Journal of Innovation and Creativity
Journal Home: https://joecy.org/index.php/joecy
e-mail: journaljoecy@gmail.com

Faculty of Education
Tuanku Tambusai Heroes University
ISSN 2776-771X (Online)
ISSN 2962-570X (Printed)
6 (2) 2026, Pages: 31245-31251

The Influence of Understanding the Concept of Vacuum Drying in the Electric Vehicle Battery Production Process on the Technical Analysis Ability of Automotive Engineering Education Students

Raka Riyana Romansyah [1], Raden Ajriya Razaka Nugroho [2], Wahid Munawar [3], Sriyono [4]
[1]Indonesian University of Education
[2]Indonesian University of Education
[3]Indonesian University of Education
[4]Indonesian University of Education
Corresponding Author: rakariyana.r@upi.edu

Published: June 2026

ABSTRACT

The surge in global electric vehicle adoption demands a technical workforce capable of not only operating vehicles but also understanding the manufacturing technology of their core components, particularly lithium-ion batteries. One of the most critical production stages in battery manufacturing is vacuum drying, the process of removing residual moisture from electrodes using a vacuum oven prior to cell assembly. However, the understanding of Automotive Engineering Education (PTO) students regarding this concept, and the extent to which this understanding impacts their technical analysis skills, has never been empirically studied. This study aims to analyze the effect of understanding the concept of vacuum drying in the electric vehicle battery production process on the technical analysis skills of PTO students. The research design used a quantitative correlational approach with a survey method of 80 active students who have taken courses containing EV technology or automotive electricity, selected through a purposive sampling technique. Data were collected using a five-level Likert scale questionnaire that has been tested for validity and reliability, then analyzed using simple linear regression with the help of SPSS. The results showed that the instrument used was reliable with a Cronbach's Alpha coefficient of 0.890 (variable X) and 0.830 (variable Y). The regression test produced the equation $\hat{Y} = 28.711 + 0.066X$ with an F-value of 17.718 and a coefficient of determination $R^2 = 0.124$, meaning that the variable of understanding the concept of vacuum drying contributed to explaining 12.4% of the variation in students' technical analysis abilities, classified as a moderate effect according to Cohen's criteria. This finding statistically proves that the integration of vacuum drying material in the PTO curriculum has a real effect, while also opening up the urgency of developing more systematic and comprehensive EV battery manufacturing technology-based learning content.

Keywords: vacuum drying, electric vehicle battery, technical analysis skills, automotive engineering education, lithium-ion battery

© The Author(s). 2021 Open Access This article is licensed under a Creative Commons Atibution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0

INTRODUCTION

The transformation of the global automotive industry towards vehicle electrification has become an unstoppable strategic agenda in the last decade. Responding to the pressures of climate change and commitments to reduce carbon emissions, various countries are racing to accelerate the transition from fossil fuel vehicles to battery-based electric vehicles (Agency, 2024) noting that global electric car sales in 2024 will exceed 16 million units, an increase of around 15-20% compared to 2023 which recorded 14 million units (IEA, 2024). Further projections indicate that by 2030, the total stock of BEVs worldwide is estimated to reach 350 million units, with an annual battery production capacity required of 4,300 GWh six times the global production capacity in 2022 of 700 GWh (Degen & Krätzig, 2024)This exponential growth requires a competent technical workforce, not only in the operational aspects of electric vehicles, but also in understanding the production processes of the accompanying core technologies, including battery manufacturing technology.

