

BIBLIOGRAPHIC RECORD	Volume 5/ Issue 1/ Page 47-56/ Article ID 317
DOI	https://doi.org/10.59397/edu.v5i1.317
MANUSCRIPT HISTORY	Received: August 4, 2026 / Revised: September 7, 2026 / Accepted: September 22, 2026 / Published: January 31, 2027
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Low-Power Grass Chopping Machine Performance as an Authentic Project for Vocational Engineering Education

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ORCID iDs: Not provided in the source manuscript.

Research profile: Experimental engineering design with prospective authentic-project interpretation | Reporting guideline: EDUCATIONE Original Research Article template; no field-specific reporting guideline was specified | Preregistration/protocol: not reported in the source manuscript

ABSTRACT

Background and Objective: Vocational engineering education requires authentic projects that connect design, fabrication, measurement, testing, and evidence-based improvement, yet technical machine studies are rarely organized as reusable educational cases. This study evaluated a compact low-power grass chopping machine and examined its suitability as an authentic project case for vocational engineering education. **Methods:** An experimental engineering design was conducted from February to August 2026 using a FLASH-250G 1/4-HP motor, one 1.6-mm steel-plate blade, and a compact steel frame. Elephant, odot, and sansibar grass were tested at 1-5 kg loads. Rotational speed, chopping time, and post-chopping mass were recorded, and three test series were averaged for each condition; analysis was descriptive because run-level dispersion data were unavailable. **Results:** The machine completed all reported conditions at 2,457-2,978 rpm. Chopping time increased from approximately 2-3 minutes at 1 kg to approximately 10 minutes at 5 kg, with descriptive load-time slopes of 116.28-121.41 seconds/kg. Derived batch processing rates were approximately 22.49-29.37 kg/h. **Conclusion:** The prototype demonstrates functional feasibility under the reported conditions and provides a technically grounded authentic-project structure for vocational engineering learning in design, fabrication, measurement, safety, data interpretation, and redesign. Educational effectiveness was not tested and requires direct student-outcome evidence.

Keywords: Agricultural machinery; Authentic assessment; Project-based learning; Technical education; Vocational engineering

INTRODUCTION

Vocational engineering education is expected to connect technical knowledge with the design, fabrication, measurement, troubleshooting, and evaluation practices encountered in workshops and workplaces. Authentic projects can create this connection when learners address a tangible problem, work within real material and safety constraints, and interpret performance evidence rather than merely reproduce a finished artifact. Project-based learning (PjBL) is widely used for this purpose, but reviews show that its educational value depends on explicit learning outcomes, assessment design, facilitation, and meaningful disciplinary reasoning rather than on making alone (Guo et al., 2020; Chen et al., 2021; Kokotsaki et al., 2016; Lavado-Anguera et al., 2024). In mechanical engineering, practice-oriented and experiential learning similarly emphasizes complete cycles of requirements analysis, prototyping, testing, and redesign that approximate professional engineering activity (Dym et al., 2005; Mann et al., 2021; Kuppaswamy & Mhakure, 2020).

Agricultural machinery is especially suitable for authentic vocational projects because it combines mechanisms, material selection, fabrication, power transmission, instrumentation, occupational safety, and performance evaluation while addressing recognizable community needs. Grass chopping for livestock-feed preparation is one example: a compact chopper requires the designer to translate a practical need into specifications, select a motor and

cutting system, fabricate and assemble components, inspect mechanical and electrical conditions, and test how material type and load influence operation. Prior agricultural-engineering research shows that forage-chopping performance varies with machine configuration, operating speed, material properties, and test conditions (Nipa et al., 2021; Mulatu, 2021; Awad et al., 2022; Xie et al., 2018). These studies establish the grass chopper as an experimental system rather than merely a fabricated object.

A specific gap appears at the intersection of engineering performance research and vocational education. Machine-development studies commonly report fabrication and performance but do not organize technical evidence so that instructors and learners can reuse it as an analyzable project case. Engineering-education studies, in contrast, frequently emphasize student perceptions, teamwork, or learning outcomes without providing enough machine-level detail for workshop replication. The gap is particularly relevant for low-power, workshop-scale machinery: the present prototype uses a 1/4-HP motor and one blade, a configuration that is feasible for supervised fabrication but not directly comparable with larger agricultural machines. The study therefore treats technical performance and educational interpretation as linked but distinct: machine feasibility can support curricular use, but it is not evidence that student learning has improved.

