No Left-Hander Left Behind: Finding the Right Way in the Physics Laboratory

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Abstract

Laboratory work is central to physics education, yet the design of laboratory instruments, demonstrations, and safety procedures almost universally assumes right-handed operation. This study investigates the disadvantages that left-handed students face in high school physics laboratories through three complementary approaches. First, a handedness survey of 4,226 Grade 10–12 students across three public high schools in China revealed that while 9.5% of students were naturally left-handed, over three-quarters had been corrected to write with their right hand, leaving only 2.2% who still used their left hand — a finding that highlights the extent to which cultural correction masks the true scale of the affected population. Second, a measurement experiment using vernier calipers ($N = 583$) showed that both left-handed and corrected left-handed students exhibited higher error rates (53% and 52%, respectively) than right-handed students (31%), with a Kruskal–Wallis test confirming significant group differences ($H = 11.73$, $p = 0.003$). Video behavioural coding ($N = 51$) further revealed that left-handed students required longer task completion times (median 165 s vs. 118 s) and substantially more frequent re-grasping of the instrument (median 9 vs. 2), patterns corroborated by thermal imaging of grip distributions. Third, a classroom investigation of circular saw operation demonstrated that the interaction between tool asymmetry and operator handedness can extend beyond efficiency into safety: left-handed students tended to position their bodies within the potential kickback trajectory, a hazard not consistently recognised by the students themselves. Importantly, overall academic performance showed no meaningful differences among handedness groups, indicating that the observed laboratory disadvantages are environmentally imposed rather than intrinsic. The paper concludes with practical inclusive teaching strategies, including pre-laboratory handedness audits, body-neutral safety language, positional compensation training, and the use of symmetrically designed instruments as transitional scaffolding.

Keywords: left-handedness, physics laboratory, inclusive pedagogy, equipment asymmetry, cognitive load

1 Introduction

During a fabrication activity in the author's laboratory teaching, students were instructed to cut a piece of wood using a hand saw. The task was demonstrated by gripping the saw with the right hand while securing the wood with the left, following a standard handbook. One student, however, struggled to make a straight cut. The difficulty was initially assumed to stem from carelessness

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— until the student explained that she was left-handed and could not adapt to the right-handed demonstration.

This anecdote reflects a broader, systemic issue. According to the largest meta-analysis of handedness to date, synthesizing data from over 2.3 million individuals across 200 studies, approximately 10.6% of the global population is left-handed [1]. In a typical class of 30, roughly three students are likely to be left-handed. Yet in East Asian educational contexts, this population is substantially underrepresented in practice: cultural pressure to conform to right-handedness has historically led to widespread correction of left-handed children, producing an exceptionally low proportion of self-reported left-handers [2, 3, 4]. Neuroimaging evidence suggests that such forced switching is not merely a behavioural adjustment: structural MRI data show that individuals who were compelled to write with their right hand exhibit a reversal of interhemispheric asymmetry along the central sulcus and a significant reduction in left putamen grey-matter volume, indicating lasting environmental effects on basal-ganglia maturation [5]. The result is a doubly invisible population — small in number to begin with, and further concealed by correction — whose needs are easily overlooked [6].

The physics laboratory is a setting where this invisibility carries concrete consequences. Nearly all laboratory instruments are designed for right-handed operation [7], and pedagogical demonstrations are almost invariably performed right-handed. For left-handed learners, this creates what cognitive load theory terms *extraneous* load: cognitive effort arising not from the learning content itself but from the instructional format [8]. Left-handed students must continuously translate right-handed demonstrations into their own motor coordinates, a process of "mental mirroring" that neuroimaging research has shown to require additional cortical processing [9, 10, 11]. While students with poor eyesight are provided with corrective lenses and shorter students are offered front-row seats, left-handed students have rarely received comparable accommodations.

Despite these challenges, relatively little attention has been paid to handedness as a factor in physics laboratory instruction. The present study addresses this gap by investigating three questions. First, what is the actual distribution of handedness — including the prevalence of correction — among high school students, and how does it compare with global estimates? Second, do left-handed and corrected left-handed students exhibit measurable disadvantages in laboratory instrument use, specifically in measurement accuracy and operational behaviour when using a vernier caliper? Third, does the asymmetric design of common workshop tools introduce differential safety risks for left-handed operators? To answer these questions, the study draws on a large-scale survey of 4,226 students from three high schools, a controlled measurement experiment with behavioural video coding and thermal imaging, and a classroom investigation of hazard perception and body positioning during circular saw operation. Based on the findings, the study discusses instructional strategies aimed at fostering a more inclusive laboratory environment in which no left-handed student is left behind.

2 Survey of Handedness in Grade 10–12 Students

2.1 Motivation for the Survey

Previous research suggests that approximately 10% of the population is left-handed [1]. However, through informal observations during examination proctoring, the author noticed that very few students appeared to be writing with their left hand. This discrepancy between the expected prevalence and the observed behavior motivated a systematic survey to investigate students' handedness preferences.

2.2 Survey Method and Participants

Students' handedness preferences were assessed using a questionnaire adapted from the Edinburgh Handedness Inventory (EHI), a widely used instrument for evaluating hand preference in everyday activities [12]. The questionnaire asked students which hand they typically use for several common tasks, such as writing, brushing teeth, and throwing. In addition to these standard items, an additional item was included to identify students who were naturally left-handed but had been encouraged or required to switch to writing with their right hand. For students who indicated a left-hand preference on any item or who reported a history of correction from left to right hand, the questionnaire included an additional open-ended question asking them to describe any difficulties they had encountered in daily life or school activities because of their left-handedness.

