limits. Equation (6) can be used to determine the confidence interval.

$$\bar{d} \pm t_{\propto/2}\left(\frac{s_d}{\sqrt{n}}\right) \quad (6)$$

The t-value is the value used to determine the confidence bound. It is based on levels of confidence and degree of freedom. If the average difference value and the average difference's standard error are known, the t value can be determined using (7).

$$t = \frac{\bar{d}}{s_{\bar{x}}} \quad (7)$$

The degrees of freedom (8) can be used to determine the formation of the t distribution.

$$df = n - 1 \quad (8)$$

A choice can be made by comparing the value of the t statistic with the t-table if the values of t and df are known. The decision-making principle is if the t-statistical value is greater than the t-table value. H0 is rejected (no significant difference) and Ha is accepted and vice versa.

In addition to the t-value, significance can also be determined from the significant value or p-value in the table of t-test results (column sig. (2-tailed)). The basis for decision-making is if the sig. (2-tailed) <0.05, indicating a significant difference between the initial variable and the final variable (H1 accepted). There is a significant effect on the difference in the treatment given to each variable. However, if the sig. (2-tailed) >0.05, indicating no significant difference between the initial variable and the final variable (H0 accepted). Also, there is no significant impact on the difference in the treatment given to each variable. The significance value of the control class is 0.081, while the experimental class is 0.000.

For the control class, H0 is accepted, meaning that the treatment given to students in the control class has no significant effect on the results of the pre-test and post-test results of students. For the experimental class, the significance value is <0.05, which shows that H1 is accepted. This means that the treatment given to the experimental class (experimental demonstration method) has a significant effect on students' post-test results. Further conclusions mean that the experimental demonstration method has a significant influence on learning outcomes, especially effective for conveying the concept of adsorption to students.

Table 6. The paired sample t-test result

		Paired differences							
		Mean	Std. Deviation	Std. Error mean	95% confidence interval of the difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Control	Pre-test Post-test	-11.000	22.694	5.859	-23.567	1.567	-1.877	14	0.081
Experiments	Pre-test Post-test	-17.667	11.932	3.081	-24.275	-11.059	-5.734	14	0.000

4. CONCLUSION

The study explained step-by-step process in calculating t-test using SPSS and interpret the results. To support this study, we also carried the bibliometric research for understanding the research trend for the use of t-test, confirming that the t-test analysis was widely used in research in the medical and educational fields. This research provides a visualization of the use of the t-test in various research fields and provide step by step to conduct the t-test using SPSS and also how to interpret the results.