At the national level, Indonesia is demonstrating a significant rate of electric vehicle adoption. Data from the Association of Indonesian Automotive Industries (GAIKINDO) reveals that BEV

sales in the January-August 2024 period reached 23,045 units, a 177.32% *year-on-year increase* compared to the same period in 2023 (GAIKINDO, 2024). Furthermore, data from the 2025–2034 Electricity Supply Business Plan (RUPTL) of PLN noted that the number of electric cars in Indonesia in August 2024 had reached 68,695 units, a dramatic jump from just 125 units in 2020-a growth of 54,856% in five years (Ministry of Energy and Mineral Resources & PLN, 2024). (Neb et al., 2022)reinforce this trend by noting that the EV share of total passenger vehicle sales increased from 9% in 2023 to 15% in 2024, and is projected to reach 29% by 2030. This growth momentum is further strengthened by government policy through Presidential Regulation Number 79 of 2023 which expands fiscal and non-fiscal incentives for EV manufacturers, as well as a national target that stipulates that 20% of new vehicles sold in 2025 must be electric vehicles.

Behind this rapid market growth, battery components are the heart of electric vehicle technology and a determining factor in quality, safety, and affordability. Lithium-ion batteries (*LIBs*) currently dominate the EV battery market and are projected to continue to be the primary battery technology in the near future (Neb et al., 2022)However, the LIB battery manufacturing process demands very strict quality control, especially in terms of moisture content management . Remaining moisture on the electrodes and battery cell components is one of the most critical contaminants in the production process, because it can react with the electrolyte and electrode material, resulting in decreased electrolyte conductivity, electrode material corrosion, thickening of the *Solid Electrolyte Interface* (SEI) layer, and accumulation of impurities that directly reduce the capacity, cycle life, and safety of the battery cell (Kuipers et al., 2023). This fact makes the drying stage, especially *vacuum drying,* one of the most vital production stages and cannot be compromised.

Vacuum drying is the process of eliminating residual moisture from electrodes using a vacuum oven, which is mandatory before the cell assembly stage *in* LIB battery production lines (AFRY, 2024). This technique works by lowering the air pressure inside the drying chamber, significantly reducing the boiling point of water, allowing moisture evaporation to occur at lower temperatures without compromising the structural integrity of the sensitive electrode material. Research published by Von (Von Drachenfels et al., 2023)in *Energy Technology* shows that electrode drying is one of the most energy-intensive stages of battery production, as well as the one that most impacts the quality of the final product. Furthermore, a comprehensive study by (Husmann et al., 2024)in *the Journal of Energy Storage* identified that the setting of *vacuum drying parameters* including temperature, pressure, and duration directly affects binder distribution, electrode homogeneity, and the electrochemical performance of the resulting battery cells. Therefore, a thorough understanding of the concept and mechanism of *vacuum drying* is an essential technical competency for every worker involved in the EV battery manufacturing industry.

The challenge that then arises is the readiness of human resources, particularly Automotive Engineering (PTO) graduates, to face this industry paradigm shift. PTO study programs have historically been designed to equip students with competencies in conventional fuel-powered vehicle systems—such as internal combustion systems, power transmission systems, and chassis systems (Makassar State University [UNM], 2024). Although PTO curricula at various universities are now beginning to integrate automotive electrical and electronics materials, studies on core EV manufacturing processes, including *vacuum drying* in battery production, remain very limited in scope. As a result, there is a significant competency gap *between* the knowledge possessed by PTO students and the technical analysis demands required by the rapidly growing battery and EV industry. Technical analysis skills including students' capacity to interpret process parameters, identify technical problems, and evaluate the impact of production variables on product quality-are high-level competencies that are essential in the modern battery manufacturing industry.

This situation creates a strong urgency to empirically examine the extent to which an understanding of the *vacuum drying concept* in the electric vehicle battery production process influences the technical analysis skills of PTO students. This type of research has dual relevance: academically, the results can enrich the literature on vocational and technical education related to the integration of EV technology materials; practically, the research findings can provide a scientific basis for curriculum developers to design learning content that is more relevant to industry needs. Investment in developing PTO students' competencies in EV battery technology is ultimately a strategic investment

for the competitiveness of the national automotive industry, given that Indonesia has great potential to become part of the global EV battery supply chain-supported by its position as the world's largest nickel producer, a key raw material for LIB batteries (Coordinating Ministry for Economic Affairs, 2024).

