Integrating a Practical Fume Hood Face Velocity Experiment in Teaching and Learning: Comparing 150 mm and 300 mm Grid Methods for Industrial Hygiene Students

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ABSTRACT

Fume hoods are important engineering controls in laboratories. Face velocity measurements are commonly used to assess airflow across the sash opening. This paper presents a laboratory experiment for industrial hygiene students comparing two nominal grid sizes: 150 mm × 150 mm and 300 mm × 300 mm. A hot-wire anemometer was used to measure face velocity at 40 sampling points with the finer grid (150 mm × 150 mm) and 10 sampling points with the coarser grid (300 mm × 300 mm). Measurements were repeated three times for each grid configuration. The recorded readings were in meters per second (m/s). The mean face velocity was 0.6705 m/s for the 150 mm grid and 0.6360 m/s for the 300 mm grid. The absolute difference was 0.0345 m/s, corresponding to a 5.42% increase in mean face velocity relative to the coarse-grid measurement. The finer grid produced a higher mean in this measurement session, but this result does not establish that it is more accurate. The experiment provides a straightforward way for students to practice airflow measurement, calculate means, compare results, and discuss how sampling layout affects a reported value. The comparison is limited to the measured hood and conditions; face velocity alone does not demonstrate containment performance.

Keywords: Fume Hood; Face Velocity; Hot-Wire Anemometer; Grid Sizes; Industrial Hygiene; Laboratory Experiment

INTRODUCTION

Under the Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000 (USECHH Regulations), engineering controls are used to reduce employees' exposure to chemicals hazardous to health. These controls include local exhaust ventilation (LEV), water sprays, enclosure, and isolation (Department of Occupational Safety and Health [DOSH], 2000, 2008). Engineering controls remain important because they can capture or control contaminants before they spread into the workplace (Mahaki et al., 2022; Lin et al., 2024).

In Malaysia, engineering control equipment is subject to inspection, examination, and testing requirements. Regulations 17 and 18 of the USECHH Regulations 2000 specify inspection at intervals not exceeding one month and thorough examination and testing at intervals not exceeding twelve months by a registered Hygiene Technician (DOSH, 2000). The DOSH guidelines provide further guidance on the design, inspection, testing, and examination of LEV systems (DOSH, 2008). Recent work on LEV performance also demonstrates the value of measuring airflow and evaluating the effectiveness of contaminant capture under workplace conditions (Ngali & Mustaffa, 2023).

Laboratory fume hoods are a common example of local exhaust ventilation systems designed to reduce exposure to hazardous airborne contaminants. Their performance depends on hood design, exhaust airflow, sash position, and surrounding air currents (American Society of Heating, Refrigerating and Air-Conditioning

Engineers [ASHRAE], 2016, 2023). Face velocity measurement is one method used to assess airflow at the hood opening. ANSI/ASHRAE Standard 110 describes procedures for measuring face velocity at defined grid locations (ASHRAE, 2016).

Recent research has reviewed developments in face velocity measurement, airflow visualization, and tracer-gas testing for evaluating fume hood performance (Chen, 2025). Experimental and computational studies have also examined the control of nanoparticles and gases by different fume hood designs (Lin et al., 2024). However, face velocity alone does not establish the complete containment performance of a fume hood (Chen, 2025).

In industrial hygiene education, students need opportunities to apply measurement procedures, handle instruments correctly, record observations, and interpret results. Practical exercises allow students to connect ventilation theory with workplace assessment. Reviews of science laboratory teaching highlight the importance of practical skills, conceptual understanding, and experimental competence (Agustian et al., 2022; Oliveira & Bonito, 2023).

Active learning and challenge-based approaches have also been examined as ways to support student engagement and learning in science and engineering (Doulougeri et al., 2024; Ridani & Arianingrum, 2024). Research on virtual laboratory approaches further considers how practical learning activities can be supported in engineering education (Li & Liang, 2024). These findings support the use of practical ventilation measurements as an educational activity.

Although standardized procedures describe how face velocity should be measured, the choice of measurement grid can influence the reported mean velocity. ANSI/ASHRAE Standard 110-2016 provides a framework for testing laboratory fume hood performance (ASHRAE, 2016). A coarse grid (300 mm × 300 mm) requires fewer measurements and less time but might miss detailed local airflow variations.