REFERENCES

[1] T. K. Kim, "T test as a parametric statistic," *Korean Journal of Anesthesiology*, vol. 68, no. 6, pp. 540–546, 2015.
[2] P. Mishra, U. Singh, C. Pandey, P. Mishra, and G. Pandey, "Application of student's t-test, analysis of variance, and covariance," *Annals of Cardiac Anaesthesia*, vol. 22, no. 4, p. 407, 2019, doi: 10.4103/aca.ACA_94_19.
[3] T. K. Kim and J. H. Park, "More about the basic assumptions of t-test: normality and sample size," *Korean Journal of Anesthesiology*, vol. 72, no. 4, pp. 331–335, Aug. 2019, doi: 10.4097/kja.d.18.00292.
[4] J. C. F. de Winter, "Using the student's t-test with extremely small sample sizes," *Practical Assessment, Research and Evaluation*, vol. 18, no. 10, pp. 1–12, 2013, doi: https://doi.org/10.7275/e4r6-dj05.
[5] M. Xu, D. Fralick, J. Z. Zheng, B. Wang, X. M. Tu, and C. Feng, "The differences and similarities between two-sample t-test and paired t-test," *Shanghai Archives of Psychiatry*, vol. 29, no. 3, pp. 184–188, 2017, doi: 10.11919/j.issn.1002-0829.217070.
[6] A. Al-Achi, "The student's t-test: A brief description," *Research & Reviews: Journal of Hospital and Clinical Pharmacy*, vol 5, no. 1, 2019.
[7] G. Liang, W. Fu, and K. Wang, "Analysis of t-test misuses and SPSS operations in medical research papers," *Burns and Trauma*, vol. 7, 2019, doi: 10.1186/s41038-019-0170-3.
[8] H.-Y. Kim, "Statistical notes for clinical researchers: the independent samples t -test," *Restorative Dentistry & Endodontics*, vol. 44, no. 3, 2019, doi: 10.5395/rde.2019.44.e26.
[9] R. M. West, "Best practice in statistics: Use the Welch t-test when testing the difference between two groups," *Annals of Clinical Biochemistry*, vol. 58, no. 4, pp. 267–269, 2021, doi: 10.1177/0004563221992088.
[10] G. Francis and V. Jakicic, "Equivalent statistics for a one-sample t-test," *Behavior Research Methods*, vol. 55, no. 1, pp. 77–84, 2023, doi: 10.3758/s13428-021-01775-3.
[11] D. F. Al Husaeni and D. N. Al Husaeni, "Computational bibliometric analysis of research on science and Islam with VOSviewer: Scopus database in 2012 to 2022," *ASEAN Journal of Religion, Education, and Society*, vol. 1, no. 1, pp. 39–48, 2022.
[12] D. F. Ramadhan, A. M. Fabian, and H. M. Saputra, "Dental suction aerosol: Bibliometric analysis," *ASEAN Journal of Science and Engineering*, vol. 2, no. 3, pp. 295–302, 2022, doi: 10.17509/ajse.v2i3.50658.
[13] I. Hamidah, Sriyono, and M. N. Hudha, "A bibliometric analysis of COVID-19 research using Vos viewer," *Indonesian Journal of Science and Technology*, vol. 2, no. 1, pp. 1–8, 2023, doi: 10.17509/ijost.v5i2.24522.
[14] M. Setiyo, D. Yuvenda, and O. D. Samue, "The concise latest report on the advantages and disadvantages of pure biodiesel (B100) on engine performance: literature review and bibliometric analysis," *Indonesian Journal of Science and Technology*, vol. 6, no. 3, pp. 469–490, 2021, doi: 10.17509/ijost.v6i3.38430.

[15] H. Soegoto, E. Soegoto, S. Luckyardi, and A. Rafdhi, "A bibliometric analysis of management bioenergy research using Vosviewer application," *Indonesian Journal of Science and Technology*, vol. 7, no. 1, pp. 89–104, 2022, doi: 10.17509/ijost.v7i1.43328.

[16] A. Mudzakir, K. M. Rizky, H. S. H. Munawaroh, and D. Puspitasari, "Oil Palm Empty Fruit Bunch Waste Pretreatment with Benzotriazolium-Based Ionic Liquids for Cellulose Conversion to Glucose: Experiments with Computational Bibliometric Analysis," *Indonesian Journal of Science and Technology*, vol. 7, no. 2, pp. 291–310, 2022, doi: 10.17509/ijost.v7i2.50800.

[17] I. Hamidah *et al.*, "Biomass-based supercapacitors electrodes for electrical energy storage systems activated using chemical activation method: A literature review and bibliometric analysis," *Indonesian Journal of Science and Technology*, vol. 8, no. 3, pp. 439–468, 2023, doi: https://doi.org/10.17509/ijost.v8i3.60688.

[18] B. Santoso, T. Hikmawan, and N. Imaniyati, "Management Information Systems: Bibliometric Analysis and Its Effect on Decision Making," *Indonesian Journal of Science and Technology*, vol. 7, no. 3, pp. 583–602, 2022, doi: 10.17509/ijost.v7i3.56368.

[19] A. P. Shidiq, "A Bibliometric Analysis of Nano Metal-Organic Frameworks Synthesis Research in Medical Science Using VOSviewer," *ASEAN Journal of Science and Engineering*, vol. 3, no. 1, pp. 31–38, 2023, doi: 10.17509/ajse.v3i1.43345.