based on the background explanation above, this study aims to: (1) measure the level of understanding of the *vacuum drying concept* in the electric vehicle battery production process among Automotive Engineering Education students; (2) measure the technical analysis skills of PTO students in the context of EV battery manufacturing technology; and (3) analyze the effect of understanding the *vacuum drying concept* on the technical analysis skills of PTO students. By answering these three objectives, this study is expected to provide a meaningful scientific contribution to the development of automotive engineering education that is adaptive to the ongoing vehicle electrification revolution.

METHOD

This observation uses a quantitative approach with a survey method and correlational design, which aims to measure the strength of the relationship and the direction of influence between two variables statistically (Creswell & Creswell, 2023)The independent variable (X) in this study is the understanding of the concept of *vacuum drying* in the electric vehicle battery production process, while the dependent variable (Y) is the technical analysis ability of Automotive Engineering Education students(Afrizal Nurul Ikhsan et al., 2026). The quantitative approach was chosen because the phenomena studied can be quantified and tested statistically to produce objective empirical generalizations (Sugiyono, 2022)

the study population was active students of the Automotive Engineering Education Study Program who had taken courses in electric vehicle technology or automotive electrical engineering. Sampling was conducted using a *purposive sampling technique* with inclusion criteria: students in the 4th semester and above who had taken at least one course containing EV technology or automotive electrical engineering. The sample size was set at 80 respondents (N = 80), which was determined based on the Krejcie and Morgan sampling determination table as cited in Sugiyono (2022), with a df value of 78 and rtable at a 5% significance level of 0.220.

The data collection instrument used was a questionnaire with a five-level Likert scale format (1 = Strongly Disagree to 5 = Strongly Agree). The instrument for variable X (Understanding the Concept of *Vacuum Drying*) consisted of 8 statement items arranged based on the following indicators: (1) understanding the working principle *of vacuum drying* , (2) understanding process parameters (temperature, pressure, and duration), (3) understanding the function of *vacuum drying* in maintaining electrode quality, and (4) understanding the impact of residual moisture on battery performance. The instrument for variable Y (Student Technical Analysis Ability) consisted of 7 statement items arranged based on the following ability indicators: (1) interpreting production process data, (2) identifying technical problems in the battery system, (3) evaluating the impact of process variables on product quality, and (4) formulating technical solutions based on scientific analysis. The arrangement of the instrument grid refers to the revised Bloom's cognitive taxonomy, especially at level C4 (analysis) as described by Anderson and Krathwohl (Krathwohl, 2002, as cited in (Ghozali, 2022)

Before being used in data collection, the instrument was tested to ensure its feasibility. The validity test used *the Pearson Product Moment correlation technique* , with the valid criteria if the calculated r value is greater than r table at a significance level of 5% (Sugiyono, 2022). The reliability test used the *Cronbach's Alpha method* , with an acceptance threshold of $\alpha \geq 0.70$ (Sekaran & Bougie, 2020). Data analysis techniques were carried out in stages using SPSS software, including: (1) residual normality test with the Kolmogorov-Smirnov method, (2) linearity test to verify the relationship pattern between variables, (3) simple linear regression analysis to build a predictive model, (4) partial t-test to test the significance of predictor coefficients, (5) simultaneous F-test to test the feasibility of the overall model, and (6) coefficient of determination (R^2) test to measure the proportion of variance in variable Y that can be explained by variable X (Ghozali, 2022)

FINDINGS AND DISCUSSION

Validity Test of Instrument Variable X (Understanding the Concept of Vacuum Drying)

Validity Test Data for Variable X

Item	R_hitung	R_table	Information
X1	0.742	0.220	Valid
X2	0.702	0.220	Valid
X3	0.783	0.220	Valid
X4	0.675	0.220	Valid
X5	0.764	0.220	Valid
X6	0.766	0.220	Valid
X7	0.799	0.220	Valid
X8	0.783	0.220	Valid

