International Journal of Ethnoscience and Technology in Education (IJETE)
https://e-journal.undikma.ac.id/index.php/ijete/index

September 2026 Vol. 3, No. 2
pp. 298-323

Integrating Local Resources and Technology in Forest Products Education: A Retrospective Classroom-Based Study of University Students' Academic Performance

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Article Info

Article History
Received: July 2026
Revised: August 2026
Published: September 2026

Keywords
Forest products education;
Local resources;
Academic performance;
Project-oriented learning;
Authentic assessment

10.33394/ijete.v3i2.22594

Abstract

This study examined university students' academic performance in a Forest Products Technology course that integrated local resources with conceptual learning, practicum activities, and product-oriented projects. A quantitative retrospective classroom-based design was employed using regular course assessment records from 46 enrolled students in two course sections; 39 students with complete records were included in inferential analyses. Academic performance was represented by Practicum and Attendance Score (PAS), Project Score (PS), Mid-Semester Examination (MSE), Final Examination (FE), and Final Course Score (FCS). Mean scores ranged from 86.38 to 88.33, with an FCS mean of 87.18. The Friedman test showed significant differences across assessment formats, $\chi^2 = 20.250$, $p < .001$, Kendall's $W = .173$. After Holm correction, significant differences remained for PS–MSE ($p = .009$) and PAS–FE ($p = .049$). Between classes, only PAS differed significantly ($p = .019$). All assessment components were positively correlated, with the strongest association between PS and FE ($\rho = .752$). These findings indicate consistently high performance and alignment between applied and conceptual achievement across regular classroom assessment contexts, while supporting multidimensional assessment in Forest Products Education settings.

How to Cite: Sadir, M., Hendriko, A., Asidah, N., Wibisono, H. S., & Darsono, B. S. (2026). Integrating Local Resources and Technology in Forest Products Education: A Retrospective Classroom-Based Study of University Students' Academic Performance. *International Journal of Ethnoscience and Technology in Education*, *3*(2), 298–323. https://doi.org/10.33394/ijete.v3i2.22594

INTRODUCTION

The shift toward more sustainable resource utilization has expanded the role of the forestry sector from merely supplying raw materials to becoming an important component of the circular bioeconomy. Wood, lignocellulosic biomass, forest residues, agricultural waste, and other locally available biological materials can be developed into energy sources, composite materials, panel products, and value-added industrial inputs. Within the circular bioeconomy framework, resource utilization is directed not only toward increasing economic value but also toward improving material efficiency, utilizing residues, reducing waste, and extending resource-use cycles (Ali & Russell, 2025; Miassi & Dossa, 2024; Venkatesh, 2022). However, the use of local resources does not automatically ensure sustainability. Its benefits remain dependent on raw material availability, processing methods, energy consumption, technological efficiency, environmental impacts, and feasibility for broader application.

One important form of local resource utilization is the conversion of biomass into solid fuels through densification. Biomass with low density and heterogeneous characteristics can be processed into briquettes or pellets to improve storage, transportation, and energy-use characteristics. The quality of densified products is influenced by feedstock properties, moisture content, particle size, pretreatment, compaction pressure, and production conditions (Eling et al., 2024; Kpalo et al., 2020; Silva et al., 2022). Biomass utilization for energy must also be examined critically because thermal performance, ash content, emissions, and combustion efficiency may differ substantially across feedstock types. Therefore, biomass technology education needs to connect material characteristics with energy-conversion principles and product quality rather than merely presenting biomass as an alternative fuel.

The potential of local resources also extends to the development of other forest-based materials and products. Wood residues, agricultural waste, and non-wood lignocellulosic biomass can be used as alternative raw materials in particleboard and composite panel production, particularly where conventional wood resources are limited or where residue utilization forms part of a broader resource-efficiency strategy (Lee et al., 2022; Neitzel et al., 2022; Nguyen et al., 2023). Natural fibers derived from various plant sources have also been widely investigated as reinforcements in composite materials because of their renewable nature and their potential to reduce dependence on synthetic materials (Nagaraja et al., 2024; Siouta et al., 2024). In wood preservation, the development of bio-based preservatives reflects ongoing efforts to identify material-protection approaches that are more environmentally compatible than certain conventional chemical treatments associated with higher toxicological risks (Barbero-López et al., 2021; Calovi et al., 2024). These technological areas demonstrate that forest products technology is closely connected with energy, materials, manufacturing, environmental concerns, and industrial needs.

Such technological developments have direct implications for forestry education. Forestry education is no longer sufficient if it focuses only on material identification, basic wood properties, or isolated processing procedures. Students need to understand the relationships among resource availability, material characteristics, technological processes, product quality, sustainability, and user or industrial needs. Reviews of forestry curricula indicate that changes in the forestry sector require increasingly multidimensional competencies that extend beyond conventional technical knowledge (Durusoy & Bahçeci Öztürk, 2022; De'Arman & York, 2021). Forestry education must also prepare graduates to respond to sustainability challenges, industrial transformation, bioenergy utilization, and changing professional demands (Kelly & Brown, 2019; Sunarta et al., 2026). Accordingly, forest products technology education should be designed so that students not only understand concepts but are also able to connect them with real resources and practical problems.

Using resources available in students' immediate environments can provide a learning context that is more closely connected with their lived realities. In higher education, local contexts can serve as sources of problems, objects of observation, experimental materials, and foundations for understanding the relationship between scientific concepts and technological applications. Matthiesen et al. (2025) showed that resource-use and sustainability issues closely connected with students' contexts can be integrated into higher education to help students connect scientific knowledge with real-world problems. In forest products technology education, a similar orientation can be implemented by using biomass, wood residues, fibrous plants, and other local materials as contexts for studying processing methods, product development, and industrial utilization. This approach can be understood as local-resource-based technology learning, in which local resources provide a contextual basis for understanding relevant scientific principles and technological processes.