This study aimed to fabricate and evaluate a low-power electric motor-based grass chopping machine across three grass types and five material loads using rotational speed and chopping time as the principal operating indicators, and to interpret the documented engineering cycle as an authentic project case for vocational engineering education. Two questions guided the study: (1) how does the prototype perform across the reported grass-type and load conditions, and (2) what technically grounded learning opportunities can be derived from its problem-definition, design, fabrication, inspection, testing, analysis, and redesign stages? The operational expectation was that increasing material load would increase chopping time and that grass type would be associated with different operating patterns. Student achievement, motivation, teamwork, employability, and other educational outcomes were outside the empirical scope.

THEORETICAL OR CONCEPTUAL FRAMEWORK

The conceptual framework integrates authentic project-based learning, practice-based engineering education, and evidence-centered engineering design. PjBL positions learning around a purposeful product or problem and requires learners to coordinate conceptual and procedural knowledge over an extended task (Helle et al., 2006; Guo et al., 2020). Practice-based engineering education extends this logic by emphasizing work that resembles professional engineering activity, including requirements analysis, fabrication, instrumentation, testing, and iterative improvement (Mann et al., 2021). Engineering design scholarship likewise treats design as an iterative process of defining requirements, generating alternatives, prototyping, evaluating evidence, and revising decisions rather than as the production of a final artifact alone (Dym et al., 2005).

Within this framework, the authenticity of a vocational project is defined by the visibility of engineering decisions and evidence across the complete technical cycle. The grass-chopper case is therefore interpreted through seven linked stages: problem definition; concept and design; fabrication; assembly and pre-test inspection; performance testing; analysis and interpretation; and redesign and communication. These stages provide possible sites for competency-aligned assessment in engineering drawing, materials, machining and welding, mechanical assembly, measurement, occupational safety, data analysis, troubleshooting, and technical communication. This mapping is prospective. Because no students participated, the framework guides curricular interpretation but does not provide evidence of instructional effectiveness.

METHOD

Research Design and Reporting Standard

The study used an experimental engineering design with a secondary, prospective interpretation of the documented workflow as an authentic project for vocational engineering education. The unit of technical analysis was machine performance under combinations of grass type and material load. The engineering experiment was not an educational intervention because no human participants were involved. Reporting was reorganized according to the EDUCATIONE Original Research Article template; the source manuscript did not identify a separate field-specific reporting guideline. Descriptive analyses were treated as exploratory because individual run-level observations and uncertainty estimates were not available.

Context, Setting, and Study Period

Research, fabrication, and testing were conducted from February to August 2026 in the Mechanical Engineering Workshop, Department of Mechanical Engineering, Manado State Polytechnic, Indonesia. The workshop setting is

relevant to the educational interpretation because it represents the type of supervised technical environment in which a design-fabrication-testing project could later be adapted for vocational engineering instruction. The present study documents the technical case only; it does not report classroom implementation.

Participants, Sampling, or Data Sources

No human participants or live animals were used. The experimental materials were elephant grass, odot grass, and sansibar grass. Each grass type was tested at nominal input loads of 1, 2, 3, 4, and 5 kg, producing 15 grass-type-by-load condition means. The source manuscript states that three test series were averaged for each condition, but individual run-level observations are not available in the manuscript records. Consequently, standard deviations, confidence intervals, and other dispersion statistics were not reconstructed.

Variables, Constructs, and Operational Definitions

The primary technical outcomes were rotational speed (rpm) and chopping time (min:s.xx). Grass type and nominal input load (kg) were the principal test conditions. Post-chopping mass was recorded but showed no displayed difference from nominal input mass at the reported resolution. A nominal batch processing rate (kg/h) was calculated from the reported condition means as $3600m/t$, where m is nominal batch mass in kilograms and t is mean chopping time in seconds; this derived rate is not an independently measured or certified machine capacity. For the educational interpretation, an authentic project was operationalized as a documented engineering cycle that exposes problem definition, design constraints, fabrication, inspection, measurement, performance evidence, limitations, and redesign opportunities.