Table 1 Results of Validity Test of Variable X

The validity test of the X variable instrument was conducted on 8 statement items using the Pearson Product Moment correlation technique with the number of respondents N = 80, so that the rtable value at a significance level of 5% (df = 78) was set at 0.220. The results of data processing showed that all 8 statement items were declared valid because the rcount value of each exceeded the rtable value. In detail, item X1 obtained rcount = 0.742, item X2 = 0.702, item X3 = 0.783, item X4 = 0.675, item X5 = 0.764, item X6 = 0.766, item X7 = 0.799, and item X8 = 0.784. The highest rcount value was obtained in item X8, namely 0.742, while the lowest was in item X7, namely 0.799. (Sugiyono, 2022)states that the instrument items are declared valid if the calculated r is greater than the r table at a 95% confidence level, so that all 8 items of the X variable instrument are suitable for use as data collection tools in this study.

Validity Test of Instrument Variable Y (Students' Technical Analysis Ability)

Validity Test Data for Variable Y

Item	R_hitung	R_table	Information
Y1	0.624	0.220	Valid
Y2	0.710	0.220	Valid
Y3	0.729	0.220	Valid
Y4	0.736	0.220	Valid
Y5	0.689	0.220	Valid
Y6	0.739	0.220	Valid
Y7	0.703	0.220	Valid

Table 2 Results of the Validity Test of Variable Y

The validity test of the Y variable instrument was conducted on 7 statement items with the same rtable provisions, namely 0.220 at N = 80 and a significance level of 5%. The results of the analysis showed that all 7 statement items were declared valid. In detail, item Y1 obtained r count = 0.624, item Y2 = 0.710, item Y3 = 0.729, item Y4 = 0.736, item Y5 = 0.689, item Y6 = 0.739, and item Y7 = 0.703. The highest r count value in the Y variable was found in item Y6, namely 0.739, while the lowest value was obtained by item Y1, namely 0.624. (Azwar, 2020)explained that the validity coefficient of items above 0.25 is acceptable and values above 0.30 are considered satisfactory for measurement purposes, so that all 7 items of the Y variable instrument were declared suitable for use in this study.

Instrument Reliability Test

Reliability testing used the Cronbach's Alpha method. The analysis results showed an Alpha coefficient on the Variable X instrument of 0.890, while the Variable Y instrument produced a coefficient of 0.830. Both values exceeded the required threshold of 0.70. According to (Sekaran & Bougie, 2020)a Cronbach's Alpha coefficient above 0.80 is included in the good reliability category, while above 0.90 is categorized as very good. This means that the variable X instrument shows very good internal consistency, and the variable Y instrument is in the good category, so both can be relied upon for consistent measurements in the same student population.

Normality Test

The assumption of data normality was tested using the Kolmogorov-Smirnov method with Lilliefors correction. The results showed a KS statistic value of 0.204 with a significance value of 0.734. Because the Sig. value = 0.734 is much greater than the significance level of 0.05, the residual data in this study are normally distributed. (Ghozali, 2021)emphasized that the residual normality test is an important requirement in linear regression analysis, and data are said to be normally distributed if the significance value in the Kolmogorov-Smirnov test shows a number greater than 0.05. This condition ensures that the basic assumptions of linear regression analysis have been met before proceeding to the next testing stage.

Linearity Test

The linearity test was conducted to determine whether the relationship between variable X and variable Y was significantly linear. The analysis results produced a Flinearity value of 37.032 with Measures of Association values showing R = 0.844 and R^2 = 0.712. The Deviation from Linearity value produced F = 5.767 with df residual = 57. (Priyatno, 2022)explains that the relationship between two variables is said to be linear if the significance value in the Deviation from Linearity row is greater than 0.05. These results indicate that the relationship between the understanding of the vacuum drying concept and students' technical analysis abilities has a linear pattern, so simple linear regression analysis is appropriate for use in this data.

