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Assessment of Noise Exposure Levels Generated by Equipment in University Engineering Laboratories

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ABSTRACT

Noise generated by machinery and equipment can be an important safety consideration in university engineering laboratories. However, equipment-generated sound levels should be distinguished from individual personal noise exposure, which depends on exposure duration, distance from the source, task frequency, simultaneous equipment operation, and individual movement. This study characterized equipment-generated noise levels in selected university engineering laboratories and identified sources that may warrant further exposure assessment. A quantitative observational approach was used to measure mean noise level, maximum noise level (Lmax), and peak noise level (Lpeak). Fourteen noise sources were assessed across the Composite, General Machining, and Aerospace Laboratories. The results showed clear differences in noise levels among the equipment. The air gun recorded the highest mean noise level at 92.9 dB(A), followed by the air filter at 91.7 dB(A), Fume-Air 750 at 90.7 dB(A), and the aeronautical wind tunnel at 89.4 dB(A). Milling M3 recorded the lowest mean level at 67.8 dB(A). The air gun also produced the highest Lmax and Lpeak values, at 103.7 dB(A) and 121.8 dB(C), respectively. Four of the 14 noise sources exceeded 85 dB(A), while five exceeded 82 dB(A). These comparisons are presented as source-level screening information and do not establish individual daily noise exposure or regulatory exceedance. The findings identify several equipment sources that may warrant task-based exposure assessment, personal dosimetry, and noise-control evaluation. The study provides equipment-specific baseline information that can support a staged approach to noise risk assessment in university engineering laboratories.

1. Introduction

Noise is an important environmental and occupational factor in educational environments because excessive sound can interfere with communication, concentration, learning activities, and well-being. Educational environments differ substantially in their acoustic characteristics depending on building design, occupancy, activities, and equipment operation. Previous research has shown that acoustic conditions can influence students' learning-related activities and perceptions of their

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environment [1,2,3,4,5]. These findings indicate that noise assessment in educational settings should consider both acoustic comfort and potential occupational or task-related noise hazards.

Noise exposure in Malaysia is regulated under the Occupational Safety and Health (Noise Exposure) Regulations 2019 [6]. The Regulations define excessive noise in relation to daily noise exposure exceeding 82 dB(A), daily personal noise dose exceeding 50%, maximum sound pressure level exceeding 115 dB(A) at any time, or peak sound pressure level exceeding 140 dB(C). The Regulations also establish an 85 dB(A) daily noise exposure limit for an eight-hour working day, with a 3-dB exchange rate [6]. Importantly, these criteria are intended for assessment of occupational noise exposure and personal noise dose rather than direct classification of individual equipment based solely on a measured sound level.

Accordingly, the regulatory values are used in this study only as reference points for source-level screening. An equipment source with an LAeq above 82 or 85 dB(A) should not be interpreted as demonstrating that a student or laboratory worker has exceeded the corresponding daily exposure criterion. Actual personal exposure depends on the duration of exposure, distance from the source, frequency and duration of laboratory activities, simultaneous operation of multiple noise sources, and individual movement within the laboratory. Therefore, equipment producing elevated sound levels should be regarded as a priority for further exposure assessment rather than as evidence of regulatory exceedance by an individual.

Engineering laboratories represent a distinct acoustic environment compared with conventional classrooms. Practical training may involve machinery, pneumatic tools, ventilation systems, compressors, shredders, lathes, milling machines, and wind tunnels, which can generate substantially higher sound levels than ordinary teaching spaces. Students and laboratory personnel may work near these sources while conducting experiments, operating equipment, observing demonstrations, or completing practical assignments [8]. However, the presence of a high-noise source does not by itself establish an individual's daily noise exposure because exposure depends on the duration of the activity, distance from the source, frequency of laboratory sessions, simultaneous operation of equipment, and movement of the individual within the laboratory.