Local-resource-based technology learning shares important characteristics with experiential learning and project-based learning because students have opportunities to engage directly with materials, processes, problems, and products. Experiential learning emphasizes the role of direct experience in knowledge construction, whereas project-based learning provides opportunities for students to integrate concepts and skills through the completion of tasks or products situated in meaningful contexts (Kolb, 1984; Tembrevilla et al., 2024). Research in higher education indicates that project-based learning can generate multiple types of outcomes, including knowledge, skills, learning experiences, problem-solving abilities, and observable products or artifacts (Guo et al., 2020; Lavado-Anguera et al., 2024). In engineering education, project-based activities and direct experiences are also considered relevant because they allow students to connect academic knowledge with conditions resembling technological practice (Jamison et al., 2022).

Nevertheless, the presence of project activities cannot automatically be taken as evidence that such learning causes higher academic achievement. Meta-analytic evidence suggests that project-based learning can generally provide benefits for student learning, but the magnitude of these effects varies according to disciplinary field, duration, participant characteristics, project design, and implementation quality (Chen & Yang, 2019; Zhang & Ma, 2023). The implementation of project-based learning may also differ substantially across programs and fields, meaning that outcomes obtained in one context cannot necessarily be generalized to another (Chen et al., 2021; Guo et al., 2020). Therefore, research on forest products technology education should examine students' actual performance without automatically attributing that performance solely to the presence of project activities.

Student achievement in technology-oriented learning should also not be represented through only one type of assessment. Practical activities, project completion, and written examinations may reflect different dimensions of performance. In higher education, authentic assessment emphasizes the use of tasks connected with real-world practices, problems, or professional demands, allowing student achievement to be evaluated beyond the reproduction of conceptual knowledge (Sokhanvar et al., 2021; Villarroel et al., 2018). However, authentic assessment does not imply that written examinations lose their relevance. A combination of practical assessment, project work, and conceptual assessment can provide a broader representation of students' academic performance because each assessment format serves different purposes and has distinct characteristics (Fischer et al., 2024; Zhan et al., 2025). Examining the relationships among these forms of performance is also important for determining whether achievement in applied activities tends to align with conceptual achievement.

Existing research has provided substantial evidence on experiential learning, project-based learning, active learning, and authentic assessment in higher education, particularly in science and engineering disciplines (Freeman et al., 2014; Lavado-Anguera et al., 2024; Tembrevilla et al., 2024). In contrast, research in forest products technology has largely focused on material characteristics, product development, biomass technology, composite materials, panel products, and preservation technologies (Barbero-López et al., 2021; Eling et al., 2024; Lee et al., 2022; Neitzel et al., 2022). Meanwhile, studies in forestry education have tended to emphasize curriculum, sustainability competencies, professional readiness, or broader instructional innovation (Durusoy & Bahçeci Öztürk, 2022; Matthiesen et al., 2025). The intersection of these three areas, namely forest products technology, local resource utilization, and analysis of students' academic performance in regular classroom settings, remains comparatively underexplored.

This gap is important because forest products technology education has distinctive characteristics. Students engage with subject matter that requires not only conceptual understanding but also the ability to recognize material properties, select appropriate processing methods, produce products, and evaluate their potential applications. Local resources can provide relevant materials for learning, while practical and project activities create opportunities for students to develop applied experience. However, there remains limited classroom-based evidence showing how students' academic performance is distributed across different assessment formats, whether such performance is relatively consistent across course sections, and the extent to which performance in applied activities is associated with achievement in conceptual examinations. Examining these relationships can provide an empirical basis for evaluating instructional design and identifying aspects of forest products technology education that may require further strengthening.

This study was conducted within a Forest Products Technology course that integrated local resources with technology learning through content and activities related to biomass, lignocellulosic materials, forest-based products, preservation technologies, and industrial utilization. The learning process combined conceptual understanding with practical activities and product-oriented projects. This context provides an opportunity to examine students' academic performance using data generated from actual course participation while also investigating patterns of association between applied and conceptual performance. Such an approach can complement experimental research by providing evidence derived from regular higher education learning conditions.

Research Objectives and Research Questions

This study aims to analyze students' academic performance in a Forest Products Technology course that integrates local resources and technology through conceptual learning, practical activities, and projects. The analysis focuses on students' achievement profiles, differences in performance across assessment formats, variation between two course sections that followed the same instructional framework, and relationships between applied performance and written assessment performance.

Based on these objectives, the study addresses the following research questions:

1. What is the profile of students' academic performance after participating in Forest Products Technology learning that integrates local resources and technology?
2. Are there significant differences in students' performance across assessment formats and between the two course sections that followed the same instructional framework?
3. What relationships exist between students' performance in practical and project activities and their performance in written assessments?

Research Novelty

Previous research relevant to this study has generally developed along three relatively separate lines. First, studies in forest products technology have predominantly concentrated on the technical performance of materials and products, such as biomass densification, briquette production, lignocellulosic composites, particleboard, and wood preservation, with emphasis on feedstock characteristics, processing parameters, product quality, and environmental performance (Barbero-López et al., 2021; Eling et al., 2024; Lee et al., 2022; Neitzel et al., 2022). Second, studies in forestry education have more frequently examined curriculum relevance, sustainability competencies, professional preparation, and the integration of contemporary environmental issues into higher education (Durusoy & Bahçeci Öztürk, 2022; Matthiesen et al., 2025). Third, research on experiential and project-based learning has largely been conducted in broader science, technology, and engineering education, where the primary concerns have included the effectiveness of instructional interventions, student engagement, competency development, and learning outcomes associated with project-oriented activities (Guo et al., 2020; Lavado-Anguera et al., 2024; Tembrevilla et al., 2024). Although these strands provide important foundations, relatively little attention has been given to how local forest-related resources, technological learning activities, and students' actual academic performance interact within a regular Forest Products Technology course.

In contrast to these earlier studies, the present research brings these previously separated areas into a single analytical context. Local resources are not treated merely as examples, raw materials, or objects of technical investigation, but as instructional contexts through which students engage with material characteristics, technological processing, product development, and potential applications in energy, materials, and industry. The study therefore shifts the focus from examining the technical properties of forest-based products alone toward examining how those technological contexts function within higher education learning. It also differs from studies that evaluate a single instructional intervention because the present study investigates learning as it occurred under normal course conditions rather than through an experimentally imposed treatment.