The survey was administered to 4,226 students from Grades 10–12 across three public high schools. Data collection was conducted collaboratively by two physics teachers at the participating schools and the author. The questionnaire was distributed electronically, and responses were collected through an online survey platform.

In addition to the questionnaire, students' academic performance data were retrieved from the schools' online grading system. Specifically, the accuracy rates on examination items involving the left-hand rule and the right-hand rule were analyzed to explore whether handedness preference is associated with performance on tasks that involve hand-based physics mnemonics.

2.3 Results

Distribution of Handedness

The distribution of students' handedness preferences is summarized in Table 1. Among the 4,226 surveyed students, 92 (2.17%) reported a left-hand preference (L), while 308 (7.30%) reported that they were naturally left-handed but had been corrected to write with the right hand (C). A small number of students (n = 10, 0.24%) identified as mixed-handed without a history of correction; owing to the small sample size, this group was not analyzed further. The remaining 3,816 students (90.29%) were right-handed (R). Hereafter, we use L, R, and C to denote these three groups.

Table 1: Distribution of handedness preferences among surveyed students.

Handedness Group	**Label**	**n**	**Percentage**
Left-handed	L	92	2.17%
Corrected left-handed	C	308	7.30%
Mixed-handed	—	10	0.24%
Right-handed	R	3,816	90.29%
Total		**4,226**	**100%**

Overall Academic Performance

Because the three participating schools administered different examinations with varying levels of difficulty, and because the proportion of left-handed, right-handed, and corrected students differed across schools, raw scores could not be directly compared. To enable a fair cross-school comparison, each student's score was converted to a z-score by standardizing within the student's own school. The resulting mean z-scores were 0.05 for L students (n = 92), 0.00 for R students (n = 3,816), and −0.03 for C students (n = 308). The differences among the three groups were small and did not indicate a meaningful difference in overall academic achievement. This finding is consistent with the conclusions of a large-scale meta-analysis by Ntolka and Papadatou-Pastou,

who synthesized 36 studies totalling 66,108 participants and found that the IQ difference between right-handers and left-handers, while statistically detectable, was negligible in magnitude (Cohen's $d = -0.07$, corresponding to roughly 1–2 IQ points) and disappeared once the single largest study was excluded [13]. In short, handedness per se does not predict intellectual ability.

Performance on Physics Questions Involving Hand Rules

To further examine the relationship between handedness and physics learning, accuracy rates on examination items involving the left-hand rule and the right-hand rule were compared across the three handedness groups. Because these rules are not introduced until Grade 11, only Grade 11 and Grade 12 students were included in this analysis.

Because the three participating schools administered different examinations, direct comparison of raw accuracy rates across schools was not meaningful. Therefore, the analysis was conducted separately within each school and grade level, drawing on three to four successive examinations taken by the same cohort of students. Note that the fourth examination at School C did not include any items involving hand rules and is therefore excluded from the analysis.

To account for variations in examination difficulty, the accuracy rate of the R group on each examination was used as a baseline. Because the L group was small in each school, its accuracy ratios fluctuated considerably; however, the direction of the trend—starting below parity and converging toward 1.0—was consistent with that of the C group. The two groups were therefore combined into a single non-right-handed group (L & C) to improve statistical stability, using a weighted average based on group size. The accuracy of the L & C group was then expressed as the ratio to that of the R group, denoted as (L & C) / R.

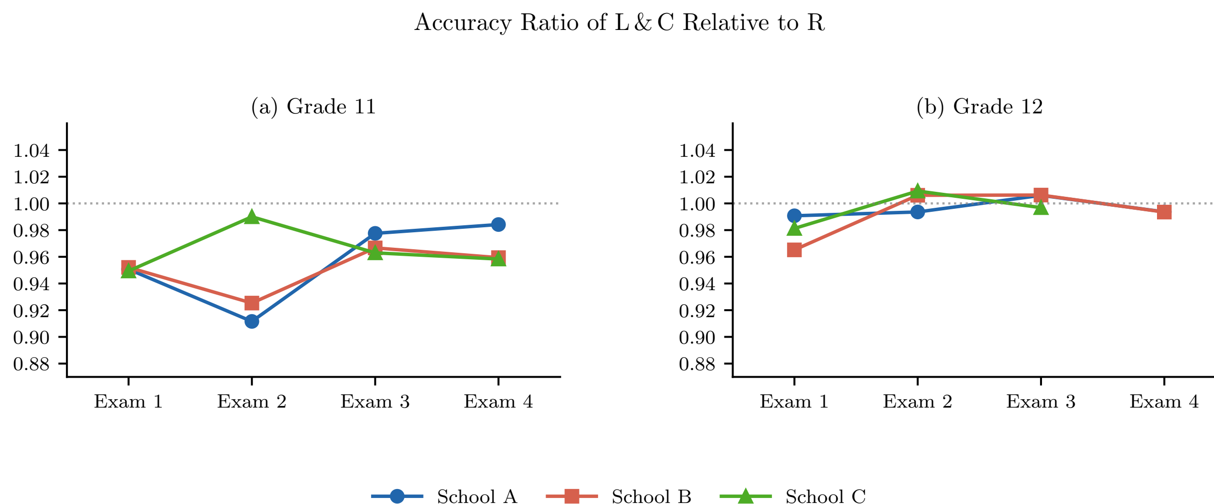


Figure 1: Accuracy ratios on hand-rule examination items across successive examinations. Each data point represents the weighted-average accuracy of the combined L & C group relative to the R group on a given examination. The horizontal dotted line at 1.0 indicates parity with the R group. School C administered only three examinations containing hand-rule items in Grade 12.

