Supplementary Material S1. Standardized Prompt Used During Activity 5

In addition to the standardized prompt used by all students, this supplementary file includes an illustrative maintenance case (TT-01) and the corresponding validation checklist. These materials are provided exclusively to demonstrate how the standardized prompt was applied during the educational activity and how students were instructed to critically evaluate AI-generated responses. Neither the TT-01 case nor the validation checklist corresponds to an individual student's submission.

Role: Act as a specialist in predictive maintenance of industrial machinery with expertise in vibration analysis, infrared thermography, acoustic monitoring, and IoT-based condition monitoring.

Objective: Analyze the following maintenance case study developed from experimental data collected by engineering students during laboratory activities.

The information provided originates exclusively from measurements obtained through:

- Vibration analysis;
- Infrared thermography;
- Acoustic monitoring;
- IoT-based monitoring systems.

Case Data

[Students inserted the technical data corresponding to the assigned maintenance case.]

Instructions

1. Analyze only the information explicitly provided.

2. Do not generate, assume, or infer data that have not been supplied.
3. Clearly distinguish among:
    - Direct evidence: Findings directly supported by the available measurements.
    - Probable inferences: Plausible conclusions supported by partial evidence.
    - Insufficient data: Diagnoses or conclusions that cannot be established with confidence based on the available information.
4. Consider the limitations of each monitoring technique when formulating your response.
5. If multiple faults are possible, indicate the level of uncertainty associated with each one.

Required Output

Based on the information provided, prepare a table containing the following columns:

- Monitoring technique;
- Relevant finding;
- Possible mechanical cause;
- Criticality level (Low, Moderate, High);
- Confidence level (Low, Moderate, High);
- Preliminary diagnosis;
- Recommended maintenance action.

Final Assessment

After completing the table, provide:

1. The most probable overall diagnosis.
2. The principal maintenance recommendation.
3. Additional measurements or inspections required to improve diagnostic confidence.
4. A brief statement describing the limitations of the analysis.

Important

- Do not provide definitive conclusions unless they are fully supported by the available evidence.
- Explicitly acknowledge uncertainty when the information is insufficient.
- Do not include personal, academic, or identifiable information in the response.
- Assume that the final diagnostic decision will be made by a maintenance engineer after reviewing all available evidence.

Maintenance Case Analysis – TT-01 (Takoma Lathe)

Role: Predictive Maintenance Specialist
Monitoring Technique Available: Vibration Analysis only.
Important: No thermographic, acoustic, or IoT monitoring data were provided; therefore, conclusions are limited to vibration measurements.

Monitoring Technique	Relevant Finding	Possible Mechanical Cause	Criticality	Confidence	Preliminary Diagnosis	Recommended Maintenance Action
Vibration Analysis	Dominant component at 1X (14 Hz) with amplitude of 0.40 m/s^2.	Rotor imbalance.	Moderate	Moderate	Evidence suggests possible imbalance.	Verify balance condition and inspect rotating components.
Vibration Analysis	Presence of 1.5X (20 Hz, 0.17 m/s^2).	Transmission or gear-related issue.	Low	Low	Possible transmission-related abnormality.	Inspect gears, couplings, and transmission elements.

Vibration Analysis	Presence of 2X (28 Hz, 0.18 m/s²).	Mechanical looseness or loss of fastening elements.	Moderate	Low	Possible mechanical looseness.	Verify mounting bolts and structural integrity.
Vibration Analysis	Presence of 3X (47 Hz, 0.16 m/s²).	Shaft misalignment.	Moderate	Low	Potential misalignment requiring confirmation.	Perform alignment verification.
Vibration Analysis	Peak at approximately 10X (139 Hz, 0.466 m/s²), the highest measured amplitude.	Friction, lubrication deficiency, or other high-frequency mechanical interaction.	Moderate	Moderate	Possible lubrication-related condition.	Inspect lubrication practices and bearing condition.

Evidence Category

- Direct Evidence: Frequencies identified at 14, 20, 28, 47, 61.5, and 139 Hz with their corresponding amplitudes.
- Probable Inferences: Imbalance, misalignment, mechanical looseness, and lubrication issues based on harmonic relationships.
- Insufficient Data: Bearing specifications, machine baseline, historical trends, load conditions, ISO severity criteria, and manufacturer limits were not provided.

Final Assessment

1. Most Probable Overall Diagnosis

The most probable diagnosis is the presence of a developing mechanical condition characterized by a combination of possible rotor imbalance and lubrication/friction-related effects. The strongest evidence is the occurrence of the fundamental frequency (1X = 14 Hz) and the highest measured amplitude at approximately 10X (139 Hz). However, the available data are insufficient to establish a definitive diagnosis.

2. Principal Maintenance Recommendation

Conduct a targeted inspection including:

- Dynamic balancing verification.
- Shaft alignment inspection.

- Lubrication assessment.
- Bearing inspection.
- Verification of mechanical fasteners and machine mounting.

3. Additional Measurements Required

To improve diagnostic confidence, the following are recommended:

- Repeat vibration measurements in horizontal, vertical, and axial directions.
- Collect time-waveform data and full FFT spectra.
- Record operating load and speed during acquisition.
- Obtain historical vibration data for trend analysis.
- Compare amplitudes with manufacturer or ISO vibration limits.
- Perform thermographic inspection of bearings and transmission components.
- Conduct acoustic measurements to confirm friction or bearing-related issues.

4. Limitations of the Analysis

This analysis is limited because:

- Only vibration data were available.
- No baseline measurements or historical trends were provided.
- No thermography, acoustic, or IoT data were included.
- No bearing frequencies or machine specifications were supplied.
- Severity thresholds from applicable standards or manufacturer recommendations were not available.
- Therefore, all fault identifications should be considered preliminary and require confirmation by a maintenance engineer.

Student Validation Checklist

- All numerical values originate from the case data.
- No missing measurements were assumed.
- Direct evidence was separated from probable inference.

- Alternative fault mechanisms were considered.
- Confidence levels reflect the available evidence.
- Diagnostic uncertainty was explicitly acknowledged.
- Recommendations are proportional to the available information.
- Final diagnosis remains subject to engineering review.