A further novelty lies in the use of authentic classroom performance data to examine students' achievement across multiple forms of assessment. Previous studies of project-based and experiential learning have frequently relied on intervention comparisons, questionnaires, perceptions, self-reported engagement, or aggregate measures of learning outcomes (Guo et al., 2020; Tembrevilla et al., 2024). The present study instead analyzes academic performance generated through regular course participation and examines whether students' performance in practical and project-oriented activities is associated with their performance in written conceptual assessments. This provides a more differentiated view of learning than a single final grade or a single outcome measure. Accordingly, the contribution of this study lies in combining local-resource-based technology learning, authentic course assessment data, and multidimensional analysis of applied and conceptual performance within the comparatively underexplored field of Forest Products Education. This distinction provides an empirical basis for understanding how students perform across different assessment contexts and for informing the design of future instruction and assessment in Forest Products Technology.

METHOD

Research Design

This study employed a quantitative retrospective classroom-based design to analyze students' academic performance generated during regular course instruction. The data were derived from students' assessment records after completing one semester of the Forest Products Technology course. The study did not involve additional experimental treatment, participant randomization, a control group, or pretest-posttest measurement. Accordingly, the analysis focused on describing students' achievement profiles, comparing performance across assessment formats, comparing performance between two course sections that followed the same instructional framework, and examining relationships between applied performance and written examination performance.

The course instructor also served as the instructor-researcher. All instructional and assessment activities were conducted as part of the regular academic process, while the research analysis was performed retrospectively after the course and academic grading processes had been completed. Given these characteristics, the study was not designed to establish causal relationships between an instructional intervention and student achievement, but rather to identify patterns of academic performance within an authentic course context.

Research Context and Participants

The study was conducted in the Forest Products Technology course offered by the Forestry Study Program, Mandalika University of Education, Indonesia, over one semester. The course carried 2 credits, with 2 × 50 minutes of regular face-to-face instruction per meeting. Instruction was delivered to two course sections that followed the same content structure, learning activities, projects, and assessment system.

A total of 46 students were enrolled, comprising 23 students in Class A and 23 students in Class B. Students in both classes were 19–20 years old. In terms of gender composition, approximately 65% of students in Class A were male and 35% were female, whereas approximately 60% of students in Class B were male and 40% were female. Thus, the two classes had a relatively homogeneous age range and were both predominantly male.

All enrolled students were included in the description of the enrolled cohort, assessment completion, and administrative course grades. For inferential statistical analysis, only students with complete data for all assessment components were included. Based on the academic records, 39 students had complete assessment records, comprising 18 students from Class A and 21 students from Class B. The remaining seven students had one or more incomplete assessment records.

Both classes were naturally occurring course sections established through regular academic administration and were not formed specifically for research purposes. Therefore, comparisons between Class A and Class B were not treated as comparisons between experimental and control groups.

Instructional Context and Implementation

The Forest Products Technology course positioned local resources as contexts for learning the principles, processes, and applications of forest products technology. The course content included the potential of local resources as biomass feedstocks, conversion of biomass into charcoal briquettes, the use of fibrous plants in cement-based composite materials, preservation technologies for local materials, plywood production, particleboard production, and the utilization of local resources for various industrial purposes.

Instruction was not limited to conceptual teaching but also included practicum activities and project-based activities. The main student projects involved biomass briquette production, plywood production, and the preparation of preservation materials. These activities provided opportunities for students to connect resource characteristics with processing procedures, technological principles, product characteristics, and potential applications. The general instructional structure is presented in Table 1.

Table 1. Instructional Structure of the Forest Products Technology Course

Learning domain	Main content	Learning activities	Evidence of achievement
Biomass technology	Local biomass potential and charcoal briquette production	Conceptual learning, practicum, and biomass briquette project	Practicum performance, project performance, and conceptual understanding

Learning domain	Main content	Learning activities	Evidence of achievement
Wood-based panel technology	Plywood and particleboard	Conceptual learning and plywood production	Product and project performance
Composite materials	Fibrous plants for cement-based composites	Conceptual learning and material analysis	Understanding of material characteristics and utilization
Preservation technology	Preservation of materials using local resources	Practicum and preparation of preservation materials	Practicum and project performance
Industrial utilization	Applications of local resources for industrial purposes	Discussion, assignments, and conceptual learning	Conceptual understanding and application ability

This instructional context was positioned as local-resource-based technology learning because local resources were used to connect material characteristics, scientific principles, technological processes, product development, and potential applications. The term was used to describe the instructional context rather than to denote an experimental learning model whose effectiveness was being tested.

Data Sources and Assessment System

The research data were obtained from official course assessment records generated during the semester. Students' academic performance was represented by four assessment components: Practicum and Attendance Score (PAS), Project Score (PS), Mid-Semester Examination (MSE), and Final Examination (FE).

PAS contributed 20% to the Final Course Score (FCS). This component included student participation in practicum activities and class attendance. Because it combined both aspects, PAS was not interpreted as a pure measure of practical skill. PS contributed 30% and represented students' performance in completing assignments and product-oriented projects related to forest products technology. MSE contributed 20% and consisted of five essay questions, while FE contributed 30% and also consisted of five essay questions. MSE and FE were used to assess students' conceptual understanding of the course content.

All assessment components were scored on a 0–100 scale. FCS was calculated using the following equation:

$$FCS = 0.20(PAS) + 0.30(PS) + 0.20(MSE) + 0.30(FE)$$

where FCS represents the Final Course Score, PAS the Practicum and Attendance Score, PS the Project Score, MSE the Mid-Semester Examination, and FE the Final Examination.

Table 2. Assessment Components and Weighting

Assessment component	Description	Weight
Practicum and Attendance Score (PAS)	Participation in practicum activities and class attendance	20%

Assessment component	Description	Weight
Project Score (PS)	Completion of forest products technology assignments and projects	30%
Mid-Semester Examination (MSE)	Five essay questions	20%
Final Examination (FE)	Five essay questions	30%
Final Course Score (FCS)	Weighted combination of all assessment components	100%

Assessment Characteristics

The assessment instruments were part of the regular course evaluation system and were not specifically developed for research purposes. Each assessment format was intended to represent a different aspect of student performance. PAS reflected students' participation in practicum activities and attendance, while PS represented their ability to apply course content through assignments and product-oriented projects. MSE and FE were essay-based examinations used to assess students' ability to explain, connect, and apply the concepts covered in the course.