The accuracy ratios reveal a consistent pattern across schools and successive examinations. In the early Grade 11 examinations, the combined L & C group exhibited noticeably lower accuracy than the R group on items involving hand rules, with ratios falling well below 1.0 in all three schools. As the semester progressed, however, this gap narrowed steadily, and by the later Grade 11 examinations the ratio had risen to near parity. The Grade 12 data appear to be a natural continuation

of this trend: the ratios remained close to 1.0 throughout, indicating that the performance gap had largely closed.

This pattern suggests that the initial disadvantage experienced by L and C students on hand-rule tasks is not a persistent deficit but rather a transient difficulty during the early learning phase — likely reflecting the additional extraneous cognitive load of translating a right-handed demonstration into left-handed motor execution [8, 14]. Once students have had sufficient practice, this gap largely disappears.

Self-Reported Difficulties of Left-Handed Students

Open-ended responses from L and C students offer a possible explanation for this initial gap. Many left-handed students reported that, during hand-rule demonstrations, they instinctively mirrored the teacher's gesture and raised their left hand instead of their right. As several students explained, years of classroom learning had trained them to mirror everything an instructor does — reversing left and right as a matter of habit. The hand rules, however, represent a rare case in which the specific hand matters: mirroring the demonstration produces an incorrect physical result. Students described needing extra conscious effort to suppress the mirroring reflex and deliberately select the correct hand, an added cognitive demand that right-handed students did not face.

Beyond this hand-rule-specific difficulty, the questionnaire responses also revealed a range of other recurring challenges in both classroom and laboratory settings: (1) lighting interference during writing — classrooms typically have windows on the left-hand side, so when overhead lights are off, a left-handed writer's own hand casts a shadow over the writing area; (2) hand occlusion during mathematical derivations — because left-to-right scripts place newly written content to the right of the pen, a left-handed writer's hand and wrist cover the expressions just written, making it difficult to review preceding steps while carrying out multi-step calculations; (3) seating conflicts — when a left-handed student is seated to the right of a right-handed student, their elbows collide during writing; (4) asymmetric furniture — some laboratory rooms are equipped with tablet-arm chairs that have the writing surface on the right side only; (5) right-hand-biased instruments — tools such as scissors, vernier calipers, micrometers, and burettes are designed for right-handed operation and are awkward or difficult to use with the left hand; and (6) letter-formation differences — when writing certain Roman and Greek letters, left-handed students naturally curve strokes in the opposite direction from their right-handed peers, which can be perceived as incorrect.

3 Equipment Asymmetry in Physics Laboratories: The Case of Vernier Calipers

According to standard metrological practice, a vernier caliper is intended to be held in the right hand, with the thumb positioned on the thumb roller to open and close the jaws, while the graduated scale faces the operator for direct reading [15]. This design ensures that gripping, adjusting, and reading proceed in an ergonomically seamless sequence for right-handed users — an example of the pervasive right-hand bias in hand tool design documented in the ergonomics literature [16].

For left-handed students, however, this intended workflow breaks down. In classroom observations, two distinct operating strategies were identified. In the first strategy, the student mirrors the right-handed grip by placing the left thumb on the thumb roller. Although this allows smooth jaw adjustment, the graduated scale now faces away from the user, making it difficult to see clearly. In the second strategy, the student rotates the caliper upside down so that the scale faces toward them; however, the scale now appears inverted, and the thumb roller must be operated awkwardly with the side of the index finger. In some cases, this inverted orientation also leaves insufficient clearance to position the caliper beneath the specimen for a depth measurement. In practice, because neither

strategy is fully satisfactory, left-handed students were frequently observed switching between the two grips during a single measurement, resulting in repeated re-grasping of the instrument.

3.1 Method

As part of the regular high school laboratory curriculum, all Grade 10 students were required to practice using a vernier caliper and record their measurements in a laboratory report. The instrument used was a 10-division vernier caliper with a resolution of 0.1 mm, which is the standard type provided in Chinese high school physics laboratories. The task involved a series of measurements on multiple specimens, including outer diameter, inner diameter, depth, and spherical diameter. A reference value for each dimension was obtained using a digital caliper (resolution 0.01 mm). By cross-referencing the laboratory reports with the handedness survey data collected in Section 2, the measurement accuracy of the three handedness groups (L, C, and R) could be compared.

According to ISO 13385-1 [17], the maximum permissible error for vernier calipers of this class is within ± 0.1 mm. When operated correctly, the reading uncertainty of such an instrument should not exceed 0.1 mm [18]. Therefore, an absolute deviation $E > 0.1$ mm from the reference value was treated as a significant error, indicative of misreading the scale or visual misalignment rather than normal instrument uncertainty.

To further investigate the behavioral mechanisms underlying any performance differences, a video camera was positioned in front of a designated laboratory bench to record students' instrument-handling behavior during the measurement task. In the laboratory, students were seated in groups of four at each bench. L and C students were preferentially seated at the recorded bench so that their handling behavior could be captured. The recordings were subsequently coded for two measures: (i) task completion time, defined as the interval from the moment the caliper first contacted the specimen to the moment the final value was recorded on the data sheet; and (ii) the number of re-grasping events, defined as the count of instances in which the caliper completely left either hand. Under this definition, a hand transfer (e.g., left to right) was counted as one re-grasping event because the caliper completely left the original hand.

In addition, a handheld thermal imaging camera was used to visualize the contact patterns between students' hands and the caliper. During the laboratory activity, 42 students from all three handedness groups were briefly asked to place the instrument on a workbench so that the residual heat distribution from recent hand contact could be captured.