Previous research has demonstrated that noise is present in educational, technical training, and university environments, but the existing studies have used different assessment approaches and addressed different exposure questions. For example, Misran and Ismail [7] investigated noise in university laboratories, providing an initial assessment of laboratory noise sources. Abdul Rahim et al. [8] subsequently examined noise associated with training activities, machines, equipment, and power tools in Malaysian TVET institutions and incorporated both source measurements and task-based exposure assessment. Their findings demonstrated that training activities can generate substantial noise levels and highlighted the importance of identifying sources for noise-control planning. Similarly, Khasawneh et al. [9] characterized environmental noise at the USM Engineering Campus using measurements at 30 spatial locations and noise mapping, providing a campus-scale environmental perspective rather than an equipment-specific assessment. More recently, Torres-Cobo et al. [10] investigated occupational noise in a university setting using dosimetry assessment, demonstrating the value of personal or area-based exposure assessment for understanding cumulative noise exposure.

Despite these contributions, a specific gap remains in the systematic characterization and comparison of noise generated by individual engineering laboratory equipment within a Malaysian university setting. Existing studies have generally emphasized laboratory or training-environment noise, task-based exposure, campus-scale environmental noise, or personal dosimetry [8, 9]. Less attention has been given to establishing an equipment-level noise profile across different types of engineering laboratory machinery using multiple acoustic descriptors, including LAeq, Lmax, and

Lpeak, under operating conditions. Such source-level information is useful as a preliminary screening tool for identifying equipment that warrants subsequent personal exposure assessment and noise-control evaluation. Therefore, the present study does not seek to determine students' daily personal noise exposure. Instead, it provides equipment-specific acoustic characterization of selected engineering laboratory sources and uses the findings to identify sources that may warrant priority for more detailed exposure assessment.

These regulatory values provide a useful framework for interpreting noise measurements in engineering laboratories, but care is needed when making comparisons. Despite the potential for significant noise generation in engineering laboratories, relatively limited research has examined equipment-specific noise levels in Malaysian university laboratory environments. Existing studies have addressed noise in technical training and laboratory settings, but further equipment-specific evidence is needed to identify the sources that should receive priority for exposure assessment and control.

Therefore, this study was conducted to assess noise generated by equipment in selected university engineering laboratories. The study focused on three acoustic parameters: mean A-weighted noise level, maximum noise level (Lmax), and peak noise level (Lpeak). Fourteen noise sources across the Composite, General Machining, and Aerospace Laboratories were assessed. The study also compared the measured noise levels with selected Malaysian occupational noise reference values to identify equipment that may require further exposure assessment and noise-control measures. By providing equipment-specific noise information, the study aims to contribute to a better understanding of noise hazards in engineering education and support the development of safer laboratory environments for students and laboratory personnel.

The contribution of this study is therefore not the estimation of individual student noise dose, but the development of an equipment-level noise profile that can support subsequent exposure assessment and laboratory noise management. By measuring 14 individual sources across three engineering laboratory environments and examining LAeq, Lmax, and Lpeak, the study provides a source-specific screening dataset that can be used to identify equipment requiring closer investigation. This source-level approach complements existing campus-scale, task-based, and dosimetric studies by focusing on the identification and characterization of individual noise-generating equipment before personal exposure assessment is undertaken.

2. Methodology

2.1 Study Area and Noise Measurement

The study was conducted in three engineering laboratories at Universiti Teknologi MARA (UiTM) Shah Alam, Selangor, Malaysia. The selected laboratories were the Composite Laboratory, General Machining Laboratory, and Aerospace Laboratory. The Composite Laboratory contained equipment including a shredder, air gun, air filter, and fume-air system. The General Machining Laboratory contained lathe and milling machines, while the Aerospace Laboratory contained an aeronautical wind tunnel. Noise exposure measurements were conducted using a Larson Davis SoundAdvisor Class 1 Sound Level Meter. A Larson Davis CAL200 acoustic calibrator was used for instrument calibration. Pre- and post-measurement calibration was performed with a precision of 0.5 dB(A). The sound level meter recorded samples at 10-second intervals and measured A-weighted equivalent continuous sound level (LAeq) [9].

Measurements were conducted at approximately 1.0 m from each noise source and 1.0 m above the floor. At least three measurements were obtained for each noise source, and the mean value was used to represent the measured sound level [11]. Because the machinery operated continuously

during measurements, background noise could not be completely eliminated. Consequently, the measured values represent the noise environment while the respective sources were operating.

The measurements were conducted while the respective equipment was operating under the available laboratory operating conditions. Therefore, the measured values represent sound levels associated with the selected equipment and measurement conditions rather than the daily personal noise exposure of students or laboratory personnel. Background sound from other operating activities could not be completely eliminated and may have contributed to the measured values.