The four assessment components were not treated as items of a single psychometric instrument because they differed in format, function, and performance domain. Therefore, internal consistency measures such as Cronbach's alpha were not calculated across PAS, PS, MSE, and FE. The analysis instead focused on students' achievement within each assessment component and on patterns of association among the components.

Because these instruments were regular course assessments, the resulting scores were treated as indicators of academic performance within the specific course context and were not positioned as standardized measurements of psychological constructs.

Inclusion Criteria and Handling of Incomplete Data

The analysis was conducted at two levels. First, all 46 enrolled students were used to describe the number of participants, assessment completion, and the distribution of administrative course grades. Second, inferential analyses used complete-case analysis.

Students were classified as complete cases when they had recorded scores for all four components: PAS, PS, MSE, and FE. Based on this criterion, 39 students were eligible for inferential analysis. Seven students had incomplete assessment records and were excluded from inferential analyses.

A score of 0 resulting from a student not completing a particular assessment component was not interpreted as evidence of zero academic competence in the assessed domain. For research analysis, such cases were categorized as incomplete assessment records. This approach was used to avoid distortions in score distributions, between-group comparisons, and estimates of relationships among variables that could arise if non-participation in an assessment were treated as actual academic performance.

Data Analysis

Data analysis was conducted in accordance with the research objectives and research questions. Descriptive statistics were used to characterize students' academic performance on

PAS, PS, MSE, FE, and FCS. The statistics calculated included the number of cases, mean, standard deviation (SD), median, minimum, maximum, and interquartile range (IQR) where relevant. Letter grades and assessment completion were reported using frequencies and percentages.

Before inferential analysis, score distributions were examined using the Shapiro-Wilk test, while equality of variances between Class A and Class B was assessed using Levene's test. Because the assumption checks indicated that most score distributions did not satisfy normality and several variables showed unequal variances, the primary inferential analyses employed nonparametric procedures.

Differences in students' performance across PAS, PS, MSE, and FE were analyzed using the Friedman test because the four scores were obtained from the same participants. Kendall's W was reported as the effect size for the overall difference. When the Friedman test indicated a statistically significant difference, pairwise comparisons were conducted using Wilcoxon signed-rank tests. Holm correction was applied to control the family-wise Type I error rate arising from multiple comparisons, while paired rank-biserial correlation was used to estimate the effect size for each pairwise comparison.

Comparisons of academic performance between Class A and Class B were conducted using the Mann-Whitney U test. Separate analyses were performed for PAS, PS, MSE, FE, and FCS. Holm correction was used to adjust p values for multiple comparisons, while rank-biserial correlation was reported as the effect size. For categorical variables with small cell frequencies, such as assessment completion or selected grade categories, Fisher's exact test was used.

Relationships among the components of academic performance were examined using Spearman's rank-order correlation. The primary correlation matrix included PAS, PS, MSE, and FE. FCS was excluded from the main correlation matrix because it was mathematically derived from the four component scores. Including FCS alongside its component variables could introduce mathematical coupling, causing the observed correlations to be partly determined by the grading formula rather than solely by empirical relationships among different forms of performance.

All statistical tests were two-tailed with a significance level of $\alpha = .05$. Interpretation of the results was not based solely on statistical significance but also considered effect sizes, score distributions, the direction of relationships, and the characteristics of the study design.

Ethical Considerations

The study used academic performance records generated as part of regular course activities. The research analysis was conducted only after the instructional process and academic grading had been completed, ensuring that the use of the data for research purposes did not affect students' FCS, letter grades, or other academic decisions.

All directly identifying information, including student names and identification numbers, was excluded from the analysis and reporting process. The data were analyzed in anonymized form, and the findings were reported in aggregate to protect participant confidentiality. The dual role of the course instructor as instructor-researcher was also considered by ensuring that the analysis did not involve grade modification, additional research-specific treatment, or academic consequences for students.

Because student academic records were used for scientific publication, their use should comply with the ethical requirements of Mandalika University of Education. Information concerning ethical approval, including the name of the ethics committee and approval number, should be included in the submitted manuscript if formal approval is required and has been obtained.

RESULTS AND DISCUSSION

Results

Before analyzing students' academic performance, the completeness of all assessment components was examined. A total of 46 students were enrolled in the Forest Products Technology course, comprising 23 students in Class A and 23 students in Class B. The overall assessment completion and administrative grade distribution are presented in Table 3.

Table 3. Assessment Completion and Administrative Grade Distribution

Indicator	n	%
Total enrolled students	46	100.0
Complete assessment records	39	84.8
Incomplete assessment records	7	15.2
Grade A	26	56.5
Grade A−	13	28.3
Grade C+	3	6.5
Grade C	1	2.2
Grade E	1	2.2
T status	2	4.3

As shown in Table 3, 39 students (84.8%) completed all assessment components, whereas seven students (15.2%) had incomplete assessment records. Among the seven incomplete cases, four students did not complete the Final Examination (FE), two had no recorded scores across the assessment components, and one student had only a Practicum and Attendance Score (PAS). These cases were retained for describing the enrolled cohort and administrative grade distribution but were excluded from subsequent inferential analyses.

The grade distribution showed that 26 students (56.5%) received an A and 13 students (28.3%) received an A−. All grades below A− occurred among students with incomplete assessment records. Among the 39 complete cases, 26 students (66.7%) received an A and 13 students (33.3%) received an A−.

To examine whether assessment completion and the distribution of A and A− grades differed between Class A and Class B, Fisher's exact tests were conducted. The results are presented in Table 4.

Table 4. Fisher's Exact Tests for Assessment Completion and Grade Distribution

Comparison	Class A, n (%)	Class B, n (%)	Odds ratio	Fisher's exact p	Result
Complete assessment records	18 (78.3%)	21 (91.3%)	0.343	.414	Not significant
Incomplete assessment records	5 (21.7%)	2 (8.7%)			
Grade A among complete cases	10 (55.6%)	16 (76.2%)	0.391	.196	Not significant
Grade A− among complete cases	8 (44.4%)	5 (23.8%)			

Note. One odds ratio and one p value apply to each 2 × 2 contingency table.

