LESSON 6.3.2
Improving Precision, Validity and Reliability

Choose an improvement that addresses a specific weakness. Then check whether it actually reduces scatter, tests the intended relationship or makes the conclusion more dependable.

PRECISION

How tightly do repeat measurements agree?

Reduce random variation or its contribution to the result. A finer display alone does not guarantee less scatter.

VALIDITY

Does the method measure what it intends to?

Control relevant influences and use suitable instruments and model assumptions. Repeats cannot rescue an unsuitable method.

RELIABILITY

Is the result dependable when checked again?

Support this broad claim with repeatability, reproducibility and uncertainty evidence. Do not treat it as a synonym for accuracy.

SPECIFY THE KIND OF REPEAT

Repeatability: the same operator and method over a short interval. Reproducibility: agreement when operators, apparatus or methods change. State which conditions were kept or changed.

A biased timer can give tightly grouped results every time. Precision and repeatability do not, by themselves, establish accuracy or validity.

Terminology: Pearson IAL Physics specification, Appendix 10, p. 76.

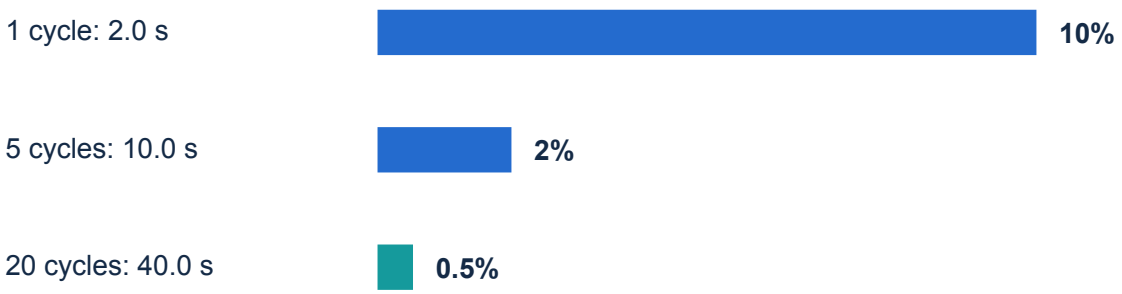
1 Make the signal large relative to noise

For oscillations, time N complete cycles and divide by N. Start and stop at the same reference position, travelling in the same direction; count cycles, not every crossing.

$$T = \frac{t}{N} \qquad \delta T = \frac{\delta t}{N} \qquad \frac{\delta T}{T} = \frac{\delta t}{t}$$

Assume an exact cycle count and a stable period of 2.00 s. The illustrative uncertainty in each complete timed interval is ±0.20 s, including start and stop effects.

SAME ABSOLUTE TIMING UNCERTAINTY; DIFFERENT FRACTIONS



Bar length shows percentage uncertainty in the period.

20 CYCLES: QUANTIFIED IMPROVEMENT

$$T = \frac{40.0}{20} = 2.00\ \text{s} \qquad \delta T = \frac{0.20}{20} = 0.01\ \text{s}$$

Fractional uncertainty falls from 10% to 0.5%: a factor of 20.

CHOOSE A PRACTICAL LIMIT

Do not keep extending the run if damping, drift or missed cycles become important. A fixed marker helps identify phase. A light gate or motion sensor can reduce reaction-time effects, but its trigger and sampling settings still need checking.

Repeat complete runs to measure the actual spread. For times 39.8, 40.0 and 40.2 s, the mean is 40.0 s and half range is 0.2 s. This also gives a period half range of 0.01 s; do not count the same timing effect twice.

Longer timing does not correct a miscalibrated clock. Separate random timing variation from a systematic timebase error.

Method reference: Pearson Student Practical Guide, timing and repeated readings.

2 Keep the comparison scientifically valid

Investigation: how does the total suspended mass m affect the period of a vertical mass-spring oscillator? Use a light spring, weak damping and motion within its linear elastic range.

VARY MASS; MEASURE PERIOD; KEEP THE SAME SPRING

$$T^2 = \frac{4\pi^2}{k} m$$

INPUT: m

Include the hanger mass.

→

OUTPUT: T²

Square the mean period.

A. CONTROL WHAT COULD CHANGE THE RELATIONSHIP

SPRING / SUPPORT	Use the same spring and rigid support. Changing the spring changes k; a moving support can change the measured motion.
RELEASE / MOTION	Use a consistent small displacement and release without a push. Avoid sideways motion; check that the period is stable as amplitude changes slightly.
RANGE / CONDITION	Use several well-spaced masses without permanently stretching the spring. Revisit a reference mass to check for a shift during the experiment.

B. CHECK THE MODEL AND THE ANALYSIS

Plot T² against total suspended mass. Inspect the intercept and residuals rather than forcing the line through zero. An appreciable spring mass can contribute to the oscillating inertia and alter the simple model.

Interleave or vary the order of mass settings and repeat a reference setting to detect drift. Changing order alone does not eliminate drift. Correct balance zero and validate timing against a suitable reference.

Physics reference: OpenStax University Physics 1, §15.1 Simple harmonic motion.

3 Build evidence that others can check

Write a reproducible method: apparatus, ranges, controls, release procedure, cycle count, timing reference and uncertainty estimates. Record raw data before calculating averages.

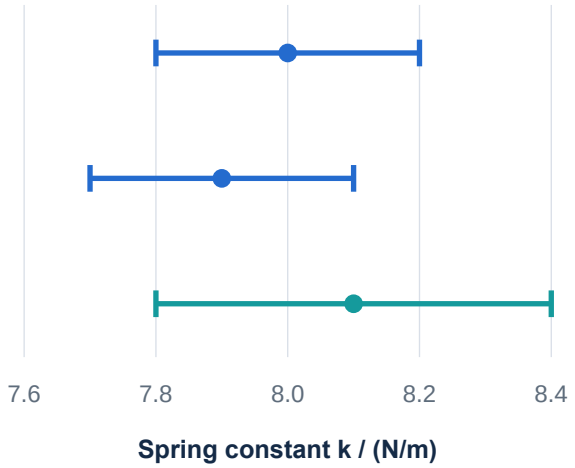
ILLUSTRATIVE CHECKS OF THE SAME SPRING CONSTANT

Intervals are stated uncertainty estimates, not confidence intervals.

A: original timing
8.0 ± 0.2 N/m

B: reset and repeat
7.9 ± 0.2 N/m

C: static force-extension
8.1 ± 0.3 N/m



A and B support repeatability when the operator and method are unchanged. An independent operator using method C adds a stronger reproducibility check. The common interval is 7.8 to 8.1 N/m; agreement supports consistency, not proof of accuracy.

MAKE EACH REPEAT INFORMATIVE

RESET AND REPEAT
Repeat the release and measurement at each mass, not just the reading of a frozen display. Keep the individual values so scatter remains visible.

INVESTIGATE ANOMALIES
Recheck the setup and repeat the setting. Keep the original reading and document any justified exclusion; do not delete points merely to improve a line.

COMPARE FAIRLY
Use the same physical quantity, units and spring condition. Compare differences with uncertainties and consider shared calibration or model errors.

A complete improvement states: change → physical reason → expected evidence. Verify the benefit and note any new limitation introduced.

Further reading: Pearson Student Practical Guide, planning and evaluation.

Next: 6.3.3 Linking conclusions to physical theory.