3.2 Results

A total of 583 students submitted valid laboratory reports that could be matched to the handedness survey. Although the laboratory task involved multiple measurement types (outer diameter, inner diameter, depth, and spherical diameter), the following analysis focuses on the outer-diameter measurement, which is the most typical mode of vernier caliper use and best reflects the standard right-handed operating posture described above. figure 2 presents the distribution of absolute measurement deviations from the reference value for the three handedness groups using a cloud-rain plot.

As shown in figure 2, most right-handed students' measurements clustered near the reference value: 59.5% of R students recorded a reading of exactly 27.4 mm, yielding a median absolute deviation of 0.00 mm and an interquartile range of 0.00–0.30 mm. The L group showed a higher median deviation of 0.30 mm with an interquartile range of 0.00–2.00 mm, though the small sample size ($n = 15$) warrants cautious interpretation. The C group displayed a similar pattern, with a median deviation of 0.25 mm and an equally wide interquartile range (0.00–2.00 mm). When a

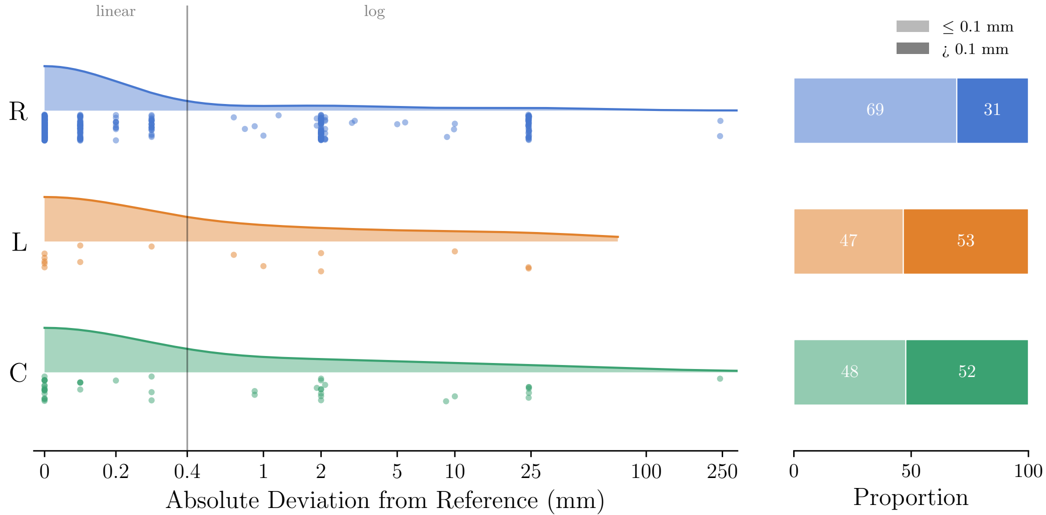


Figure 2: Cloud-rain plot of absolute measurement deviation from the reference value (27.4 mm) by handedness group (R: right-handed, $n = 524$; L: left-handed, $n = 15$; C: corrected left-handed, $n = 44$). Left panel: each point represents one measurement; the shaded area (cloud) shows the kernel density estimate. The x-axis uses a hybrid linear–logarithmic scale (linear below 0.4 mm, logarithmic above) to accommodate extreme deviations. Right panel: proportion of measurements within the instrument resolution (≤ 0.1 mm, light shading) versus those exceeding it (> 0.1 mm, solid shading).

threshold of $E > 0.1$ mm was applied to identify significant errors, the L and C groups exhibited higher observed error rates (53.3% and 52.3%, respectively) than the R group (30.5%). Deviations within approximately 0.4 mm were mainly attributable to misjudging the alignment of vernier graduation lines. A recurring deviation of approximately 2 mm was observed across all three groups, consistent with students mistaking the edge of the vernier scale for the zero line when reading the main scale. A small number of students recorded extreme deviations on the order of 25 mm or 250 mm, which were traced to unit-conversion errors. These systematic errors were proportionally more frequent among L students (13.3%) and C students (13.6%) than among R students (8.4%).

A Kruskal–Wallis test confirmed a statistically significant difference in absolute deviation among the three handedness groups ($H = 11.73$, $p = 0.003$). Post hoc pairwise Mann–Whitney U tests showed that the C group's deviations were significantly larger than those of the R group ($U = 14{,}260$, $p = 0.004$, rank-biserial $r = 0.24$). The L group also showed larger deviations than the R group, though the difference was only marginally significant ($U = 4{,}972$, $p = 0.049$, rank-biserial $r = 0.27$). When the analysis was restricted to the binary error-rate threshold ($E > 0.1$ mm), a Fisher exact test confirmed a significantly higher error rate for the C group relative to the R group, with an odds ratio of 2.49 ($p = 0.004$). Although the corresponding comparison for the L group did not reach conventional significance ($p = 0.086$), the odds ratio of 2.60 (95% CI: [0.87, 7.78]) is consistent in magnitude with that observed for the C group (OR = 2.49, $p = 0.004$), suggesting that the absence of significance reflects limited statistical power rather than a null effect ($n = 15$). Taken together, these results indicate a robust measurement disadvantage for corrected left-handed students, and a similar trend — consistent in direction and effect size but underpowered — for left-handed students.

Video recordings were obtained from 51 students across multiple laboratory sessions (R: $n = 22$;

L: $n = 14$; C: $n = 15$). Through the stratified seating arrangement described above, the recorded sample included a higher proportion of L and C students than the general population, yielding sufficient data for between-group comparison. All videos were independently coded by two raters (the author and a laboratory technician). Re-grasping counts showed perfect inter-rater agreement; task completion times differed by no more than 2 s between raters, and the mean of the two ratings was used for analysis. figure 3 summarizes the behavioral coding results for task completion time and re-grasping events.