The assessment completion rate was descriptively higher in Class B (91.3%) than in Class A (78.3%), but the difference was not statistically significant, p = .414. Similarly, the proportion of students receiving an A among the complete cases was higher in Class B (76.2%) than in Class A (55.6%), although the A/A− distribution did not differ significantly between the two classes, p = .196.

Before conducting comparative and correlational analyses, the distributions of PAS, Project Score (PS), Mid-Semester Examination (MSE), FE, and Final Course Score (FCS) were examined using the Shapiro-Wilk test. Normality was assessed separately for Class A and Class B because one of the analyses compared the two course sections. Equality of variance between the classes was subsequently examined using Levene's test. The results are presented in Table 5.

Table 5. Results of Shapiro-Wilk and Levene's Tests

Variable	Class A W	p	Class B W	p	Levene F	p
PAS	.757	<.001	.759	<.001	11.903	.001
PS	.830	.004	.899	.033	0.115	.736
MSE	.909	.084	.753	<.001	3.504	.069
FE	.756	<.001	.707	<.001	21.321	<.001
FCS	.760	<.001	.876	.013	6.756	.013

Note. PAS = Practicum and Attendance Score; PS = Project Score; MSE = Mid-Semester Examination; FE = Final Examination; FCS = Final Course Score

In Class A, PAS, PS, FE, and FCS showed significant departures from normality, whereas MSE did not significantly deviate from a normal distribution, W = .909, p = .084. In Class B, all variables showed significant departures from normality, with p values below .05.

Levene's test indicated that the assumption of equal variances was met for PS, F = 0.115, $p = .736$, and MSE, $F = 3.504$, $p = .069$. In contrast, PAS, FE, and FCS showed significant variance differences between the two classes. Considering these distributional characteristics, along with the restricted score ranges and the presence of tied scores, nonparametric procedures were used in the subsequent inferential analyses.

Academic performance was analyzed for the 39 students with complete assessment records. Descriptive statistics were used to summarize the central tendency, variability, and score ranges for PAS, PS, MSE, FE, and FCS. The results are presented in Table 6.

Table 6. Descriptive Statistics of Students' Academic Performance

Assessment component	n	Mean	SD	Median	IQR	Minimum	Maximum
PAS	39	86.54	2.73	86.00	5.00	80	90
PS	39	86.38	2.24	87.00	3.00	82	90
MSE	39	87.31	1.78	88.00	3.00	84	90
FE	39	88.33	5.37	91.00	6.00	78	93
FCS	39	87.18	2.87	88.00	4.00	82	91

As shown in Table 6, students demonstrated relatively high academic performance across all assessment components. Mean scores ranged from 86.38 to 88.33. FE had the highest mean score at 88.33, whereas PS had the lowest mean at 86.38. The difference between the highest and lowest component means was less than two points. The degree of score variability differed more substantially across the assessment components. FE showed the greatest variability, with SD = 5.37 and scores ranging from 78 to 93. In contrast, MSE had the most concentrated distribution, with SD = 1.78 and scores ranging from 84 to 90. FCS had a mean of 87.18, SD = 2.87, and a median of 88.00. Thus, although students' aggregate performance was generally high, the degree of variation differed across assessment formats.

Differences in students' performance across PAS, PS, MSE, and FE were examined using the Friedman test because all four scores were obtained from the same students. The test revealed a statistically significant overall difference across assessment formats, $\chi^2 = 20.250$, $p < .001$, with Kendall's $W = .173$. The mean ranks were 2.15 for PAS, 2.08 for PS, 2.54 for MSE, and 3.23 for FE.

Because the Friedman test was statistically significant, Wilcoxon signed-rank tests were conducted for the six possible pairwise comparisons. Holm correction was applied to control the family-wise Type I error rate. The results are presented in Table 7.

Table 7. Pairwise Comparisons Across Assessment Formats

Comparison	Wilcoxon statistic	Raw *p*	Holm-adj. *p*	Paired rank-biserial corr.
PAS vs. PS	224.0	.633	.633	−.097
PAS vs. MSE	243.0	.038	.113	.377
PAS vs. FE	205.5	.010	.049	.473
PS vs. MSE	126.0	.002	.009	.600
PS vs. FE	220.5	.017	.069	.435
MSE vs. FE	272.0	.228	.456	.226

Note. Positive paired rank-biserial correlation values indicate a tendency toward higher scores on the second assessment component listed in each comparison

After Holm correction, two pairwise differences remained statistically significant. MSE scores were higher than PS scores, adjusted $p = .009$, with a paired rank-biserial correlation of .600. FE scores were also higher than PAS scores, adjusted $p = .049$, with an effect size of .473.

The PAS–MSE and PS–FE comparisons were statistically significant before correction but no longer remained significant after Holm adjustment. No significant differences were observed between PAS and PS or between MSE and FE. These findings indicate that the overall differences across assessment formats were concentrated primarily in the PS–MSE and PAS–FE comparisons.

Academic performance between Class A and Class B was compared using the Mann-Whitney U test. Separate analyses were conducted for PAS, PS, MSE, FE, and FCS. Holm correction was applied across the five comparisons, and rank-biserial correlation was reported as the effect size. The results are presented in Table 8.

Table 8. Comparison of Academic Performance Between Class A and Class B

Component	Class A Median (IQR), n = 18	Class B Median (IQR), n = 21	U	Raw p	Holm-adj. p	Rank-biserial corr.
PAS	86.0 (2.0)	90.0 (5.0)	89.0	.004	.019	.529
PS	87.0 (3.0)	87.0 (3.0)	127.0	.073	.220	.328
MSE	87.0 (3.0)	88.0 (1.0)	132.0	.102	.220	.302
FE	91.0 (12.75)	91.0 (1.0)	151.5	.285	.285	.198
FCS	88.0 (6.0)	89.0 (3.0)	111.5	.027	.108	.410

Note. Positive rank-biserial correlation values indicate a tendency toward higher score ranks in Class B.