In contrast, a finer grid (150 mm × 150 mm) provides greater spatial resolution at the cost of additional measurement time. This study compares the two configurations to examine how sampling density influences the measured mean face velocity. The comparison is intended for educational purposes and does not replace standardized fume hood performance testing.

Airflow around a fume hood can also be affected by disturbances near its opening. Mahaki et al. (2022) investigated how human movement affects the capture efficiency of an LEV system. Similarly, Shen et al. (2022) examined the effects of body wake and operator motion on fume hood containment using computational fluid dynamics. Lin et al. (2024) further examined fume hood performance for nanoparticle and isopropanol control.

These studies indicate that airflow distribution and containment depend on more than the mean velocity alone. Comparing two grid layouts can therefore help students understand the importance of measurement location and sampling density. Nevertheless, direct experimental comparison is needed to establish the differences between the two layouts under the conditions tested.

This experiment uses a hot-wire anemometer to compare face velocity measurements obtained from two grid layouts on the same laboratory fume hood. The hood and operating conditions are kept as consistent as possible during the comparison. Students calculate the mean velocity for each layout and examine the differences in the resulting values.

The exercise is intended as an educational comparison rather than a replacement for the full standardized assessment of fume hood performance. This approach is consistent with research emphasizing practical and experiential learning in engineering education (Tembrevilla et al., 2024). It also encourages students to consider measurement uncertainty, spatial variation, and the limitations of using a single mean value to describe airflow.

The primary objectives of this educational experiment paper are

1. To provide a straightforward, practical exercise for industrial hygiene students to practice face velocity measurement using a thermal hot-wire anemometer.

2. To enable students to calculate mean velocities, compare empirical results, and analyse data obtained from two different grid layouts (150 mm × 150 mm vs. 300 mm × 300 mm).

3. To facilitate critical discussion on how sampling grid resolution affects reported average face velocity values and the detection of local airflow variations in laboratory environments.

METHODOLOGY

Study Design

This is a practical measurement-comparison experiment for teaching. The same fume hood was measured using both grid layouts under as similar operating conditions as possible. The sash was maintained at its maximum opening throughout the measurements. The fan or exhaust setting, room doors and windows, nearby air supply, and items inside the hood were kept unchanged during the comparison.

Equipment

The equipment used in this study included a hot-wire anemometer (TSI Airflow Instruments Velocity Meter, Model TA430), a measuring tape, thread for marking the measurement grid, a recording sheet, and a sensor holder. The anemometer was operated in accordance with the manufacturer's instructions (TSI Incorporated, 2022). A sensor holder was used to maintain consistent sensor positioning and orientation during measurements. The instrument's calibration status was checked before measurement.

Grid Layout

The physical dimensions of the fume hood sash opening were measured as 1422 mm in width and 457 mm in height. Based on these measurements, two grid layouts were constructed. The fine grid (150 mm nominal size) consisted of 40 sampling cells (10 columns × 4 rows). Meanwhile, the coarse grid (300 mm nominal size) comprised 10 sampling cells (5 columns × 2 rows). All calculated grid counts were rounded up to the nearest whole number to ensure that the dimensions of each grid cell did not exceed the respective nominal grid size.

Measurement Procedure

Face velocity was measured at the centre of each grid cell using a calibrated TSI Airflow Instruments Velocity Meter (Model TA430). Before measurement, a zero check was performed by covering the hot-wire sensor and checking that the instrument displayed a zero reading. The sensor was then uncovered for face velocity measurements. At each sampling location, the instrument’s running-average function was used to obtain an average face velocity over a 20-second measurement period, with the display updating at 1-second intervals. Measurements were conducted with the fume hood sash at its maximum opening.

The procedure was repeated three times for each grid configuration, beginning with the coarse grid (300 mm nominal size), followed by the fine grid (150 mm nominal size), while maintaining the same measurement conditions. For each trial, the mean face velocity was calculated by averaging the cell-level mean velocities across all sampling locations. The final mean for each grid configuration was determined by averaging the mean velocities from the three trials. The instrument was operated in accordance with the manufacturer’s instructions (TSI Incorporated, 2022).