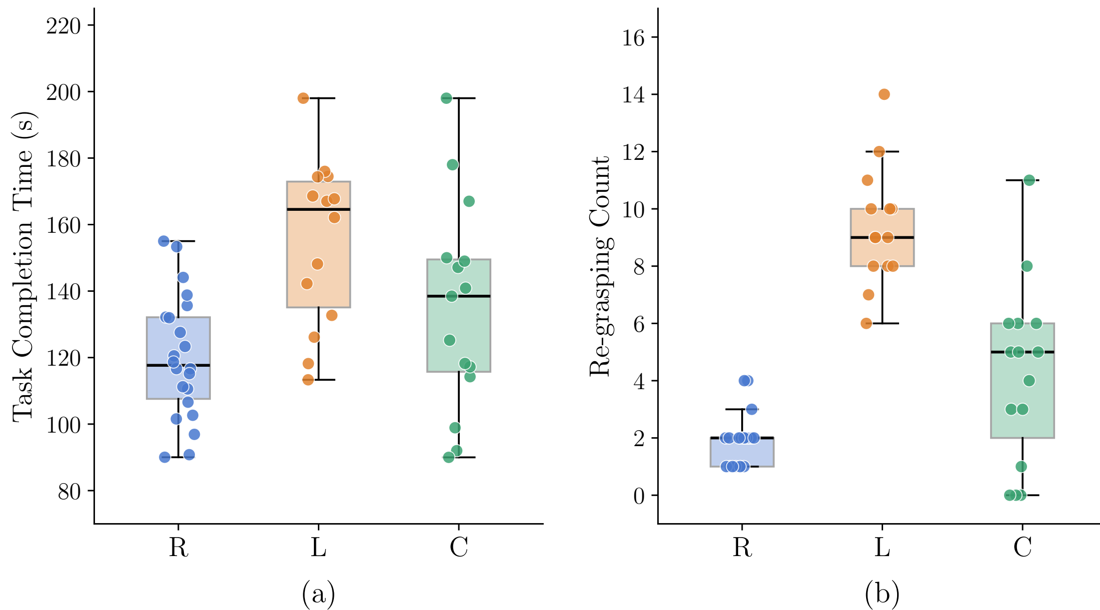


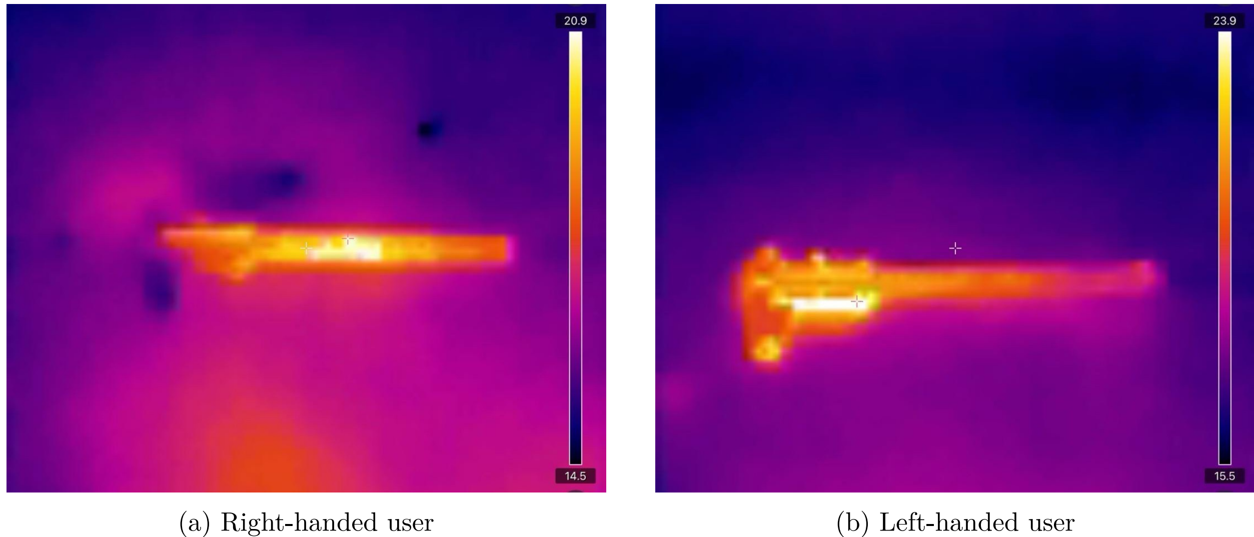
Figure 3: Behavioral coding results for vernier caliper measurement by handedness group (R: right-handed; L: left-handed; C: corrected left-handed). (a) Task completion time (s). (b) Number of re-grasping events. Each point represents one student. Box plots show the median (horizontal line), interquartile range (box), and range (whiskers).

As shown in figure 3(a), the R group completed the measurement task in a median time of approximately 118 s, whereas the L group required noticeably longer (median $\approx$ 165 s). The C group fell between the two (median $\approx$ 138 s). The greater spread observed in the L group suggests higher individual variability, likely reflecting different coping strategies adopted by left-handed students.

The re-grasping data in figure 3(b) reveal an even more pronounced group difference. Right-handed students rarely re-grasped the caliper during the task (median = 2), whereas left-handed students did so frequently (median = 9). Corrected students showed an intermediate pattern (median = 5), with noticeably lower re-grasping counts than the L group. Video review suggested an explanation: C students could hold the caliper in their left hand while recording data with the right, allowing simultaneous operation without switching hands — a coordination advantage unavailable to L students, who had to alternate their single dominant hand between measuring and writing.