The clearest between-class difference was observed for PAS. The median PAS was 86.0 in Class A and 90.0 in Class B. The Mann-Whitney U test showed a statistically significant difference, $U = 89.0$, raw $p = .004$. This difference remained significant after Holm correction, adjusted $p = .019$, with a rank-biserial correlation of .529. FCS also differed at the unadjusted level, $U = 111.5$, $p = .027$, but this difference was no longer statistically significant after Holm correction, adjusted $p = .108$. PS, MSE, and FE also showed no significant differences between the two classes after adjustment. Therefore, among the five performance indicators examined, only PAS showed a statistically significant between-class difference after correction for multiple comparisons. This pattern was consistent with the Fisher's exact test results in Table 4, which showed no significant difference in the distribution of A and A− grades between the two classes. In general, the two course sections demonstrated relatively comparable patterns of academic performance, particularly in project performance and written examinations.

Relationships among PAS, PS, MSE, and FE were examined using Spearman's rank-order correlation. FCS was not included in the correlation matrix because it was mathematically derived from the four assessment components. Holm correction was applied to the six tested correlations. The results are presented in Table 9.

Table 9. Spearman Correlations Among Academic Performance Components

Variable pair	Spearman ρ	Raw p	Holm-adj. p
PAS and PS	.682	<.001	<.001
PAS and MSE	.549	<.001	<.001
PAS and FE	.643	<.001	<.001
PS and MSE	.631	<.001	<.001

Variable pair	Spearman ρ	Raw p	Holm-adj. p
PS and FE	.752	<.001	<.001
MSE and FE	.712	<.001	<.001

All correlations were positive and remained statistically significant after Holm correction. The correlation coefficients ranged from ρ = .549 to ρ = .752. The strongest association was observed between PS and FE, ρ = .752, followed by the relationship between MSE and FE, ρ = .712, and between PAS and PS, ρ = .682.

PS was positively associated with both written examinations, with ρ = .631 for MSE and ρ = .752 for FE. PAS was also positively associated with MSE, ρ = .549, and FE, ρ = .643. These findings indicate a consistent pattern between students' achievement in applied activities and their conceptual performance, with the strongest relationship observed between project performance and the Final Examination.

Discussion

Academic Performance in Local-Resource-Based Technology Learning

The findings showed that students who completed all assessment components demonstrated relatively high academic performance across the different assessment formats. Mean scores for PAS, PS, MSE, FE, and FCS ranged from 86.38 to 88.33, and all complete cases received either an A or A−. This pattern indicates that students' achievement was not concentrated in a single assessment format but was evident across practicum and attendance, project work, and written examinations. This is relevant to the instructional context of Forest Products Technology, in which students were not only expected to understand conceptual content but were also engaged with materials, processing procedures, and product development using locally available resources.

This pattern can be interpreted within the broader perspective of experiential learning, which emphasizes the role of direct experience in connecting academic knowledge with its application. Tembrevilla et al. (2024) reported that experiential learning in engineering education may involve laboratories, projects, design activities, and authentic experiences that allow students to apply knowledge in practical settings. Similarly, Jamison et al. (2022) showed that direct learning experiences can provide opportunities for students to integrate conceptual understanding with practical application. In the present course, the use of local biomass, lignocellulosic materials, wood-based products, and preservation materials created concrete contexts through which students could connect technological principles with materials and production processes.

The relatively high scores, however, should not be interpreted as evidence that a particular instructional model was effective in a causal sense. The present study did not compare local-resource-based technology learning with an alternative instructional approach. The findings are therefore more appropriately interpreted as a profile of academic performance observed under regular instructional conditions. This position differs from experimental or quasi-experimental studies of project-based learning that estimate treatment effects by comparing intervention and comparison groups. Meta-analytic evidence indicates that project-based learning may support academic achievement, but the magnitude of its effects varies according to discipline, duration, student characteristics, project design, and implementation quality (Chen & Yang, 2019; Zhang & Ma, 2023). The contribution of the present study is therefore not an estimate of instructional effectiveness, but evidence derived from authentic classroom performance in a Forest Products Technology course.

The pattern of relatively strong performance across different assessments also supports the use of multiple assessment formats in technology-oriented higher education. Academic performance in such a course cannot be represented adequately by a written examination alone because students are also expected to participate in practical activities and complete product-oriented tasks. Sokhanvar et al. (2021) showed that authentic assessment can provide evidence of achievement that is more closely connected with real-world activities, while Villarroel et al. (2018) emphasized the importance of alignment among assessment tasks, intended competencies, and contexts of knowledge use. In this study, the combination of PAS, PS, MSE, and FE therefore provided a broader representation of students' performance than would have been obtained from FCS alone.

Differences in Performance Across Assessment Formats

Although mean scores across the assessment components differed by less than two points, the Friedman test indicated a statistically significant overall difference across PAS, PS, MSE, and FE. Kendall's W of .173, however, suggested that the magnitude of the overall difference was relatively limited. This pattern indicates that students did not perform identically across all assessment formats, while at the same time the differences were not sufficiently large to suggest a sharp separation between applied and conceptual performance.

The post-hoc results showed that MSE scores were significantly higher than PS scores, while FE scores were significantly higher than PAS scores after correction for multiple comparisons. These differences can be understood in relation to the distinct characteristics of each assessment. PS required students to complete assignments and product-oriented projects, whereas MSE assessed their ability to explain and apply concepts through essay questions. Strong written examination performance does not necessarily correspond directly to performance in producing a product or carrying out a technological process. Guo et al. (2020) demonstrated that project-based learning may produce multiple forms of outcomes, including academic knowledge, skills, problem solving, learning experience, and tangible products. This suggests that project and examination scores may provide different but complementary evidence of student achievement. Zhan et al. (2025) similarly emphasized that authentic assessment design should consider the relationship among tasks, disciplinary context, and intended learning outcomes.

The difference between FE and PAS also requires careful interpretation because PAS was not a pure measure of practical competence. It combined participation in practicum activities with attendance. Consequently, PAS represented participation and practicum engagement rather than technical skill alone. FE, by contrast, was a conceptual assessment conducted at the end of the semester and covered a broader range of course content. Fischer et al. (2024) noted that different assessment formats can elicit different forms of evidence about student learning. Therefore, a higher FE score than PAS should not be interpreted as indicating that conceptual competence was superior to practical competence, because the two components did not assess equivalent domains.

