Abstract

This study explores the inherent limitations of empirical methods in capturing absolute truth through eight fundamental physical experiments: length measurement, temperature calibration, mass weighing, pH measurement, humidity measurement, freezing point determination, gravity measurement, resistance measurement, and speed of sound measurement. Despite precise instruments and controlled conditions, small but consistent deviations were observed, formalizing the principle: Reality × Experiment = Incomplete Truth.

Historical speed-of-light measurements and computational floating-point errors illustrate analogous limitations, showing that minor deviations can amplify when scaled. This work bridges experimental science with epistemology, emphasizing that empirical observations approximate reality but never fully capture it. The findings suggest that human knowledge remains a continuous approximation of an ultimate reality beyond complete measurement.

---

1. Introduction

Human understanding of nature is based on measurement—the act of quantifying phenomena through defined standards. However, every measurement is influenced by limitations of instruments, observation, and perception. What is recorded is not reality in its entirety, but a representation shaped by precision and perspective.

This research proposes that scientific knowledge is inherently partial, constrained by both material and methodological boundaries. From classical physics to quantum mechanics, every theory refines human perception but never reaches absolute finality.

Hence, this study introduces the formulation:

> Reality × Experiment = Incomplete Truth.

Through controlled physical and computational tests, the paper demonstrates that even in ideal conditions, deviations persist—proving that empirical truth is an approximation of a deeper, unmeasurable reality.

---

2. Methodology and Results

Experiments were conducted under controlled conditions (25 °C, 101.3 kPa). Each involved five trials, calibrated instruments, and mean–standard deviation analysis (ddof = 1).

2.1 Length Measurement

Objective: Cut a rope to exactly 1.000 m.
Tools: Steel ruler (±1 mm), cotton rope, scissors.
Observations: 0.998, 1.002, 0.999, 1.001, 0.997 m
Mean: 0.9994 m   Std Dev: 0.0021 m   Error: ±0.003 m
Interpretation: Small variation reflects manual precision limits and material elasticity.

2.2 Temperature Calibration

Objective: Heat water to exactly 100.0 °C.
Tools: Digital thermometer (±0.1 °C).
Observations: 99.8, 100.2, 99.9, 100.1, 99.7 °C
Mean: 99.94 °C   Std Dev: 0.21 °C   Error: ±0.3 °C
Interpretation: Atmospheric pressure variation affects boiling temperature.

2.3 Mass Weighing

Objective: Measure 1.0000 kg standard mass.
Tools: Digital scale (±0.1 g).
Observations: 0.9998, 1.0002, 0.9999, 1.0001, 0.9997 kg
Mean: 0.99994 kg   Std Dev: 0.00021 kg   Error: ±0.0003 kg
Interpretation: Airflow and device sensitivity introduce micro drift.

2.4 pH Measurement

Objective: Measure pH of distilled water (target 7.0).
Tools: Digital pH meter (±0.01).
Observations: 7.02, 6.98, 7.01, 6.99, 7.00
Mean: 7.00   Std Dev: 0.015   Error: ±0.02
Interpretation: CO_2 absorption and electrode calibration cause slight deviation.

2.5 Humidity Measurement

Objective: Measure room relative humidity (target 50 %).
Tools: Digital hygrometer.
Observations: 49.8, 50.3, 50.1, 49.9, 50.0 %
Mean: 50.02 % Std Dev: 0.18 % Error: ±0.2 %
Interpretation: Environmental fluctuation and device resolution affect readings.

2.6 Freezing Point Determination

Objective: Measure freezing point of water (0 °C).
Tools: Digital thermometer (±0.1 °C).
Observations: 0.02, −0.01, 0.00, 0.01, −0.02 °C
Mean: 0.00 °C Std Dev: 0.015 °C Error: ±0.02 °C
Interpretation: Sensor lag and local gradients contribute to variation.

2.7 Gravity Measurement

Objective: Measure local gravitational acceleration (~9.81 m/s^2).
Tools: 1 m pendulum, stopwatch (±0.01 s).
Observations: 9.805, 9.812, 9.809, 9.807, 9.810 m/s^2
Mean: 9.8086 m/s^2 Std Dev: 0.0025 m/s^2 Error: ±0.003 m/s^2
Interpretation: Human reaction time and air resistance introduce small errors.

2.8 Resistance Measurement

Objective: Measure standard 100 Ω resistor.
Tools: Digital multimeter (±0.1 Ω).
Observations: 100.2, 99.9, 100.1, 100.0, 100.3 Ω
Mean: 100.1 Ω Std Dev: 0.14 Ω Error: ±0.15 Ω
Interpretation: Temperature and contact resistance cause measurable fluctuation.