Three acoustic parameters were considered in the assessment: mean A-weighted noise level, maximum noise level (Lmax), and peak noise level (Lpeak). These parameters were selected to provide a more comprehensive description of the noise generated by the laboratory equipment. The mean noise level was used to describe the general noise level associated with each equipment source, Lmax was used to identify the highest time-weighted noise level, and Lpeak was used to identify the highest instantaneous sound-pressure event [12, 13].

2.2 Statistical Analysis

Descriptive statistical analysis was conducted to summarize the noise characteristics of the 14 assessed equipment sources. The analysis included the mean, standard deviation (SD), minimum, maximum, and median for the three acoustic parameters: mean noise level, Lmax, and Lpeak.

Because the study was designed as a source-level screening assessment and did not include personal dosimetry or individual exposure-duration measurements, no daily personal noise dose was calculated. The measured equipment noise levels were therefore interpreted descriptively and as indicators for prioritizing equipment for further exposure assessment rather than as direct evidence of occupational exposure-limit exceedance.

3. Result and Discussion

3.1 Noise Levels and Exposure Characteristics of Engineering Laboratory Equipment

The measured noise levels varied considerably across the three engineering laboratories, demonstrating that noise characteristics were strongly influenced by the type and operating characteristics of the equipment. As presented in Table 1, the Composite Laboratory exhibited the highest overall equipment noise levels, followed by the Aerospace Laboratory and General Machining Laboratory. This variation is consistent with the different operating mechanisms of the equipment, particularly the use of pneumatic, ventilation, cutting, and high-speed airflow systems, which can generate substantially higher sound pressure levels than conventional machining equipment.

In the Composite Laboratory, four noise-producing sources were assessed, namely the shredder, air gun, air filter, and Fume-Air 750. The air gun produced the highest mean noise level at 92.9 dB(A), followed by the air filter at 91.7 dB(A) and Fume-Air 750 at 90.7 dB(A). The shredder recorded a lower mean level of 83.7 dB(A). Thus, three of the four sources exceeded 85 dB(A), while all four sources were at or above the 82 dB(A) level used by Malaysian regulations to identify excessive noise. The relatively high levels recorded for the air gun and air-handling equipment may be associated with turbulent airflow, pneumatic discharge, vibration, and high-velocity air movement during operation.

The Lmax and Lpeak measurements further demonstrate that the acoustic environment around these sources was characterized not only by relatively high continuous noise but also by short-duration increases in sound pressure. The air gun recorded a Lmax of 103.7 dB(A) and an Lpeak of 121.8 dB(C), representing the highest values among all equipment investigated. Although these values remained below the Malaysian regulatory criteria of 115 dB(A) for maximum sound pressure

level and 140 dB(C) for peak sound pressure, they demonstrate that the air gun can generate substantially higher instantaneous noise than its mean operating level. This distinction is important because students or laboratory personnel may experience intermittent high-level noise during particular tasks even when their overall daily exposure remains uncertain. The Malaysian Industry Code of Practice similarly emphasizes the importance of considering maximum and peak sound pressure levels in addition to daily noise exposure.

Table 1
Summary of noise exposure levels

Laboratory	Noise source	Mean noise level, dB(A)	Lmax dB(A)	Lpeak dB(C)
Composite	Shredder	83.7	92.8	106.6
Composite	Air gun	92.9	103.7	121.8
Composite	Air filter	91.7	97.6	114.9
Composite	Fume-air 750	90.7	98.5	114.8
General Machining	Lathe L5	80.3	87.2	100.4
General Machining	Lathe L4	81.9	91.1	100.7
General Machining	Lathe L3	76.3	84.5	95.8
General Machining	Lathe L2	74.5	83.6	95.9
General Machining	Milling M5	68.2	76.4	89.3
General Machining	Milling M4	70.8	79.1	92.5
General Machining	Milling M3	67.8	73.9	83.7
General Machining	Milling M2	78.1	85.9	99.8
General Machining	Milling M1	71.6	81.3	92.6
Aerospace	Aeronautical wind tunnel	89.4	96.8	112.7

The findings are consistent with previous research conducted in Malaysian educational and technical-training environments [8]. A study of noise levels associated with skill-training activities in Malaysian TVET institutions reported that machinery, equipment, and practical training activities can generate substantial occupational noise exposure and emphasized the value of combining source measurements with task-based and personal exposure monitoring. Similarly, recent investigations at the UiTM Faculty of Engineering have identified machinery-generated noise as an important issue requiring source identification, noise mapping, and appropriate control measures. Therefore, the relatively high noise levels observed in the Composite Laboratory are not isolated to the present study but reflect a broader pattern in engineering and technical-training environments where practical activities involve machinery and powered equipment.