Instruments, Measures, and Data Collection

The fabricated machine used a FLASH-250G electric motor rated at 1/4 HP/1.7 A, 220 V/50 Hz, with a nominal motor speed of 2,870 rpm. The chopping system used one blade fabricated from 1.6-mm steel plate and a compact steel frame. Fabrication and testing equipment included a welding machine, grinding machine, drilling machine, measuring tools, vernier caliper, square ruler, tachometer, and weighing scale. Rotational speed was measured with a tachometer, chopping time was timed in minutes:seconds.hundredths, and mass was measured with a weighing scale. The source records do not identify instrument model numbers, resolution, calibration status, the exact rotational-speed measurement point, the tachometer sampling moment, or the precise timing criterion; therefore, the measurements are treated as descriptive operational readings rather than metrologically traceable measurements.

Procedure or Intervention

The technical procedure proceeded through problem identification, literature review, concept and machine design, preparation of tools and materials, component fabrication, assembly, pre-test inspection, performance testing, data recording, descriptive analysis, and formulation of redesign priorities. Pre-test inspection covered bolt tightness, shaft position, blade installation, V-belt condition and tension, and the electrical system. For each test condition, grass was prepared and weighed to the specified load, fed into the chopping section, and processed while rotational speed and chopping time were recorded. The source records do not provide complete blade geometry, cutting clearance, feed-opening dimensions, standardized feed-rate rules, formal guarding specifications, emergency-stop provisions, or electrical-protection details. The prototype should therefore be regarded as an experimental workshop machine rather than an instructional- or field-ready device until formal safety review is completed.

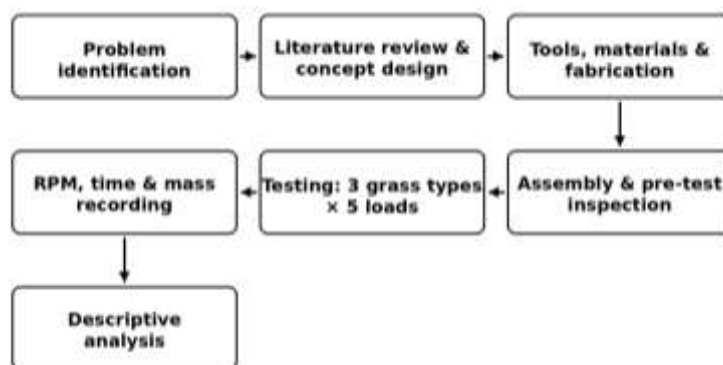


Figure 1. Engineering design, fabrication, testing, and analysis workflow used for authentic-project interpretation.

Data Analysis

The analysis was descriptive. Machine performance was compared across grass types and loads using the reported condition means for rotational speed and chopping time. Nominal batch processing rates were calculated from the load-time pairs. Simple linear trend summaries for chopping time across the five aggregated load points were used only as descriptive diagnostics. No inferential significance tests were introduced because run-level data, standard deviations, and measurement uncertainties are unavailable. The resulting coefficients of determination therefore describe the five displayed condition means and should not be interpreted as estimates of inferential precision.

Research Quality and Rigor

Procedural consistency was supported by using the same machine configuration, the same nominal 1-5 kg load sequence, and repeated test series whose means were reported. Rigor is limited by the absence of run-level observations and by unmeasured or uncontrolled material and operating factors, including grass moisture, stem geometry, density, standardized feed rate, blade sharpness over time, electrical current, environmental conditions, and instrument uncertainty. These variables are treated as potential uncontrolled covariates rather than demonstrated explanations. Future replications should archive individual runs, instrument metadata and calibration, randomized or otherwise documented test order, material properties, blade condition, and safety checks.

Ethical Considerations

No human participants, human data, live animals, or feeding trials were involved; informed consent was therefore not applicable to the reported experiment. Ethical considerations centered on responsible workshop operation, mechanical and electrical safety, transparent reporting, and separation of machine-performance findings from educational claims. Any future implementation with students should obtain institutional ethical approval where required, apply documented guarding and electrical-protection procedures, provide instructor supervision and risk controls, and assess student outcomes separately from machine-performance outcomes.

RESULTS

Low-Power Prototype and Test Dataset

Table 1. Technical specifications of the fabricated low-power grass chopping machine.