[20] A. Ruzmetov and A. Ibragimov, "Past, current, and future trends of salicylic acid and its derivatives: A bibliometric review of papers from the Scopus database published from 2000 to 2021," *ASEAN Journal for Science and Engineering in Materials*, vol. 2, no. 1, pp. 53–68, 2023.

[21] N. Nordin, "Correlation between process engineering and special needs from bibliometric analysis perspectives," *ASEAN Journal of Community and Special Needs Education*, vol. 1, no. 1, pp. 9–16, 2022.

[22] M. R. Bilad, "Bibliometric analysis for understanding the correlation between chemistry and special needs education using Vos viewer indexed by Google," *ASEAN Journal of Community and Special Needs Education*, vol. 1, no. 2, pp. 61–68, 2022.

[23] H. Sudarjat, "Computing bibliometric analysis with mapping visualization using Vos viewer on 'pharmacy' and 'special needs' research Data in 2017-2021," *ASEAN Journal of Community and Special Needs Education*, vol. 2, no. 1, pp. 1–8, 2023.

[24] I. R. Firdaus, M. F. Febrianty, P. N. Awwaludin, M. N. F. Ilsya, Y. Nurcahya, and K. Sultoni, "Nutritional Research Mapping for Endurance Sports: A Bibliometric Analysis," *ASEAN Journal of Physical Education and Sport Science*, vol. 2, no. 1, pp. 23–38, 2023.

[25] I. B. Mulyawati and D. F. Ramadhan, "Bibliometric and Visualized Analysis of Scientific Publications on Geotechnics Fields," *ASEAN Journal of Science and Engineering Education*, vol. 1, no. 1, pp. 37–46, 2021, doi: 10.17509/ajsee.v1i1.32405.

[26] N. A. H. M. Nordin, "A bibliometric analysis of computational mapping on publishing teaching science engineering using VOSviewer application and correlation," *Indonesian Journal of Teaching in Science*, vol. 2, no. 2, pp. 127–138, 2022.

[27] M. D. H. Wirzal and Z. A. Putra, "What is The Correlation Between Chemical Engineering and Special Needs Education from The Perspective of Bibliometric Analysis Using VOSviewer Indexed by Google Scholar," *Indonesian Journal of Community and Special Needs Education*, vol. 2, no. 2, pp. 103–110, 2022, doi: 10.17509/ijcsne.v2i2.44581.

[28] M. Solehuddin, M. Muktiarni, N. I. Rahayu, and R. Maryanti, "Counseling Guidance in Science Education: Definition, Literature Review, and Bibliometric Analysis," *Journal of Engineering Science and Technology*, vol. 18, no. Special issue, pp. 1–13, 2023.

[29] I. Sahidin *et al.*, "Phytochemical Profile and Biological Activities of Ethylacetate Extract of Peanut (Arachis hypogaea L.) Stems: In-Vitro and In-Silico Studies with Bibliometric Analysis," *Indonesian Journal of Science and Technology*, vol. 8, no. 2, pp. 217–242, 2023, doi: 10.17509/ijost.v8i2.54822.

[30] S. N. Hofifah and A. B. D. Nandiyanto, "Water hyacinth and education research trends from the scopus database: A bibliometric literature review," *ASEAN Journal of Science and Engineering Education*, vol. 4, no. 2, pp. 121–132, 2023.

[31] K. Kumar, "Mapping of Nanotechnology Research in Animal Science: Scientometric Analysis," *ASEAN Journal of Science and Engineering*, vol. 1, no. 2, pp. 97–112, 2021, doi: 10.17509/ajse.v1i2.35092.

[32] A. B. D. Nandiyanto *et al.*, "Rice Husk for Adsorbing Dyes in Wastewater: Literature Review of Agricultural Waste Adsorbent, Preparation of Rice Husk Particles, Particle Size on Adsorption Characteristics with Mechanism and Adsorption Isotherm," *Journal of Advanced Research in Applied Mechanics*, vol. 106, no. 1, pp. 1–13, 2023, doi: 10.37934/aram.106.1.113.