The General Machining Laboratory showed comparatively lower noise levels. The four lathe machines recorded mean noise levels between 74.5 and 81.9 dB(A), while the milling machines ranged from 67.8 to 78.1 dB(A). Lathe L4 produced the highest mean level at 81.9 dB(A), followed by Lathe L5 at 80.3 dB(A). None of the individual equipment sources recorded a mean LAeq above 82 dB(A). Nevertheless, several machines produced Lmax values above 85 dB(A), including Lathe L4 at 91.1 dB(A) and Lathe L5 at 87.2 dB(A). This indicates that equipment with a relatively moderate mean sound level can still produce short-duration increases in noise during particular operating conditions.

The results therefore suggest that assessment based solely on mean LAeq may underestimate the practical significance of intermittent noise generated during machining operations. This is particularly relevant in educational laboratories because students may move between several machines, while instructors or laboratory technicians may remain in the laboratory for longer periods. Consequently, the measured source levels should be regarded as indicators for identifying potentially noisy tasks and locations rather than as direct estimates of an individual's daily noise dose.

This interpretation is supported by previous Malaysian TVET research, which used task-based monitoring and personal dosimetry to determine how individual training activities contributed to

daily noise exposure [8]. Such an approach is particularly relevant to laboratory environments because exposure depends not only on the sound level of an individual machine but also on the duration of the activity and the sequence of tasks undertaken by an individual.

The Aerospace Laboratory also demonstrated a potential noise exposure concern. The aeronautical wind tunnel recorded a mean noise level of 89.4 dB(A), with a Lmax of 96.8 dB(A) and a Lpeak of 112.7 dB(C). The mean level was substantially above the 82 dB(A) excessive-noise identification level and also exceeded the 85 dB(A) daily Noise Exposure Limit when interpreted as an equivalent continuous exposure over the relevant reference period. However, because the present study measured equipment noise rather than an individual's complete workday exposure, the result should not be interpreted as evidence that students or laboratory personnel necessarily exceeded their daily personal NEL.

The relatively high wind-tunnel noise is nevertheless important from a preventive occupational health perspective. High-speed airflow, aerodynamic turbulence, vibration, and associated mechanical systems can produce sustained broadband noise, potentially exposing individuals working close to the equipment. Similar concerns have been identified in research on educational and technical laboratories, where machine-generated noise has been recognized as an important occupational and learning-environment issue [14]. A recent study of power-loom noise in a textile engineering laboratory, for example, specifically assessed noise exposure among students and laboratory technicians because practical training activities can create conditions requiring additional noise-control and awareness measures [15].

The present findings are also comparable with recent Malaysian research on machine-generated noise. A large-scale assessment of 796 machines in Malaysian manufacturing facilities found that 53.5% of machines exceeded 82 dB(A), while 35.6% exceeded 85 dB(A), demonstrating that machine-level noise above the Malaysian excessive-noise and NEL-related thresholds is not uncommon in machinery-intensive environments [16]. Although manufacturing workplaces differ from university laboratories in terms of operating duration and worker exposure patterns, the comparison supports the interpretation that equipment generating noise above 82–85 dB(A) should be prioritized for further exposure assessment and noise-control consideration.

3.2 Overall Distribution of Equipment Noise Levels

Table 2 summarizes the acoustic characteristics of the 14 equipment sources assessed in the three laboratories. The overall mean LAeq was 79.85 dB(A), with a standard deviation of 8.83 dB(A), indicating substantial variation between equipment types. The measured LAeq values ranged from 67.8 to 92.9 dB(A), with a median of 79.20 dB(A). The mean Lmax was 88.03 dB(A) (SD = 9.00), ranging from 73.9 to 103.7 dB(A), while the mean Lpeak was 101.54 dB(C) (SD = 11.14), with values ranging from 83.7 to 121.8 dB(C).