In addition, a thermal imaging camera was used to capture the calipers immediately after student use. Among the 42 thermal images collected, right-handed users consistently showed a localized thermal footprint at the standard grip position, whereas left-handed and corrected users typically exhibited a broader distribution along the beam, consistent with the frequent grip adjust-

ments quantified in the re-grasping analysis. figure 4 shows representative thermal images from each group.



(a) Right-handed user

(b) Left-handed user

Figure 4: Representative thermal images of vernier calipers captured immediately after use. (a) Right-handed user: thermal footprint concentrated at the standard grip position. (b) Left-handed user: thermal footprint distributed along the entire beam, consistent with frequent grip repositioning.

4 Safety Considerations in Laboratory Activities: The Case of the Circular Saw

Although measurement instruments, such as vernier calipers, primarily affect efficiency and accuracy, certain fabrication tools found in school workshops can introduce serious safety risks due to their inherently asymmetric mechanical design.

4.1 A Brief Mechanical Analysis of Circular Saw Operation

Circular saws commonly used in school workshops are typically manufactured in two configurations: blade-right and blade-left. Although the position of the blade differs, both designs are largely optimized for right-handed operation in terms of trigger placement, weight distribution, and the assumed stance of the operator [16].

In a blade-left saw, the operator grips the handle with the right hand, allowing the line of sight to fall naturally on the cutting interface. In contrast, a blade-right saw typically requires two-handed operation: the right hand holds the main handle containing the trigger, while the left hand grasps the auxiliary front handle. This configuration improves stability and allows the relatively heavy saw to travel smoothly along a straight cutting path.

Most importantly, in both configurations the rotational plane of the blade is positioned laterally relative to the operator's torso and does not intersect the body's central axis. Consequently, even if kickback occurs, the rotating blade is not initially directed toward the operator's body.

When a left-handed operator attempts to use the same saws, however, the operation cannot be fully mirrored because of the asymmetric mechanical layout. With a blade-left saw, gripping the

handle with the left hand places the motor housing between the operator and the cutting interface, obstructing the line of sight. With a blade-right saw, holding the trigger handle with the left hand while grasping the auxiliary handle with the right causes the arms to cross, producing an unbalanced torque that may increase the likelihood of twisting or kickback.

More critically, left-handed operators may be inclined to position themselves along the cutting direction rather than to the side of it. In such a stance, the plane of the rotating blade may intersect the operator's body midline, significantly increasing the risk of severe injury in the event of kickback. Epidemiological data confirm that kickback is the leading mechanism of circular saw injuries, accounting for nearly half of all cases in one cross-sectional study [19]; a forensic analysis of 131 circular saw hand injuries similarly identified kickback as the most common trauma mechanism [20]. More broadly, left-handers have been found to experience a significantly elevated risk of injuries requiring medical attention (odds ratio = 1.89), an effect attributed in part to the right-handed bias of tools and equipment [21]. Similar asymmetries may arise with other common workshop tools. For example, the angle grinder has a fixed disc rotation direction and power switch location. Even when the auxiliary handle and wheel guard are repositioned for left-handed use, a left-handed operator may face sparks and debris directed upward toward the face rather than downward, and kickback may drive the tool toward rather than away from the body. These geometric differences suggest that the interaction between tool design and operator handedness may influence not only operational convenience but also the distribution of safety risks. To explore how students perceive and respond to these potential hazards, a classroom investigation was conducted using the circular saw as a representative case.

4.2 Classroom Investigation of Hazard Perception

To investigate how students perceive hazards during circular saw operation, a classroom activity was conducted in three woodworking elective classes ($N = 62$). Each student was shown a schematic illustration of a circular saw in use and asked to identify the areas they considered potentially dangerous by marking them directly on the illustration.

To allow spatial analysis of the responses, the illustration was overlaid with a 10×10 grid. Each grid cell marked by a student was tallied, and the frequencies were aggregated across all participants. The resulting distribution is presented as a heatmap (figure 5), in which darker shading indicates areas more frequently identified as hazardous.

As the heatmap shows, students' attention was concentrated primarily around the exposed blade and the immediate cutting interface, indicating a general awareness of the danger posed by direct blade contact. Notably fewer markings appeared in the region corresponding to the kickback trajectory behind the saw. This pattern suggests that students' hazard perception was strongly anchored to the visible position of the blade, whereas the dynamic risk associated with kickback — a hazard that depends on the operator's stance relative to the blade plane, as discussed in Section 4.1 — was less consistently recognized.

To further examine whether this perception pattern is reflected in students' actual behaviour during tool use, classroom observations were conducted during practical woodworking sessions.

4.3 Classroom Observation of Student Operation

To examine how these perceptions relate to actual behaviour during tool use, a video camera was set up in the workshop to record students' body positioning during practical woodworking sessions involving circular saw operation. Video recordings were obtained from the same 62 students who completed the hazard perception activity (5 left-handed, 57 right-handed). Post-session analysis