[33] A. B. D. Nandiyanto *et al.*, "Sustainable Biochar Carbon Microparticles Based on Mangosteen Peel as Biosorbent for Dye Removal: Theoretical Review, Modelling, and Adsorption Isotherm Characteristics," *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, vol. 105, no. 1, pp. 41–58, 2023, doi: 10.37934/arfmts.105.1.4158.

[34] A. B. Dani Nandiyanto, D. N. Al Husaeni, R. Ragadhita, M. Fiandini, D. F. Al Husaeni, and R. Maryanti, "Analysis of Adsorption Isotherm Characteristics for Removing Curcumin Dyes from Aqueous Solutions Using Avocado Seed Waste Carbon Microparticles Accompanied by Computational Calculations," *Journal of Engineering Science and Technology*, vol. 18, no. 1, pp. 706–720, 2023.

[35] A. B. D. Nandiyanto *et al.*, "Distance Learning Innovation in Teaching Chemistry in Vocational School Using the Concept of Isotherm Adsorption of Carbon Microparticles," *Journal of Technical Education and Training*, vol. 14, no. 1, pp. 14–26, 2022, doi: 10.30880/jtet.2022.14.01.002.

[36] R. Ragadhita and A. B. D. Nandiyanto, "How to calculate adsorption isotherms of particles using two-parameter monolayer adsorption models and equations," *Indonesian Journal of Science and Technology*, vol. 6, no. 1, pp. 205–234, 2021, doi: 10.17509/ijost.v6i1.32354.

[37] H. Prihastuti and T. Kurniawan, "Conversion of Indonesian Coal Fly Ash into Zeolites for Ammonium Adsorption," *ASEAN Journal for Science and Engineering in Materials*, vol. 1, no. 2, 2022.

[38] S. R. Putri, S. N. Hofifah, G. C. S. Girsang, and A. B. D. Nandiyanto, "How to Identify Misconception Using Certainty of Response Index (CRI): A Study Case of Mathematical Chemistry Subject by Experimental Demonstration of Adsorption," *Indonesian Journal of Multidiciplinary Research*, vol. 2, no. 1, pp. 143–158, 2021, doi: 10.17509/ijomr.v2i1.38738.

[39] Z. Rahal, A. Khechekhouche, A. Barkat, Sergeevna, S. Alla, and C. Hamza, "Adsorption of sodium in an aqueous solution in activated date pits," *Indonesian Journal of Science and Technology*, vol. 8, no. 3, pp. 397–412, 2023, doi: 10.17509/ijost.v8i3.60066.

[40] R. H. Khuluk, A. Rahmat, Buhani, and Suharso, "Removal of Methylene blue by adsorption onto activated carbon from coconut shell (Cocous Nucifera L.)," *Indonesian Journal of Science and Technology*, vol. 4, no. 2, pp. 229–240, 2019, doi: 10.17509/ijost.v4i2.18179.

[41] D. F. Al Husaeni and A. B. D. Nandiyanto, "Bibliometric Using Vosviewer with Publish or Perish (using Google Scholar data): From Step-by-step Processing for Users to the Practical Examples in the Analysis of Digital Learning Articles in Pre and Post Covid-19 Pandemic," *ASEAN Journal of Science and Engineering*, vol. 2, no. 1, pp. 19–46, 2022, doi: 10.17509/ajse.v2i1.37368.