Component	Specification
Motor type	FLASH-250G
Motor power	1/4 HP / 1.7 A
Voltage/frequency	220 V / 50 Hz
Nominal motor speed	2,870 rpm
Number of blades	1
Blade material	1.6-mm steel plate
Frame material	30 × 30 mm hollow steel; 30 × 30 mm angle steel; Ø8 mm steel
Machine dimensions	360 mm (L) × 560 mm (W) × 1,200 mm (H)
Test materials	Elephant grass; odot grass; sansibar grass

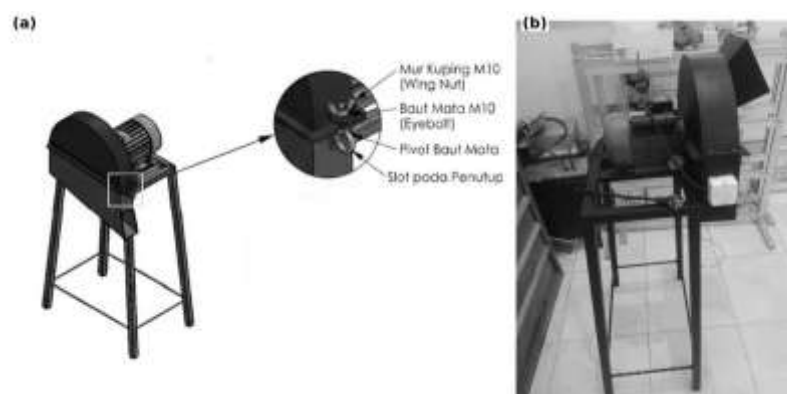


Figure 2. Low-power grass chopping machine: (a) design configuration and (b) fabricated prototype.

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The fabrication process produced a complete low-power grass chopping machine consisting of a steel frame, electric motor, chopping chamber, single chopping blade, grass inlet, and grass outlet. The prototype completed the reported tests for elephant, odot, and sansibar grass across the full 1-5 kg load range; the available records do not indicate failure to complete any condition. Table 1 summarizes the technical specifications used during testing.

Rotational-Speed and Chopping-Time Performance

Recorded average rotational speeds ranged from 2,457 to 2,978 rpm. The lowest reported value occurred with 1 kg of elephant grass, whereas the highest occurred with 5 kg of sansibar grass. Chopping time increased consistently as nominal load increased. Elephant grass required 2:10.80 at 1 kg and 10:12.95 at 5 kg; odot grass increased from 2:08.75 to 10:13.95; and sansibar grass increased from 2:40.10 to 10:20.89. Across the five aggregated load points, descriptive slopes were approximately 120.41 seconds/kg for elephant grass, 121.41 seconds/kg for odot grass, and 116.28 seconds/kg for sansibar grass, with coefficients of determination above 0.998 for all three series. These trend summaries are descriptive because replicate-level variability is unavailable.

Table 2. Reported performance across grass type and nominal load.

Grass type	Load (kg)	Rotational speed (rpm)	Chopping time (min:s.xx)	Derived rate (kg/h)
Elephant	1	2,457	02:10.80	27.52
Elephant	2	2,477	04:13.90	28.36
Elephant	3	2,836	06:12.94	28.96
Elephant	4	2,959	08:13.70	29.17
Elephant	5	2,965	10:12.95	29.37
Odot	1	2,466	02:08.75	27.96
Odot	2	2,559	04:11.83	28.59
Odot	3	2,545	06:09.55	29.22
Odot	4	2,629	08:15.56	29.06
Odot	5	2,627	10:13.95	29.32
Sansibar	1	2,464	02:40.10	22.49
Sansibar	2	2,674	04:25.30	27.14
Sansibar	3	2,880	06:40.70	26.95
Sansibar	4	2,975	08:26.50	28.43
Sansibar	5	2,978	10:20.89	28.99