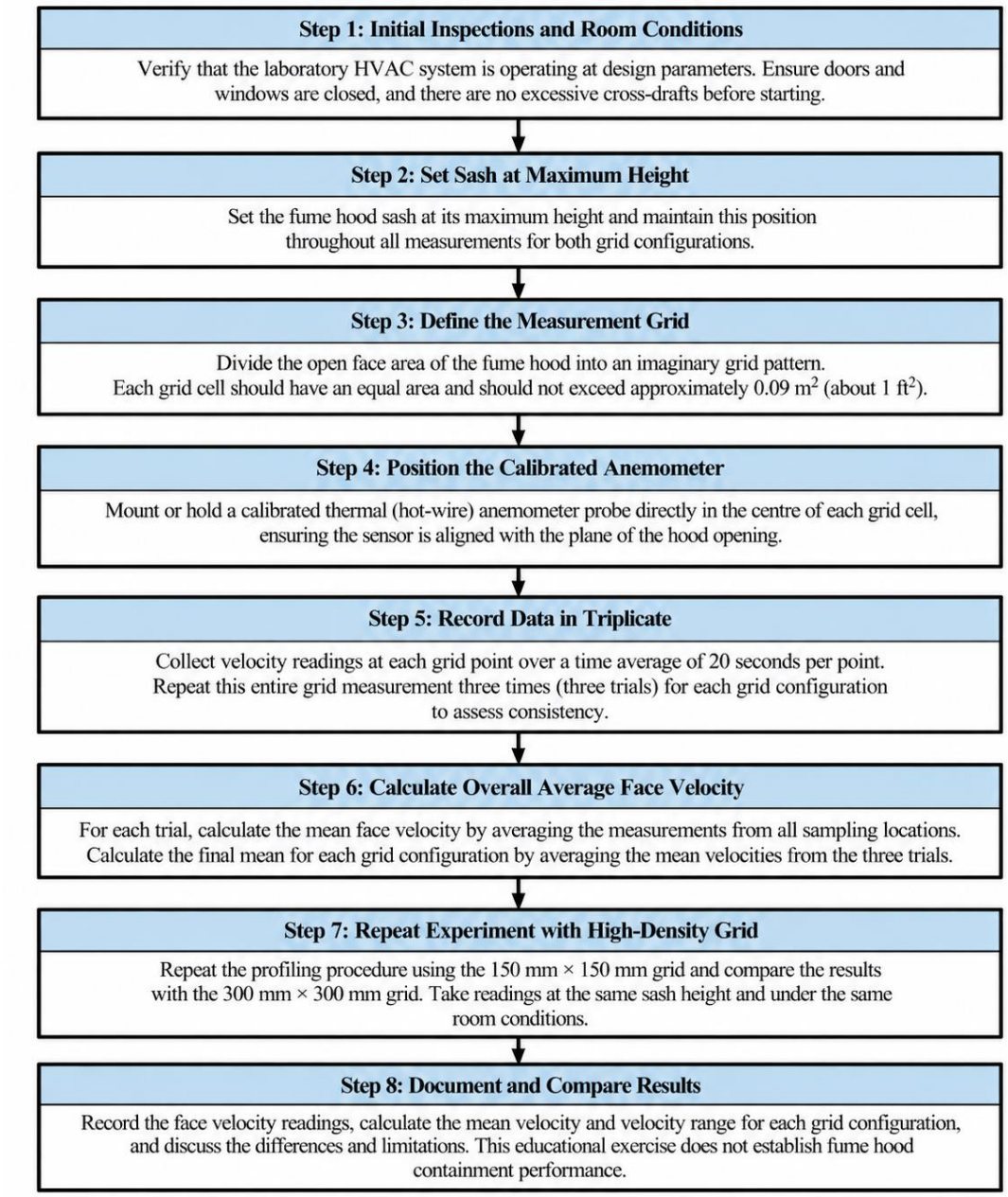


Figure 1. Flowchart of Fume Hood Face Velocity Testing and Profiling Methodology.