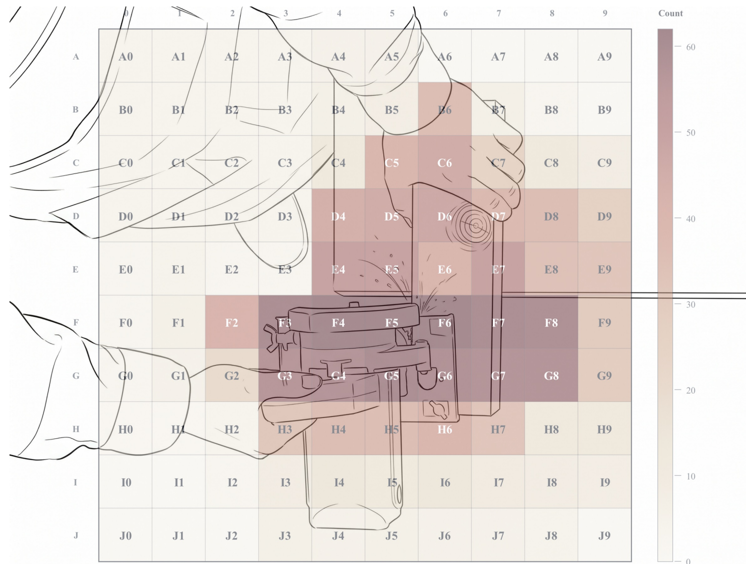
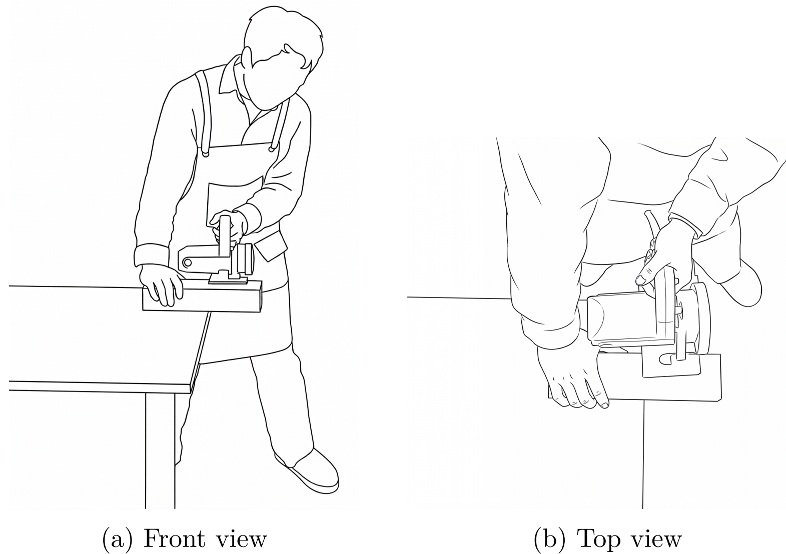


Figure 5: Heatmap of students' perceived hazard zones during circular saw operation. Students examined a schematic illustration of a circular saw in use and marked the areas they considered potentially dangerous. The illustration was divided into a 10×10 grid, and the frequency of markings in each cell was aggregated across all responses ($N = 62$). Darker shading indicates areas more frequently identified as hazardous.

of the footage revealed that all 5 left-handed students (100%) stood within the potential kickback trajectory at some point during the operation, whereas 27 of the 57 right-handed students (47.4%) did so (figure 6). Right-handed students more consistently maintained a stance offset from the cutting direction, keeping their torso outside the kickback plane. This pattern is consistent with the mechanical analysis presented in Section 4.1, and suggests that the asymmetric design of the tool may interact with handedness to shape students' instinctive operating posture.

5 Inclusive Teaching Strategies

Approximately 10% of students worldwide are left-handed. In addition, students with congenital or acquired conditions affecting the right hand — such as limb differences or amputations — must also rely on their left hand for tool operation and face many of the same, or even greater, challenges. Physics teachers should first recognize that many fundamental laboratory tools — from vernier calipers to circular saws — are implicitly designed for right-handed operation. This design assumption is often invisible to right-handed instructors, yet it can create systematic disadvantages in efficiency and accuracy, and in some cases, potential safety risks, for students who operate tools with their left hand. As recent calls for meaningful diversity, equity, and inclusion in physics learning environments have emphasized, truly inclusive practice requires attending not only to demographic representation but also to the material and procedural conditions under which students learn [22]. The Universal Design for Learning (UDL) framework offers a useful lens for this effort: by providing multiple means of engagement, representation, and action, instructors can proactively accommodate diverse learner needs rather than relying on post hoc remediation [23, 24].



(a) Front view (b) Top view

Figure 6: Observed body positioning of a left-handed student during circular saw operation. The student's torso is aligned with the cutting path rather than offset to one side, placing the body's midline within the potential kickback trajectory of the blade.

5.1 Awareness in Demonstrations and Safety Instructions

During laboratory demonstrations, teachers should be aware that some students may naturally operate tools with their left hand, even when watching a right-handed demonstration. The errors and risks that arise from such mirrored operations — such as reversed scale readings, inverted kickback trajectories, or obstructed lines of sight — should be explicitly addressed rather than left for students to discover on their own.

In safety instructions, teachers are encouraged to use body-neutral language. For example, rather than telling students to "stand to the left of the circular saw," it is more inclusive to advise students to "keep your body out of the line of the cutting path." Such phrasing conveys the same safety principle while remaining valid regardless of the student's dominant hand.

5.2 Pre-Laboratory Handedness Audit

The following checklist is intended as a pre-laboratory handedness audit. If one or more items are checked, instructors are encouraged to consider whether the activity may introduce additional challenges or risks for left-handed students.

- ☐ Are power outlets, gas valves, or water connections positioned in a way that may create cable or hose interference depending on hand dominance?
- ☐ Is the emergency stop or power switch equally accessible from both left- and right-handed operating positions?
- ☐ Are hazardous zones (e.g., high temperature, high voltage, high pressure, rotating blades, kickback trajectories) symmetrically distributed relative to the operator's stance?
- ☐ Do any instruments or tools require a dominant-hand grip, specific scale orientation, or specific trigger placement?

☐ Does the experimental procedure require an asymmetric body stance that may differ between left- and right-handed students?