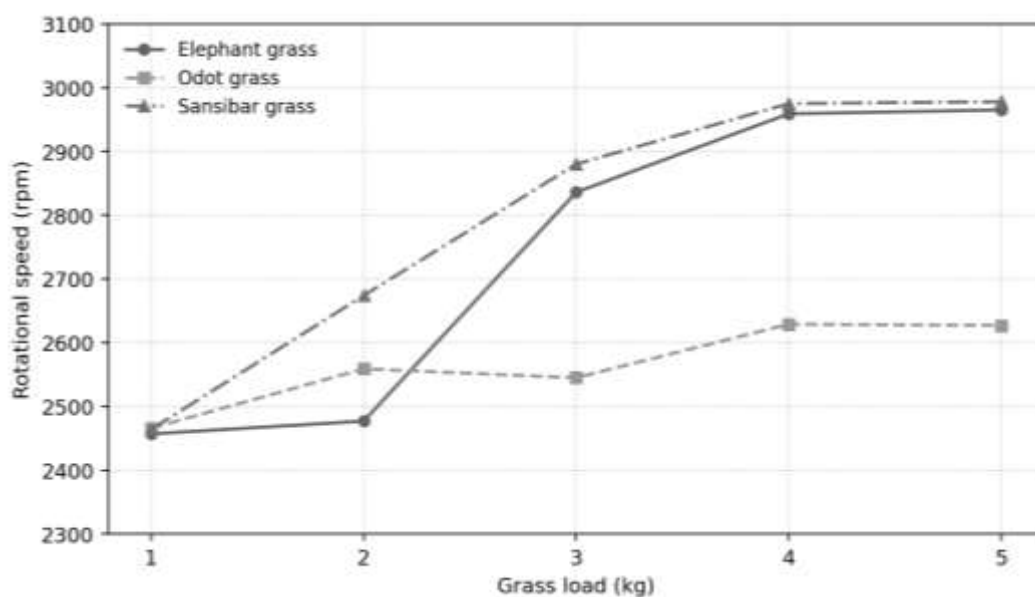


Figure 3. Performance across nominal grass load rotational speed

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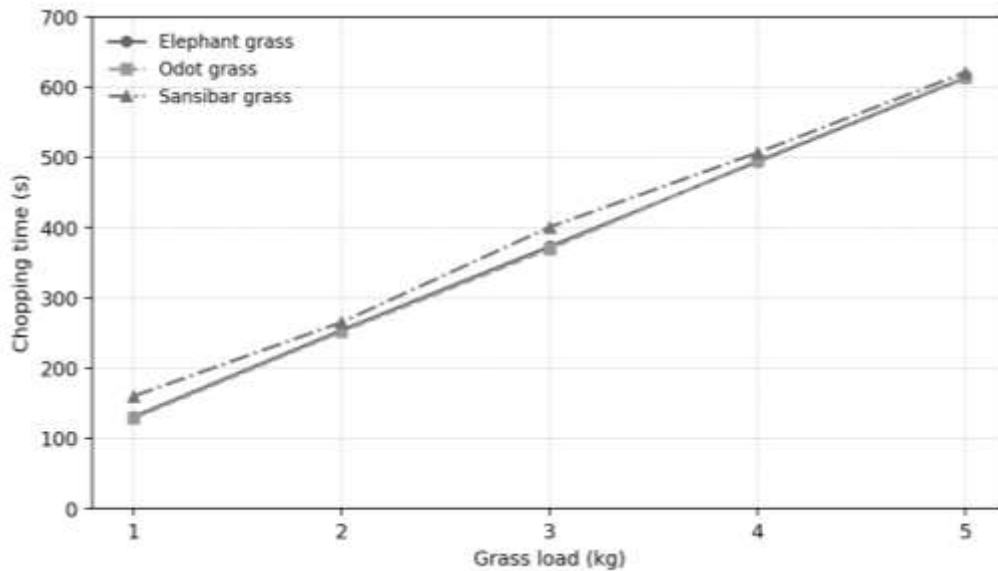


Figure 4. Performance across nominal grass load chopping time

Derived Processing-Rate and Grass-Type Patterns

The nominal batch processing rates calculated from the reported mean times clustered mostly in the high-20-kg/h range. Elephant grass increased from approximately 27.52 kg/h at 1 kg to 29.37 kg/h at 5 kg; odot grass from 27.96 to 29.32 kg/h; and sansibar grass from 22.49 to 28.99 kg/h. Grass type was also associated with different operating patterns. Elephant and odot grass had similar chopping times at most loads, while sansibar grass generally required longer processing, particularly at the lower loads. These differences cannot be attributed to specific material properties because moisture content, stem diameter, maturity, bulk density, fiber characteristics, and standardized feed rate were not measured.