RESULTS

Grid Configuration and Face Velocity Profiles

The physical dimensions of the fume hood sash opening were measured as 1422 mm in width and 457 mm in height. Based on these measurements, two grid layouts were constructed. The fine grid (150 mm nominal size) consisted of 40 sampling cells (10 columns × 4 rows). Meanwhile, the coarse grid (300 mm nominal size) comprised 10 sampling cells (5 columns × 2 rows). All calculated grid counts were rounded up to the nearest whole number to maintain the grid cell dimensions within the maximum size limits.

Table 1: Summary of Sash Opening and Grid Layout Configurations

Parameter	Fine Grid (150 mm)	Coarse Grid (300 mm)	Calculation Basis
Horizontal Grid Divisions	10 columns	5 columns	1422 mm / Grid Size
Vertical Grid Divisions	4 rows	2 rows	457 mm / Grid Size
Total Grid Cells	40 cells	10 cells	Columns × Rows
Actual Cell Size (W × H)	142.2 × 114.25 mm	284.4 × 228.5 mm	Sash Dim. / Division

Table 2: Average Face Velocity Measurement Data for Fine Grid (150 mm × 150 mm, 40 cells)

Row / Col	1	2	3	4	5	6	7	8	9	10
Row A (m/s)	0.75	0.72	0.63	0.62	0.69	0.69	0.69	0.69	0.70	0.75
Row B (m/s)	0.82	0.67	0.67	0.59	0.60	0.60	0.63	0.62	0.66	0.72
Row C (m/s)	0.77	0.67	0.62	0.56	0.57	0.58	0.59	0.61	0.64	0.72
Row D (m/s)	0.78	0.77	0.75	0.66	0.65	0.64	0.64	0.65	0.69	0.75

Table 3: Average Face Velocity Measurement Data for Coarse Grid (300 mm × 300 mm, 10 cells)

Row / Col	1	2	3	4	5
Row 1 (m/s)	0.69	0.61	0.60	0.61	0.62
Row 2 (m/s)	0.70	0.64	0.58	0.61	0.70

Comparative Analysis and Percentage Difference

To evaluate the impact of grid resolution on fume hood face velocity assessment, the overall mean velocities and range values obtained from both grid configurations were compared. The overall average face velocity for the fine grid (150 mm × 150 mm) was 0.6705 m/s, whereas the coarse grid (300 mm × 300 mm) yielded an average of 0.6360 m/s.

The percentage increase in mean face velocity obtained using the fine grid relative to the coarse grid was calculated using the following formula:

$$\text{Percentage increase (\%)} = \left(\frac{0.6705 - 0.6360}{0.6360}\right) \times 100 = 5.42\ \%$$

Table 4: Statistical Comparison between Fine Grid and Coarse Grid Measurements

Statistical Parameter	Fine Grid(150 mm)	Coarse Grid (300 mm)
Total Number of Sampling Points	40 points	10 points
Average Face Velocity (m/s)	0.6705 m/s	0.6360 m/s
Velocity Range (Min – Max)	0.56 – 0.82 m/s	0.58 – 0.70 m/s
Percentage increase (%)	5.42% higher than coarse grid	Baseline

The fine grid method recorded a 5.42% higher mean face velocity than the coarse grid method. The finer grid also recorded a wider range of face velocities (0.56–0.82 m/s) than the coarser grid (0.58–0.70 m/s). These findings suggest that the finer grid captured greater variation in the measured face velocities under the conditions tested. However, the observed differences do not establish that the finer grid is more accurate.

DISCUSSION

The main educational value of this activity is that students can see how the layout of measurement points can affect a reported mean. A finer grid includes more measurement locations and may show local changes across the opening in greater detail, whereas a coarser grid requires fewer readings but may not capture all local differences. In the current dataset, the mean from the 150 mm grid was 0.6705 m/s and the mean from the 300 mm grid was 0.6360 m/s, giving a percentage increase of 5.42%.

The higher mean face velocity obtained using the 150 mm grid reflects a difference in spatial sampling resolution rather than evidence of greater measurement accuracy. Although the finer grid provides more detailed information on airflow variation across the sash opening, accuracy cannot be established from the mean values alone. Further evaluation using a suitable reference method and consideration of measurement uncertainty would be required to determine whether either grid configuration provides more accurate results.