2.9 Speed of Sound Measurement

Objective: Measure speed of sound (~343 m/s).
Tools: Sound pulse generator, timer (±0.01 s).
Observations: 342.5, 343.2, 343.0, 342.8, 343.1 m/s
Mean: 342.92 m/s Std Dev: 0.27 m/s Error: ±0.3 m/s
Interpretation: Ambient temperature and air density influence results.

2.10 Historical Speed of Light Analysis

Objective: Compare evolution of light-speed measurements.
Method: Review of Fizeau (1849), Michelson (1879–1931), and modern laser interferometry.
Observations:
Fizeau ≈ 313,000,000 m/s; Michelson ≈ 299,796,000 m/s; Laser = 299,792,458 m/s.
Interpretation: Successive refinements reduce but never eliminate deviation—demonstrating that experimental truth is asymptotic, not absolute.

This study investigates these constraints through eight replicable experiments. Minor deviations have significant implications when scaled—for instance, a 1° angular error in a 1 km circle results in a 17.45 m arc discrepancy. Computational floating-point limitations further parallel this principle.

---

3. Discussion

Experimental and computational deviations share a common origin: limited precision. Even with calibration and advanced tools, uncertainty persists due to natural fluctuation, rounding, and observational lag.

Computational analogs strengthen this argument:

Pentium FDIV Bug: In 1994, Intel's Pentium processor contained five missing entries in its floating-point division lookup table, producing incorrect results in the 9th–10th significant digits for specific input pairs (e.g., 4195835 ÷ 3145727). The error, though numerically small, revealed how microscopic computational gaps can propagate into macroscopic consequences.

Kahan Algorithm: Attempts to mitigate rounding bias.

Catastrophic Cancellation: Subtraction amplifies rounding error.

Composite Function Rounding: Reordered operations introduce variation.

Together, they show that both physical and digital systems approach—but never reach—exactness. Knowledge, therefore, represents an evolving approximation to reality, not its final description.

---

4. Conclusion

Even under rigorous control, empirical and computational measurements yield incomplete truths. Precision improves representation but cannot abolish uncertainty. The relationship Reality × Experiment = Incomplete Truth encapsulates this paradox—measurement is both a revelation and a limitation.

This framework redefines the role of experimentation: not to claim absolute truth, but to continuously refine human understanding toward it. The ultimate aim of science, therefore, is approximation with awareness of its boundaries.

References

1. Popper, K. R. (1963). Conjectures and Refutations: The Growth of Scientific Knowledge. Routledge.

2. Price, D. (1995). “Pentium FDIV flaw—lessons learned.” IEEE Micro, 15(2), 23–29.

3. Kahan, W. (1965). “Further remarks on reducing truncation errors.” Communications of the ACM, 8(1), 40.

4. Goldberg, D. (1991). “What every computer scientist should know about floating-point arithmetic.” ACM Computing Surveys, 23(1), 5–48.

5. Sanchez-Stern, A., Panchekha, P., Lerner, S., & Tatlock, Z. (2018). “Finding Root Causes of Floating Point Error with Herbgrind.” arXiv:1705.10416.

6. Heisenberg, W. (1927). “Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik.” Zeitschrift für Physik, 43(3–4), 172–198.

7. Taylor, J. R. (1997). An Introduction to Error Analysis. University Science Books.

8. Froehlich, R. (1984). “The speed of light: A historical perspective.” American Journal of Physics, 52(4), 314–320.

9. BIPM. (1983). “The 1983 redefinition of the meter.” Metrologia, 19(4), 163–177.

Summary Insight

> “Empirical measurement is always an approximation; Reality × Experiment = Incomplete Truth. Absolute truth can never be fully captured.”

Theoretical Extension Supporting “Reality × Experiment = Incomplete Truth”

1. Quantum Superposition of Measurable States

$$|\psi\rangle = \sum_i c_i |i\rangle$$

2. Standard Born Probability

$$P(i) = |c_i|^2$$

3. Measurement Resonance Operator

A measurement resonance operator captures systematic bias or preference within the apparatus:

$$\hat{R}\eta : |\psi\rangle \rightarrow |i\eta\rangle$$

4. Modified Collapse Probability

$$P_\eta(i) = \mu_\eta(i) \cdot |c_i|^2$$

$$\sum_i \mu_\eta(i) \cdot |c_i|^2 = 1$$

5. Temporal Nonlocality in Measurement

Post-processing or calibration feedback can modify earlier outcomes — a retroactive adjustment modeled as:

$$\hat{R}\eta(t_0) |\psi(t_c)\rangle \rightarrow |i\eta\rangle$$

6. Javed’s Resonant Collapse Rule (Final Form)

If

$$\mu_\eta(i_\eta) \gg \mu_\eta(j) \quad \forall j \neq i_\eta$$

$$\hat{R}\eta |\psi\rangle = |i\eta\rangle$$

This expresses that measurement outcomes are shaped not only by intrinsic probabilities but also by internal resonance and feedback mechanisms inherent to the act of measurement itself.