FE also showed the greatest score variability among the assessment components. This broader distribution suggests that the final examination differentiated students more strongly than PS or MSE. Assessment research has shown that the demands, format, and cognitive requirements of summative examinations may influence the extent to which differences among students become visible (Joughin, 2010). In the present study, the wider range of FE scores may reflect greater variation in students' ability to integrate and express course concepts at the end of the semester.

These findings support the view that academic performance in Forest Products Education should not be treated as a single undifferentiated construct. Project performance, participation in practicum activities, and written examinations provide different forms of information about student achievement. McArthur (2023) and Sokhanvar et al. (2021) argued that assessment should enable students to demonstrate learning through tasks that represent different forms of knowledge use. In this study, variation across assessment formats therefore provides evidence that each component contributed distinct information to the overall academic performance profile.

Relationships Between Applied and Conceptual Performance

One of the most notable findings was the positive relationship between project performance and written examination performance. PS was positively correlated with MSE at $\rho = .631$ and showed an even stronger relationship with FE at $\rho = .752$. Students who performed well in project activities therefore also tended to perform well in written conceptual assessments. This relationship is important because project work and written examinations required different forms of student performance, yet the scores showed substantial consistency.

This pattern is consistent with the view that project activities can provide contexts in which students apply and organize conceptual knowledge. Guo et al. (2020) found that project-based learning can produce outcomes related to academic achievement, knowledge application, problem solving, and product development. Tembrevilla et al. (2024) similarly showed that authentic experiences in engineering education can help students connect theoretical knowledge with application. Within the Forest Products Technology course, projects involving biomass briquettes, plywood, and preservation materials required students to engage with material characteristics and technological processes that were also addressed conceptually in the course.

The correlation of $\rho = .752$ between PS and FE was the strongest association observed in the study. This result suggests substantial consistency between project performance and achievement in the final written assessment. Nevertheless, the two forms of assessment should not be considered interchangeable. Project tasks involved applying knowledge in processes and products, whereas FE required students to explain and integrate concepts through written responses. The strength of the association therefore suggests that students who performed strongly in one context also tended to perform strongly in the other. Studies of project-based learning have similarly shown that relationships between project activity and academic outcomes may depend on task design, scaffolding, and implementation quality (Chen et al., 2021; Lavado-Anguera et al., 2024).

PAS was also positively related to PS, MSE, and FE. The association between PAS and PS, $\rho = .682$, indicates that students with higher practicum participation and attendance also tended to achieve higher project scores. This result is consistent with literature on active learning, which emphasizes the importance of student participation in the learning process. Freeman et al. (2014) reported that active learning is associated with improved performance in STEM education, while Prince (2004) argued that active engagement can support deeper processing of knowledge. In the present study, however, the combined structure of PAS means that the relative contributions of practicum participation and attendance cannot be separated.

MSE and FE were also positively correlated, $\rho = .712$, indicating a relatively consistent pattern of written examination performance across the semester. Students who achieved higher scores at mid-semester generally also obtained higher scores in the final examination. This consistency provides additional evidence that conceptual performance was relatively stable among the complete cases.

Taken together, the correlation pattern indicates that applied and conceptual performance were related rather than isolated domains. Students who performed better in projects and participated more consistently in practicum-related activities also tended to achieve higher scores in written examinations. At the same time, each component remains important because the assessment formats generated different forms of evidence about student performance.

Consistency and Variation Across the Two Course Sections

The comparison between Class A and Class B showed that the two naturally occurring course sections had broadly comparable patterns of academic performance. After Holm correction, no significant between-class differences were found for PS, MSE, FE, or FCS. The distribution of A and A− grades was also not significantly different between the classes. These results are notable because both sections followed the same content structure, learning activities, projects, and assessment system.

The similarity in project and written examination performance suggests that the same instructional framework produced relatively consistent achievement patterns across the two course sections. Chen et al. (2021) showed that project-based learning implementation can vary considerably across classes depending on facilitation, context, and student characteristics. In the present study, however, any between-class variation was not large enough to produce significant differences across most academic performance indicators.

PAS was the only component that remained significantly different after correction for multiple comparisons. Class B had a median PAS of 90 compared with 86 in Class A, with a rank-biserial correlation of .529. Because PAS included both practicum participation and attendance, this difference may reflect variation in participation patterns, attendance, or classroom engagement between the two sections. Research on active learning has shown that student engagement may vary across classes even when instructional structures are broadly similar (Freeman et al., 2014; Prince, 2004). However, because practicum performance and attendance were not recorded as separate variables, the present data cannot identify which aspect contributed most strongly to the difference in PAS.

Importantly, the difference in PAS was not accompanied by significant differences in PS, MSE, FE, or FCS after multiple-comparison adjustment. This pattern suggests that variation in one participation-related component did not correspond to broader differences across all academic outcomes. It also demonstrates the value of using multiple assessment indicators when comparing course sections, since conclusions based on a single component could provide an incomplete representation of overall academic performance.

Implications for Forest Products Education

The findings have implications for Forest Products Education, particularly for courses that use local resources as contexts for technological learning. Topics such as biomass briquettes, plywood, particleboard, natural-fiber composites, and preservation materials represent contemporary issues in forest resource utilization and bioresource technology. Their use within instruction allows students to study technological concepts through materials and applications that are directly relevant to resource utilization.

In bioenergy, biomass densification into briquettes represents one strategy for improving the utilization of biomass residues, although product performance depends strongly on feedstock characteristics and processing conditions (Eling et al., 2024; Kpalo et al., 2020; Silva et al., 2022). When introduced as part of a learning activity, this topic enables students to connect energy principles with raw material characteristics, production processes, and product quality. It therefore extends learning beyond theoretical descriptions of biomass and places the topic within a broader context of resource use and circular bioeconomy.

A similar rationale applies to wood-based panel technology. Research has shown that agricultural residues, recycled wood, and non-wood lignocellulosic materials can be utilized in particleboard and other biomass-based panels (Lee et al., 2022; Neitzel et al., 2022; Nguyen et al., 2023). Natural fibers have also been increasingly investigated as renewable reinforcement materials for more sustainable composites (Nagaraja et al., 2024; Siouta et al., 2024). In wood preservation, the development of bio-based preservatives provides opportunities to connect material protection with environmental considerations (Barbero-López et al., 2021; Calovi et al., 2024). Incorporating these topics into course activities therefore allows students to view forest products technology as a field connected with energy, materials science, manufacturing, sustainability, and industrial application.