The difference between the mean LAeq and Lmax values demonstrates the importance of considering the temporal characteristics of laboratory noise. While the overall mean equipment level was below 82 dB(A), several individual sources produced substantially higher mean, maximum, and peak levels. In particular, the Composite Laboratory equipment accounted for the highest values observed in the dataset. The air gun recorded the highest LAeq, Lmax, and Lpeak values of 92.9 dB(A), 103.7 dB(A), and 121.8 dB(C), respectively. This indicates that the Composite Laboratory represents the principal area requiring further investigation of task duration, operator position, and personal exposure.

Five of the 14 equipment sources (35.7%) recorded LAeq values above 82 dB(A), while four sources (28.6%) recorded LAeq values above 85 dB(A). These proportions are noteworthy because

they indicate that more than one-third of the assessed equipment sources were associated with sound levels at or above the Malaysian excessive-noise identification level. However, these percentages should not be interpreted as the proportion of students or laboratory personnel exceeding the regulatory daily noise exposure limit. The Malaysian regulations assess excessive noise and daily personal exposure using exposure duration and cumulative dose, rather than relying solely on a single equipment-level LAeq measurement.

Table 2
The descriptive statistics for the 14 equipment sources

Acoustic parameter	Mean	SD	Minimum	Maximum	Median
Mean noise level, dB(A)	79.85	8.83	67.8	92.9	79.20
Lmax, dB(A)	88.03	9.00	73.9	103.7	86.55
Lpeak, dB(C)	101.54	11.14	83.7	121.8	100.10

The Malaysian Industry Code of Practice provides exposure-duration guidance illustrating why duration is important. At 82 dB(A), the indicative daily exposure duration is 16 hours, whereas at 85 dB(A) it is 8 hours; the allowable duration decreases progressively as sound level increases. For example, the corresponding duration is approximately 2 h 31 min at 90 dB(A) and 1 h 35 min at 92 dB(A) [17]. Therefore, the 90–93 dB(A) equipment levels measured in the Composite Laboratory could become particularly important if students or laboratory personnel remain close to these sources for extended periods.

The results are broadly consistent with previous investigations in Malaysian educational and technical-training settings. Research conducted in Malaysian TVET institutions has demonstrated that practical training activities involving machinery can contribute meaningfully to daily noise exposure and has emphasized the use of task-based assessment and personal dosimetry rather than source measurement alone [8]. Research at UiTM has likewise identified engineering laboratory and workshop environments as locations where equipment-generated noise can exceed the excessive-noise criterion, supporting the need for noise mapping, awareness, and preventive controls [18].

An important contribution of the present study is therefore its equipment-specific characterization across three different engineering laboratory environments. Whereas previous studies have often focused on overall laboratory noise, noise mapping, or personal exposure, the present assessment distinguishes individual equipment sources and reports LAeq, Lmax, and Lpeak simultaneously. This provides a more detailed indication of which equipment should be prioritized for subsequent exposure assessment and control.

3.3 Implications for Noise Control and Laboratory Safety

The findings have practical implications for the management of noise in engineering laboratories. Equipment with LAeq values exceeding 82 dB(A), particularly the air gun, air filter, Fume-Air 750, shredder, and aeronautical wind tunnel, should receive greater attention during subsequent noise-risk assessment. The priority should not be based solely on the measured sound level but should also consider the frequency and duration of equipment use, the number of students exposed, the distance between operators and equipment, and whether multiple noise sources operate simultaneously.

Where feasible, engineering controls should be considered before relying solely on personal hearing protection. Potential measures include equipment enclosure or acoustic barriers, vibration isolation, modification or maintenance of pneumatic systems, silencers for compressed-air equipment, optimization of ventilation and extraction systems, equipment relocation, and increasing

the distance between the operator and the principal noise source [19]. DOSH guidance emphasizes the importance of controlling noise at source and provides guidance for equipment noise specifications and noise-control planning [20].

Administrative controls may subsequently be used to reduce exposure duration, particularly for equipment producing levels around 90 dB(A) or higher. Laboratory scheduling, rotation of students between practical stations, limiting unnecessary operation of high-noise equipment, restricting access to high-noise areas, and providing hearing-conservation information can reduce cumulative exposure. Personal hearing protection should be considered where engineering and administrative controls are insufficient or where individuals enter areas in which hearing protection is required [21].