DISCUSSION

The principal technical finding is that the 1/4-HP single-blade prototype functioned across all reported grass-type and load conditions, while chopping time increased in an approximately linear descriptive pattern as batch mass increased. The prototype therefore provides bounded evidence of functional feasibility for small-batch chopping, not evidence of optimal capacity, energy efficiency, cut quality, field readiness, or commercial competitiveness. The rotational-speed pattern was less straightforward: average rpm generally increased with load for elephant and sansibar grass, despite a simple motor-loading expectation that greater mechanical load might reduce speed. Because feed rate, tachometer sampling timing, no-load speed before each run, material properties, and replicate variability were not documented, the pattern should be treated as an empirical observation requiring improved measurement rather than as a causal effect.

Technical Interpretation and Comparison with Previous Engineering Studies

The results are consistent with prior agricultural-machinery studies in the broad sense that chopping performance depends on machine configuration and material conditions. Nipa et al. (2021) and Mulatu (2021) evaluated fodder choppers with different architecture, motorization, and capacity targets, while Awad et al. (2022) and Xie et al. (2018) showed that rotational speed and mechanism-material interaction are important to chopping behavior. Direct performance ranking is inappropriate because those studies differ in power, blade geometry, feeding systems, crop materials, and outcome definitions. The present contribution is narrower: it documents how a compact workshop-scale configuration behaved across a structured set of grass types and loads. A logical technical progression is to move from descriptive prototype testing to controlled-factor experiments that manipulate blade speed, blade angle, number of blades, feed rate, and measured material properties while recording energy, cut-size distribution, noise, vibration, and safety outcomes.

Theoretical and Methodological Contribution

The study contributes primarily by converting a complete engineering artifact-and-evidence cycle into a reusable authentic-project case for vocational engineering education while preserving the boundary between technical feasibility and educational effectiveness. Rather than presenting the machine as a finished object, the manuscript exposes problem definition, design choices, fabrication, inspection, instrumentation, test conditions, unexpected data, measurement limitations, and redesign priorities. This structure aligns with project-based and practice-based

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engineering perspectives that emphasize purposeful products, learner responsibility, workplace-like activity, and iterative evidence-based design (Guo et al., 2020; Mann et al., 2021; Kuppuswamy & Mhakure, 2020). Methodologically, the unresolved rotational-speed pattern and incomplete metrological documentation are not hidden; they become examples of how engineering conclusions must be bounded by measurement quality and available evidence.

Implications for Education, Policy, and Practice

For vocational engineering programs, the documented machine can be used as a curricular case rather than as a ready-made teaching intervention. Instructors could organize the project around competency-aligned tasks in requirements analysis, engineering drawing, material selection, machining and welding, mechanical assembly, power transmission, instrumentation, occupational safety, data analysis, troubleshooting, redesign, and technical communication. Table 3 maps the documented technical stages to candidate competencies and possible assessment evidence. The mapping is prospective and should be validated through actual implementation with learners before any claim is made about achievement, motivation, teamwork, employability, or instructional effectiveness.

Table 3. Proposed mapping of authentic-project stages to vocational engineering competencies and assessment evidence.

Project stage	Candidate vocational engineering competencies	Possible assessment evidence
Problem definition	Requirements analysis; community-problem framing; constraint identification	Problem statement; design criteria; documented constraints
Concept and design	Engineering drawing; mechanism selection; material selection; design reasoning	Drawings; calculations; design rationale
Fabrication	Cutting, machining, welding, dimensional control, process planning	Process sheet; dimensional inspection; fabrication-quality checklist
Assembly and pre-test inspection	Mechanical assembly; power transmission; electrical/mechanical safety awareness	Assembly checklist; alignment/tension record; hazard assessment
Performance testing	Instrumentation; test planning; data recording; safe workshop procedure	Run sheet; rpm/time/mass records; measurement protocol
Analysis and interpretation	Descriptive analysis; evidence-based reasoning; uncertainty awareness	Graphs; derived-rate calculations; limitations analysis
Redesign and communication	Optimization reasoning; reflective problem solving; technical communication	Redesign proposal; justification; technical report or presentation

The most educationally useful feature may be the presence of imperfect and unexpected evidence. The rotational-speed pattern invites learners to question whether measurements captured steady-state speed, transient speed, or post-feed recovery; whether feeding was continuous; whether blade condition changed; and whether material geometry influenced blade engagement. Such questions can support evidence-based troubleshooting when they are accompanied by safe procedures, explicit scaffolding, and assessment criteria. For program-level use, however, the prototype should not be deployed routinely until guarding, emergency-stop provisions, electrical protection, operational limits, and instructor supervision requirements are formally documented.