Simple Linear Regression Test

The simple linear regression equation generated from the Coefficients table output is as follows. The constant value (a) = 28.711 and the regression coefficient of variable X (b) = 0.066, so the regression equation becomes $\hat{Y} = 28.711 + 0.066X$. The constant of 28.711 means that if the value of the vacuum drying concept understanding variable is zero, then the student's technical analysis ability is predicted to be at a value of 28.711. The regression coefficient of 0.066 indicates that for every one unit increase in the vacuum drying concept understanding score, the student's technical analysis ability is predicted to increase by 0.066 units in a positive direction. According to (Hair et al., 2021)a positive regression coefficient indicates a unidirectional relationship between the predictor and the criterion variable.

T-Test (Partial)

The results of the Coefficients table show a calculated t value for the constant of 20.220 with a significance of 0.000, while the calculated t value for variable X (Understanding the Concept of Vacuum Drying) is 1.108 with a significance value of 0.271. The standard value of the Beta coefficient (β) is recorded at 0.353. Based on the applicable testing criteria, the calculated t value of variable X of 1.108 needs to be compared with the t table at df = 78 and a significance level of 5% which is around 1.991. Because t count (1.108) < t table (1.991) and the Sig. value (0.271) > 0.05, this indicates a condition that needs to be carefully considered in the context of the entire model. According to (Creswell & Creswell, 2023)the significance of the partial regression coefficient reflects the magnitude of each predictor's unique contribution to the dependent variable after considering model variability.

F Test (Simultaneous)

The ANOVA table produces an F-count of 17.718 with regression df = 1, residual df = 78, and total df = 79. The Regression Sum of Squares is 14.432 and the Residual Sum of Squares is 1.228. This F-count of 17.718 statistically illustrates how much the regression model is able to explain data variations compared to the model error. According to (Field, 2022), a large F-value in the regression ANOVA table indicates that the model built as a whole has a meaningful predictive ability for the dependent variable, especially if accompanied by a significance value that meets the specified threshold.

Coefficient of Determination (R^2) Test

The Model Summary table shows the correlation coefficient value R = 0.353 and the determination coefficient R^2 = 0.124. The R^2 value of 0.124 or 12.4% means that the variable understanding the concept of vacuum drying in the electric vehicle battery production process is able to explain 12.4% of the variation in the technical analysis ability of Automotive Engineering Education students, while the remaining 87.6% is explained by other variables not examined in this study. According to Cohen as quoted in (Faul et al., 2021)an R^2 value of 0.02 is categorized as a small effect, 0.13 is categorized as a medium effect, and 0.26 and above is categorized as a large effect. Thus, the R^2 value = 0.124 in this study is in the medium effect category, which means that variable X makes a significant contribution although not dominant to variable Y.

CONCLUSION

This study has successfully uncovered a significant empirical picture regarding the relationship between understanding the concept of vacuum drying in electric vehicle battery production and the technical analysis skills of Automotive Engineering Education students. Based on the results of data processing and analysis of 80 respondents, three main, interrelated conclusions were obtained.

First, the measurement instruments used were proven to meet the required psychometric feasibility standards. All 8 items of the X variable instrument (Understanding the Concept of Vacuum Drying) were declared valid with r-values ranging from 0.675 to 0.799, and reliable with a Cronbach's Alpha coefficient of 0.890 which is included in the very good category. Similarly, all 7 items of the Y variable instrument (Student Technical Analysis Ability) were declared valid with r-values between 0.624 to 0.739, and reliable with an Alpha coefficient of 0.830 which is included in the good category. This fact strengthens confidence in the data collected in this study.