The results should be interpreted with the physical behavior of the hood in mind. Air does not always enter uniformly across a sash opening. Local obstructions, the position of internal baffles, room air currents, sash

geometry, and the user's position can affect readings. Published observations have reported substantial variation in face velocity across hoods and over time, which supports the need to record conditions and avoid relying on a single point. A single average can hide local low-velocity areas, so the map and range should be discussed alongside the mean.

The 120 readings from the finer grid (40 sampling points × 3 trials) and 30 readings from the coarser grid (10 sampling points × 3 trials) represent different spatial sampling layouts on the same hood. They should not be treated as independent replicates. The simple mean and percentage-increase calculation is suitable for demonstrating the comparison to students, provided the limitations are clearly explained. Further measurements on additional hoods and on different days would be needed before making broader claims.

Although each grid configuration was measured in three trials, trial-level results and between-trial standard deviations are not presented in this manuscript. The reported comparison should therefore be interpreted descriptively and does not provide a quantitative estimate of repeatability. Measurement uncertainty should also be considered in relation to the instrument specifications and potential sources of variation, including probe positioning, orientation, and changes in airflow.

The experiment has limitations. It uses a limited number of measurement locations and may involve only one hood. Its findings may not apply to other hood models, room layouts, exhaust systems, or sash heights. The hot-wire instrument has its own stated uncertainty and response characteristics. The operator can also affect readings through sensor angle, position, and movement near the opening. These limitations should be stated openly. Repeating the test on multiple hoods and on different days would improve the value of the evidence.

A further limitation is that face velocity is not the same as containment. This experiment does not test whether a hood captures a particular chemical release, and it should not be used alone to approve a hood for hazardous work. Standard performance evaluation can include face-velocity measurement, visualization of airflow, and tracer-gas testing, depending on the purpose and applicable procedure (ASHRAE, 2016). The learning outcome is therefore correct measurement and careful interpretation, not a claim that a hood is safe based only on the average.

For teaching, students can be asked to explain the trade-off between measurement detail and effort, identify the largest and smallest readings, explain why the mean may hide local differences, and decide whether the observed difference is important for the stated purpose. Their report should separate what the data show from what they infer. This approach is consistent with laboratory teaching that asks students to collect evidence, select suitable statistical summaries, and explain uncertainty rather than simply follow a set of steps.

Educational Application

The activity can be delivered in a 120 minute practical session. Before the session, students review the purpose of a fume hood, the principle of hot-wire anemometry, sensor orientation, and the difference between repeatability and accuracy. During the session, groups measure the sash, set up both grids, collect readings, and maintain a shared record. After the session, students calculate descriptive statistics, compare survey means, create a simple graph, and write a short conclusion.

Assessment can cover four areas: correct instrument handling; consistent use of the grid and recording sheet; correct calculations and graphs; and interpretation that recognizes the limits of the experiment. A strong student report should not simply state that the 150 mm layout is better because it has more points. It should explain what extra information the finer layout provides, whether the survey means differ in the observed data, what the time cost is, and whether the evidence is sufficient to support the conclusion.

The activity also provides an opportunity to assess students' psychomotor, practical, and technical skills. These competencies can be evaluated using a structured assessment checklist covering instrument handling, measurement procedures, data recording, calculation accuracy, and interpretation of results. If the instructor wishes to measure learning gains, a short pre-test and post-test may be added, with questions on sensor orientation, grid layout, mean velocity, repeatability, and limitations of face-velocity testing. That is a separate

education outcome and requires its own participant information, scoring rules, and analysis. Student satisfaction alone should not be used as proof that the experiment improves learning.

CONCLUSION

This educational experiment compared fume hood face-velocity readings obtained using 150 mm and 300 mm grid layouts. The mean velocity was 0.6705 m/s for the 150 mm grid and 0.6360 m/s for the 300 mm grid. The absolute difference was 0.0345 m/s, corresponding to a 5.42% increase relative to the mean face velocity obtained using the coarse grid (300 mm). The finer grid produced the higher mean in this session, but the comparison does not establish that it is more accurate or that the hood provides adequate containment. The analysis was kept simple: the number of readings, mean face velocity, absolute difference, and percentage increase. All velocity results are reported in m/s. The activity is suitable for helping industrial hygiene students practice measurement and basic data interpretation. Future work should repeat the comparison under documented conditions and include additional hoods if the aim is to generalize the findings.

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