Limitations and Future Research

The first limitation concerns measurement and safety scope. The experiment did not report cut-size distribution, blade wear, energy consumption, motor current, power factor, noise, vibration, feed rate, temperature, instrument resolution, calibration status, measurement uncertainty, or the exact tachometer sampling point and timing criteria. Formal safety certification, complete guarding specifications, emergency-stop provisions, and electrical-protection details were also unavailable. These omissions prevent claims that the prototype is optimized, energy-efficient, metrologically validated, or ready for routine instructional or farm use.

The second limitation is material characterization and analytical resolution. Grass type was varied, but moisture content, bulk density, stem diameter, maturity, fiber properties, and standardized feed rate were not quantified. Individual run-level observations were unavailable, preventing estimation of random variability and inferential testing. Future engineering work should retain replicate-level data, document instrument calibration, measure material properties, standardize feeding, and use controlled-factor designs that can separate machine and material effects.

The third limitation concerns educational evidence and transferability. No students, instructors, learning assessments, or classroom observations were included, so the study cannot establish effects on design competence, fabrication skill, problem solving, motivation, teamwork, safety behavior, or employability. A subsequent vocational-engineering study should implement the project as a structured instructional sequence, define

competency-aligned outcomes, document scaffolding and implementation fidelity, and evaluate learner performance with appropriate rubrics or assessments. Replication in other vocational or polytechnic workshops would also clarify whether similar low-power machinery projects are feasible across contexts.

CONCLUSION

This study evaluated a compact low-power grass chopping machine and interpreted its engineering cycle as an authentic project case for vocational engineering education. The 1/4-HP, single-blade prototype processed elephant, odot, and sansibar grass across 1-5 kg loads, with recorded rotational speeds of 2,457-2,978 rpm and chopping times that increased consistently with load. These findings establish functional feasibility only for the reported prototype and conditions. The original contribution for vocational education is the organization of a real problem-design-fabrication-inspection-testing-analysis-redesign sequence into a technically grounded case that can support competency-aligned curriculum and assessment planning. Because student learning was not measured, the educational applications remain prospective. Future work should strengthen measurement and safety evidence, retain replicate-level data, control material and operating variables, and then evaluate the project directly with vocational engineering learners.

DECLARATIONS

Acknowledgments

The authors acknowledge the Department of Mechanical Engineering, Manado State Polytechnic, for access to the workshop environment and technical facilities used for the fabrication and testing activities reported in this study.

Author Contributions (CRediT)

Individual CRediT roles were not specified in the source manuscript. The contribution statement should be completed and verified by all authors before submission, and all authors should confirm approval of the final manuscript and accountability for the work.

Funding

Funding information was not provided in the source manuscript. The authors should confirm the funding statement before submission.

Ethics Approval

Formal human-participant or animal ethics approval was not applicable to the reported materials-processing experiment because it involved no human participants, human data, live animals, or feeding trials. The source manuscript does not report a separate institutional exemption or reference number.

Informed Consent and Assent

Not applicable. The study did not involve human participants.

Consent for Publication

Not applicable. The manuscript does not report identifiable human information, quotations, or participant images.

Data, Code, and Materials Availability

The analytical dataset reported in the manuscript comprises 15 grass-type-by-load condition means formed from three repeated test series. Individual run-level observations, instrument calibration records, and the original laboratory run log were not included in the source materials available for this manuscript. No analytic code was reported. Additional records, if retained by the authors, should be made available under conditions specified by the corresponding author.

Preregistration and Protocol

Preregistration or a registered protocol was not reported in the source manuscript.

Conflict of Interest

A conflict-of-interest statement was not provided in the source manuscript. All authors should confirm and disclose any financial or non-financial competing interests before submission.

Use of Generative AI and AI-Assisted Technologies

OpenAI ChatGPT (GPT-5.6 Sol) was used to support language editing, structural reorganization, and alignment of the manuscript with the EDUCATIONE Original Research Article template. It was not used to generate or alter the

reported experimental data. The authors are responsible for verifying all AI-assisted revisions and remain fully accountable for the manuscript's accuracy, originality, confidentiality, and integrity.

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