5.3 Positional Compensation

Although many fabrication tools are designed for right-handed users, left-handed operators can maintain safety through positional compensation — that is, by deliberately adopting a modified stance that keeps the body clear of the primary hazard zone. As the classroom observations in Section 4.3 showed, left-handed students may instinctively align their torso with the cutting path, placing themselves within the potential kickback trajectory. To avoid this hazardous alignment, left-handed students should be taught to offset their body to the side of the blade plane, keeping their torso clear of the kickback direction. Rather than attempting to mirror the right-handed stance, they should learn to identify the hazard trajectory specific to their operating configuration and position themselves accordingly. Teachers should demonstrate and practice these alternative stances explicitly during safety briefings, so that positional compensation becomes a deliberate, trained habit rather than an improvised reaction.

5.4 Accessible Tools as Instructional Scaffolding

Unlike industrial production environments, educational laboratories serve students who are still developing technical skills and safety awareness. For left-handed students, the standard right-handed laboratory setup often imposes an asymmetric cognitive load: they must simultaneously acquire new conceptual knowledge and overcome biomechanical interference from tools not designed for their dominant hand. Recent work integrating cognitive load theory with motor learning highlights that such dual demands on working memory can substantially impair skill acquisition [14, 25]. For example, a fully symmetrical vernier caliper with scales engraved on both sides of the beam can be operated naturally with either the left or the right hand [26]. Educational laboratories may consider providing such tools as transitional instruments for left-handed students, allowing them to focus on mastering measurement concepts and procedural skills without the added burden of adapting to an ergonomically incompatible tool.

Once understanding and operational fluency have been established, students can transfer their knowledge to conventional vernier calipers with considerably less difficulty. In this way, accessible tools function as instructional scaffolding [27] — supporting stepwise skill acquisition and reducing extraneous cognitive load during early training [8].

6 Conclusion

This study set out to examine a form of inequity in physics education that is pervasive yet largely invisible: the systematic disadvantage imposed on left-handed students by laboratory environments designed exclusively for right-handed users. Drawing on a large-scale survey (N = 4,226), a controlled measurement experiment with behavioural coding and thermal imaging, and a safety-focused investigation of power tool operation, the findings converge on a central conclusion: the difficulties left-handed students encounter in the physics laboratory are not deficits of ability but consequences of asymmetric design — in instruments, in demonstrations, and in safety assumptions.

Three findings merit particular emphasis. First, the survey revealed that while approximately 9.5% of students were naturally left-handed, over three-quarters had been corrected to write with their right hand, compressing the visible left-handed population to just 2.17%. This widespread correction, especially prevalent in East Asian educational contexts, masks the true scale of the

population affected by handedness-related barriers. Second, the vernier caliper experiment demonstrated that both left-handed and corrected students exhibited significantly higher measurement error rates and longer task completion times than their right-handed peers. Notably, corrected students showed fewer re-grasping events than left-handed students — an advantage attributable to their ability to coordinate the left hand for instrument manipulation with the right hand for data recording — yet their measurement accuracy remained equally poor. This dissociation suggests that while correction may facilitate certain bimanual coordination tasks, it does not resolve the fundamental ergonomic mismatch between the operator and the instrument. Third, the circular saw investigation revealed that the interaction between tool asymmetry and operator handedness can extend beyond efficiency into safety: left-handed students tended to position their bodies within the potential kickback trajectory, a hazard pattern that was neither self-corrected nor consistently recognised by the students themselves.

Importantly, overall academic performance showed no meaningful differences among handedness groups, reinforcing the interpretation that the observed laboratory disadvantages are environmentally imposed rather than intrinsic.

These findings make two contributions to the physics education literature. Empirically, they provide multi-method documentation of how handedness interacts with laboratory instrument design to produce measurable disparities in performance and safety. Practically, they inform a set of inclusive strategies — pre-laboratory handedness audits, body-neutral safety language, positional compensation training, and the use of symmetrically designed instruments as transitional scaffolding — that can be adopted with minimal cost or curricular disruption.

Several limitations should be acknowledged. The number of left-handed students in the caliper experiment was small ($n = 15$), which limited statistical power for that subgroup; while the observed effects were consistent in direction and magnitude with those of the larger corrected group, the binary error-rate comparison did not reach conventional significance ($p = 0.086$; OR = 2.60, 95% CI: [0.87, 7.78]). The study was also conducted within a single regional and cultural context in which correction of left-handedness is common, and the extent to which these findings generalise to settings with lower correction rates remains an open question. Future work could address these gaps through larger-scale controlled experiments, cross-cultural comparisons of correction prevalence and its laboratory consequences, and intervention studies that evaluate whether providing symmetrically designed instruments during early training measurably reduces the performance gap.

In a discipline that prizes precision and universal laws, it is worth remembering that approximately one in ten students experiences the laboratory from a fundamentally different vantage point. Ensuring that no left-hander is left behind is not merely an act of accommodation — it is a commitment to the inclusive and equitable practice that good science education demands.

7 Ethical Considerations

This study was conducted as part of routine educational practice in the participating schools. The handedness questionnaire was administered as a classroom activity, and participation was voluntary with all responses collected anonymously. Measurement performance data were drawn from laboratory reports required by the standard curriculum. Academic performance records were retrieved from each school's online grading system, to which all teaching staff have routine access. Video and thermal imaging recordings were collected during regular laboratory sessions, and the hazard perception activity and circular saw observations were carried out within scheduled woodworking classes. No procedures were imposed beyond normal instructional activities.

All data collection was conducted with the informed consent of the participating students and

with the approval of the school administration at each site. Responses and recordings were fully anonymized, and the data were used exclusively for research purposes and did not contribute to any student evaluations. As the participating institutions are secondary schools without formal institutional review boards, ethical oversight was provided through the schools' administrative approval process.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. Anonymized survey responses, measurement records, and behavioral coding data can be provided for verification purposes. Individual-level academic performance records cannot be shared publicly owing to student privacy restrictions.

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