The findings also have implications beyond hearing conservation. Previous research in educational and vocational settings has highlighted that excessive noise can interfere with communication, concentration, and learning activities, while studies involving students exposed to machinery have investigated potential relationships between noise exposure and hearing outcomes. Therefore, although the present study did not evaluate health or cognitive outcomes, controlling high noise levels may contribute not only to occupational hearing protection but also to a safer and more effective laboratory learning environment.

3.4 Strengths and Limitations

This study provides equipment-specific noise measurements from 14 sources across three university engineering laboratories and incorporates three complementary acoustic indicators: LAeq, Lmax, and Lpeak. The use of a Class 1 sound level meter, together with pre- and post-measurement calibration, strengthens the measurement reliability. In addition, the inclusion of Composite, General Machining, and Aerospace laboratories enables comparison across different engineering activities and equipment types.

Nevertheless, several limitations should be acknowledged. First, the study measured noise generated by individual equipment rather than the personal daily exposure of students, laboratory technicians, or academic staff. Consequently, the results cannot establish whether any individual exceeded the Malaysian daily Noise Exposure Limit or personal noise dose. Second, measurements were conducted under specific laboratory operating conditions and may not represent all possible operating scenarios, including simultaneous operation of multiple machines. Third, background noise could not be completely eliminated because measurements were conducted during normal laboratory operation. Fourth, the study did not incorporate exposure duration, individual movement patterns, task sequence, or cumulative exposure from multiple sources. These factors are particularly important because daily personal exposure depends on both sound level and duration.

Finally, the study did not assess hearing status, noise annoyance, communication difficulties, concentration, stress, or other potential health and learning outcomes. These factors were beyond the scope of the present source-level acoustic assessment.

Future research should therefore extend the present findings through a combination of noise mapping, task-based monitoring, and personal dosimetry. This approach would allow the equipment-level measurements reported here to be translated into actual exposure profiles for students, laboratory technicians, and academic staff. Such an integrated approach has been adopted in Malaysian TVET research, where task-based measurements and dosimetry were used to determine the contribution of individual practical activities to daily noise exposure. Personal dosimetry should particularly target individuals working near the air gun, air filter, Fume-Air 750, shredder, and aeronautical wind tunnel, as these sources produced the highest LAeq values in the present study.

Overall, the findings demonstrate that although the average noise level across all 14 equipment sources was 79.85 dB(A), several individual machines generated substantially higher sound levels that warrant further exposure assessment. The results therefore support a source-to-exposure assessment framework, in which equipment-level measurements are used to identify priority sources, followed by task-duration assessment and personal dosimetry to determine actual individual exposure. This approach provides a more scientifically appropriate basis for evaluating compliance with Malaysian occupational noise requirements and for designing targeted noise-control measures in university engineering laboratories.

4. Conclusions

The findings showed clear differences in the noise levels produced by equipment across the three engineering laboratories at UiTM Shah Alam. The overall mean noise level for the 14 assessed sources was 79.85 dB(A), with individual measurements ranging from 67.8 to 92.9 dB(A). The air gun produced the highest mean noise level at 92.9 dB(A), followed by the air filter at 91.7 dB(A), Fume-Air 750 at 90.7 dB(A), and the aeronautical wind tunnel at 89.4 dB(A). Five equipment sources recorded noise levels above the Malaysian excessive-noise threshold of 82 dB(A), while four were above the 85 dB(A) Noise Exposure Limit. These results should be interpreted as indicative of equipment-level noise rather than individual daily exposure. None of the measured sources exceeded the maximum sound pressure limit of 115 dB(A) or the peak sound pressure limit of 140 dB(C). Therefore, the findings suggest that some equipment used in engineering laboratories can produce relatively high noise levels and may contribute to students' and staff's noise exposure during practical and labs activities. Although equipment measurements alone cannot determine a person's full-shift exposure, they are useful for identifying noisy equipment and areas that require greater attention. Regular noise monitoring, personal dosimetry where necessary, engineering controls, administrative measures, hearing protection, and appropriate safety education should therefore be incorporated into laboratory safety practices. These measures can help provide a safer environment while allowing students to gain practical engineering experience.

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