[42] S. Afifah, A. Mudzakir, and A. B. D. Nandiyanto, "How to calculate paired sample t-test using SPSS software: From step-by-Step processing for Users to the practical examples in the Analysis of the effect of application anti-fire bamboo teaching materials on student learning outcomes," *Indonesian Journal of Teaching in Science*, vol. 2, no. 1, pp. 81–92, 2022, doi:

10.17509/ijotis.v2i1.45895.
[43] S. Gul and M. Sozbilir, “Biology education research trends in Turkey,” *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 11, no. 1, pp. 93–109, 2015, doi: 10.12973/eurasia.2015.1309a.
[44] R. Kelter, “Analysis of Bayesian posterior significance and effect size indices for the two-sample t-test to support reproducible medical research,” *BMC Medical Research Methodology*, vol. 20, no. 1, 2020, doi: 10.1186/s12874-020-00968-2.
[45] F. Orcan, “Parametric or Non-parametric: Skewness to Test Normality for Mean Comparison,” *International Journal of Assessment Tools in Education*, vol. 7, no. 2, pp. 255–265, 2020, doi: 10.21449/ijate.656077.
[46] R. S. Budiarti and D. N. Harlis, “High order thinking skills for biology education: Applied microbiology learning videos based on Jambi local wisdom,” *Universal Journal of Educational Research*, vol. 8, no. 2, pp. 689–694, 2020, doi: 10.13189/ujer.2020.080242.
[47] D. N. Al Husaeni and A. B. D. Nandiyanto, “Bibliometric analysis of high school keyword using VOSviewer indexed by Google Scholar,” *Indonesian Journal of Educational Research and Technology*, vol. 3, no. 1, pp. 1–12, 2022.
[48] A. Kuznetsova, P. B. Brockhoff, and R. H. B. Christensen, “lmerTest package: Tests in linear mixed effects models,” *Journal of Statistical Software*, vol. 82, no. 13, pp. 1–26, 2017, doi: 10.18637/JSS.V082.I13.
[49] S. Li, Y. Wang, J. Xue, N. Zhao, and T. Zhu, “The impact of covid-19 epidemic declaration on psychological consequences: A study on active Weibo users,” *International Journal of Environmental Research and Public Health*, vol. 17, no. 6, 2020, doi: 10.3390/ijerph17062032.
[50] J. K. Turner, M. Wright, M. Morgan, G. T. Williams, and S. Dolwani, “A prospective study of the accuracy and concordance between in-situ and postfixation measurements of colorectal polyp size and their potential impact upon surveillance,” *European Journal of Gastroenterology and Hepatology*, vol. 25, no. 5, pp. 562–567, 2013, doi: 10.1097/MEG.0b013e32835d1f2d.
[51] A. Y. Rahmat, “The Effect of Using Educational Multimedia in Dictation on Students’ Listening Comprehension at MA Darul Hikmah Pekanbaru,” *J-SHMIC: Journal of English for Academic*, vol. 5, no. 1, pp. 1–19, 2018, doi: 10.25299/jshmic.2018.vol5(1).1096.
[52] J. K. Kruschke, “Bayesian estimation supersedes the T test,” *Journal of Experimental Psychology: General*, vol. 142, no. 2, pp. 573–588, 2013, doi: 10.1037/a0029177.
[53] J. Charan and N. Kantharia, “How to calculate sample size in animal studies?” *Journal of Pharmacology and Pharmacotherapeutics*, vol. 4, no. 4, pp. 303–306, 2013, doi: 10.4103/0976-500X.119726.
[54] H. L. Wei1 *et al.*, “Analysis of factors associated with disease outcomes in hospitalized patients with 2019 novel coronavirus disease,” *Chinese Medical Journal*, vol. 1, pp. 1–16, 2020.
[55] M. J. Curtis *et al.*, “Experimental design and analysis and their reporting II: updated and simplified guidance for authors and peer reviewers,” *British Journal of Pharmacology*, vol. 175, no. 7, pp. 987–993, 2018, doi: 10.1111/bph.14153.
[56] Y. Gao *et al.*, “Diagnostic utility of clinical laboratory data determinations for patients with the severe COVID-19,” *Journal of Medical Virology*, vol. 92, no. 7, pp. 791–796, 2020, doi: 10.1002/jmv.25770.

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