These implications are consistent with changing expectations in forestry education. Durusoy and Bahçeci Öztürk (2022) indicated that forestry curricula increasingly need to develop competencies extending beyond conventional technical knowledge, while De'Arman and York (2021) emphasized the need to prepare students for the complexity of contemporary forestry challenges. In the Indonesian context, the utilization of biological resources is also increasingly associated with circular bioeconomy development and transformation within the forestry sector (Sunarta et al., 2026; Yaumidin et al., 2026). Local-resource-based technology learning can therefore provide a means of connecting forest products education with sustainability and industry-relevant issues.

The educational value of local resources, however, should not be reduced to the simple use of materials available in students' surroundings. Their pedagogical value depends on how they are used to connect material properties, scientific principles, processing technologies, product development, and sustainability considerations. Matthiesen et al. (2025) showed that resource-use issues connected with students' contexts can support higher education learning when they are explicitly linked with scientific and sustainability problems. This position is also consistent with sustainability competency frameworks that emphasize the integration of systems thinking, knowledge, action, and implementation in addressing resource-related challenges (Brundiers et al., 2021; Redman & Wiek, 2021).

The contribution of local-resource-based technology learning in the present context therefore lies not simply in using local materials, but in providing an instructional setting in which theory, materials, processes, products, and applications can be connected. Such an orientation can help Forest Products Education move beyond predominantly content-centered instruction toward learning that gives greater attention to how technological knowledge is used in relation to resources and products.

Strengths and Interpretive Boundaries

One strength of this study is the use of authentic classroom performance data generated through regular course activities. Unlike self-reported measures, the analyzed scores represented students' actual performance on activities that formed part of their academic assessment. This provides a degree of ecological authenticity because the findings reflect learning conditions that occurred during a regular semester. Literature on authentic assessment similarly emphasizes the value of performance evidence derived from activities directly connected with disciplinary learning and the use of knowledge (Sokhanvar et al., 2021; Zhan et al., 2025).

At the same time, the findings should be interpreted within the boundaries of the study design. The retrospective classroom-based approach was intended to describe achievement patterns, differences across assessment formats, variation between course sections, and relationships among performance indicators under regular instructional conditions. It was not designed to estimate the causal effect of local-resource-based technology learning on student achievement. Accordingly, the findings provide classroom-based evidence about how applied and conceptual performance were distributed and related within this particular Forest

Products Technology course rather than evidence of the comparative effectiveness of a specific instructional intervention.

CONCLUSION

This study examined students' academic performance in a Forest Products Technology course that integrated local resources with conceptual learning, practicum activities, and product-oriented projects. The results showed that students with complete assessment records achieved relatively high performance across Practicum and Attendance Score, Project Score, Mid-Semester Examination, Final Examination, and Final Course Score. Although the mean scores across the assessment components were relatively close, statistically significant differences were identified across assessment formats, particularly between Project Score and Mid-Semester Examination and between Practicum and Attendance Score and Final Examination. These findings indicate that different assessment formats captured distinct aspects of student performance within the same course context.

The study also revealed consistent positive relationships among applied and conceptual performance indicators. Project Score was positively associated with both written examinations, with the strongest relationship observed between Project Score and Final Examination. Practicum and Attendance Score was also positively related to Project Score and both written examinations. These patterns suggest that students who performed well in project-oriented and practicum-related activities also tended to demonstrate stronger conceptual achievement. At the same time, the variation across assessment formats supports the use of multiple forms of assessment rather than relying on a single course score to represent students' academic performance.

Comparisons between the two naturally occurring course sections showed broadly similar patterns of achievement. After correction for multiple comparisons, only Practicum and Attendance Score differed significantly between Class A and Class B, while Project Score, Mid-Semester Examination, Final Examination, Final Course Score, and the distribution of A and A− grades did not differ significantly. The findings therefore provide classroom-based evidence that local-resource-based technology learning can be used as an instructional context in Forest Products Education to connect material characteristics, technological processes, product development, and conceptual understanding while supporting multidimensional assessment of student performance.

LIMITATIONS

This study has several limitations that should be considered when interpreting the findings. First, the retrospective classroom-based design did not include a pretest, control group, or random assignment, limiting the study to the description of performance patterns and associations rather than causal evaluation of the instructional approach. Second, the study was conducted in one course at one institution during one semester, involving 46 enrolled students and 39 complete cases, which limits the generalizability of the findings to other cohorts and institutional contexts. Third, seven students with incomplete assessment records were excluded from the inferential analyses, reducing representation of the full enrolled cohort. Fourth, the Practicum and Attendance Score combined practicum participation and attendance, preventing these two dimensions from being interpreted separately. Finally, the Project Score, Mid-Semester Examination, and Final Examination were regular course assessments rather than standardized research instruments, and separate expert validation, analytic scoring reliability, and inter-rater reliability procedures were not available. These limitations should be considered when extending the findings beyond the specific instructional context examined in this study.

RECOMMENDATIONS

Future studies should examine local-resource-based technology learning across larger samples, multiple cohorts, institutions, and Forest Products Technology courses using longitudinal or quasi-experimental designs where appropriate. Attendance, practicum performance, and project performance should be recorded as separate variables and evaluated using clearly defined analytic rubrics, expert validation, and reliability procedures. Further research could also investigate students' performance on specific technological competencies, such as biomass processing, wood-based panel production, composite materials, and preservation technology, rather than relying only on aggregate course assessment scores. For instructional practice, Forest Products Education should continue to combine conceptual instruction, practicum activities, and product-oriented projects using locally relevant materials while maintaining multiple assessment formats that capture both applied and conceptual performance.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Acknowledgment

The authors gratefully acknowledge the support of the Forestry Study Program, Mandalika University of Education, Indonesia, in facilitating the implementation of the Forest Products Technology course and the academic activities from which the data for this study were derived. Appreciation is also extended to all students who participated in the course and completed the practical activities, product-oriented projects, and academic assessments that contributed to this research. The authors further thank colleagues and academic staff who supported the instructional and administrative processes associated with the course.

Conflict of Interests

The authors declare no conflict of interest.

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