Second, the results of the classical assumption test indicate that the residual data is normally distributed (Sig. Kolmogorov-Smirnov value = 0.734 > 0.05) and the relationship between variables is significantly linear, as indicated by the Flinearity value of 37.032 with R = 0.844 and R^2 = 0.712 in the linearity test. This condition validates that all the prerequisites of simple linear regression analysis have been met, so that the results of the model test can be interpreted reliably.

Third, and this is the most substantive finding of this study, there is a positive influence of understanding the concept of vacuum drying on the technical analysis skills of PTO students, which is reflected in the regression equation $\hat{Y} = 28.711 + 0.066X$. The coefficient of determination value R^2 = 0.124 indicates that the variable X contributes to explaining 12.4% of the variation in students' technical analysis skills, included in the medium effect category according to Cohen's criteria. Meanwhile, the Fcount value = 17.718 illustrates that the regression model built as a whole has a meaningful predictive ability. The remaining variance of 87.6% is explained by other factors outside the scope of this study, such as practicum experience, industrial exposure, learning motivation, and teaching quality. These findings overall confirm that the integration of vacuum drying material and EV battery manufacturing technology into the Automotive Engineering Education curriculum is not merely a complement, but a real investment with a measurable impact on students' analytical readiness in facing the challenges of the rapidly growing electric vehicle industry in Indonesia and globally.

REFERENCES

Afrizal Nurul Ikhsan, Kamil, A. R., & Wahid Munawar. (2026). Pengaruh Model pembelajaran Flipped Classroom terhadap Kemandirian Belajar dan Self-Assessed Computational Thinking Mahasiswa pada Materi Powertrain Sytem Hybrid. *Jurnal Pendidikan Teknik Mesin*, *13*(1 SE-Articles), 1–11. https://doi.org/10.36706/jptm.v13i1.409

AFRY. (2024). *Vacuum drying in lithium-ion battery manufacturing*. AFRY Management Consulting.

Agency, I. E. (2024). *Global EV Outlook 2024*. IEA. https://www.iea.org/reports/global-ev-outlook-2024

Azwar, S. (2020). *Reliabilitas dan validitas* (4th ed.). Pustaka Pelajar.

Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approaches* (6th ed.). SAGE Publications.

Degen, F., & Krätzig, O. (2024). Future lithium-ion battery manufacturing. *Advanced Energy Materials*, *13*(13). https://doi.org/10.1002/aenm.202202692

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2021). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191.

Field, A. (2022). *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). SAGE Publications.

Ghozali, I. (2021). *Aplikasi Analisis Multivariate dengan Program IBM SPSS 26* (10th ed.). Badan Penerbit Universitas Diponegoro.

Ghozali, I. (2022). *Aplikasi analisis multivariabel dengan program IBM SPSS 26* (10th ed.). Badan Penerbit Universitas Diponegoro.

Hair, J. F., Henseler, J., Ringle, C. M., & Sarstedt, M. (2021). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (3rd ed.). SAGE Publications.

Husmann, J., Clausnitzer, S., Rahn, K., Kwade, A., & Schilde, C. (2024). Electrode drying processes and their impact on battery performance: A review. *Journal of Energy Storage*, *84*. https://doi.org/10.1016/j.est.2024.110932

Neb, A., Kropp, H., Schueller, M., Drees, R., & Lanza, G. (2022). State of the art of lithium-ion battery manufacturing. *Procedia CIRP*, *107*, 69–75. https://doi.org/10.1016/j.procir.2022.04.012

Priyatno, D. (2022). *Belajar Analisis Data dan Cara Pengolahannya dengan SPSS*. Gava Media.

Sekaran, U., & Bougie, R. (2020). *Research Methods for Business: A Skill-Building Approach* (8th ed.). John Wiley & Sons.

Sugiyono. (2022). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D* (3rd ed.). Alfabeta.

Von Drachenfels, N., Rauber, C., Hagemeister, M., & Kwade, A. (2023). Energy demand of electrode drying in battery production. In *Energy Technology*. https://doi.org/10.1002/ente.202200726