STEM EDUCATION TECHNICAL TRAINING

Comprehensive Guide to Practical Science: Implementing the '75 Experiments in the Classroom' Framework

Published: February 8, 2025 | Index ID: #763

The evolution of modern science education has shifted significantly from rote memorization toward inquiry-based learning. Central to this transformation is the integration of hands-on experimentation, a methodology encapsulated in the seminal work **"75 Experimentos en el aula"**(75 Experiments in the Classroom), published by the Spanish Ministry of Education, Culture, and Sport (MECD) in 2014. Originally developed for bilingual sections in Slovakia by Fernando Antolín Morales, this framework provides a robust technical and pedagogical blueprint for secondary science education. This article provides an in-depth analysis of the technical protocols, mathematical foundations, and instructional strategies required to implement such a comprehensive experimental curriculum.

The Theoretical Framework of Experimental Pedagogy

Practical science in the classroom is grounded in **Constructivism**, particularly the theories of Jean Piaget and Lev Vygotsky, which posit that learners build knowledge through active engagement with their environment. In the context of the "75 Experimentos" manual, this is extended through the **CLIL (Content and Language Integrated Learning)**approach, where scientific technicality and linguistic proficiency in Spanish are developed simultaneously.

The Scientific Method as a Technical Workflow

The implementation of any experiment within this framework must follow a rigid **technical workflow**to ensure scientific validity and safety:

- Observation and Phenomenological Analysis: Identifying the physical or chemical change to be studied.
- Hypothesis Formulation: Utilizing existing theoretical knowledge to predict outcomes based on independent and dependent variables.
- Experimental Design: Defining the control group, constant variables, and the measurement apparatus.
- Data Acquisition: Using analog or digital instruments to record quantitative and qualitative data.
- Statistical Verification: Applying error analysis to validate the results.

Technical Breakdown of Core Scientific Disciplines

The "75 Experimentos" manual categorizes activities into distinct scientific domains. Each domain requires specific laboratory conditions and technical expertise.

1. Chemical Kinetics and Thermodynamics

Experiments in chemistry often focus on **exothermic and endothermic reactions**, as well as the factors affecting reaction rates. For instance, studying the decomposition of hydrogen peroxide (H ,O ,) using a catalyst involves understanding the **Arrhenius Equation**:

k = Ae^(-Ea/RT)

Where **k** is the rate constant, **A** is the pre-exponential factor, **Ea** is the activation energy, **R** is the universal gas constant, and **T**is the absolute temperature. Students analyze how catalysts lower the activation energy, thereby increasing the reaction rate without being consumed in the process.

2. Optics and Wave Mechanics

Physics experiments frequently explore the properties of light. A core experiment involves **Snell's Law of Refraction**, which is critical for understanding how light behaves when passing through different media (e.g., air to water):

n • sin(;, ’ Ò â " 6–â ƒ ¸ ,)

Technical execution requires a laser source, a semi-circular transparent vat, and a protractor to measure angles of incidence (;, ’ æB &Vg action (;, "' Fò FWFW mine the refractive index (n) of unknown liquids.

3. Fluid Dynamics and Pressure

Understanding **Bernoulli's Principle** and **Pascal's Principle**is essential for mechanical engineering concepts taught at the secondary level. Experiments involving hydraulic presses or the Venturi effect allow students to calculate force amplification:

F •/A • = F ,/A ,

Comparative Analysis of Experimental Methodologies

The following table compares traditional theoretical instruction with the experimental approach advocated in the MECD framework.

Feature	Traditional Theoretical Approach	Experimental Framework (75 Experimentos)
Learning Mode	Passive Reception	Active Inquiry & Manipulation
Retention Rate	Low (10-20% after 2 weeks)	High (75-90% via "Doing")
Skill Acquisition	Conceptual/Abstract	Technical, Analytical, & Procedural
Assessment	Standardized Testing (Memory)	Performance-Based & Logbook Analysis
Safety Integration	Theoretical only	Practical Lab Safety Management

Detailed Procedure: Implementing a pH Indicator Experiment

One of the most effective experiments for secondary students involves the extraction of natural pH indicators (e.g., from red cabbage or *Brassica oleracea*). This experiment bridges organic chemistry and analytical techniques.

Technical Requirements

- Reagents: Red cabbage, ethanol (96%), distilled water, various substances (lemon juice, vinegar, baking soda, bleach).
- Equipment: Mortar and pestle, filter paper, test tubes, graduated pipettes.

Step-by-Step Execution

1. Pigment Extraction: Grind the cabbage leaves with ethanol to extract anthocyanins. The ethanol acts as a solvent for the polar pigment molecules.
2. Filtration: Use gravity filtration to isolate the liquid indicator from the solid cellular waste.
3. Standardization: Create a reference scale by adding the indicator to solutions of known pH (1 to 14).
4. Testing: Introduce the indicator to unknown household substances and observe the color shift.
5. Molecular Analysis: Discuss how the structural change in the anthocyanin molecule (protonation or deprotonation) alters its light absorption spectrum, resulting in a color change.

Engineering the Classroom Laboratory: Safety and Infrastructure

Implementing 75 experiments requires more than just a manual; it requires a controlled environment that meets **ISO 45001** standards for occupational health and safety in an educational setting.

Laboratory Safety Protocols

- Personal Protective Equipment (PPE): Mandatory use of nitrile gloves, Z87+ rated safety goggles, and flame-retardant lab coats.
- Ventilation: Use of fume hoods for experiments involving volatile organic compounds (VOCs) or irritant gases.
- Chemical Storage: Implementation of the Globally Harmonized System (GHS) for labeling and segregating incompatible chemicals (e.g., keeping oxidizers away from flammables).
- Waste Management: Neutralization of acids/bases before disposal and separation of halogenated vs. non-halogenated organic waste.

Quantitative Data Analysis in Student Experiments

A technical writer must emphasize that an experiment is incomplete without **mathematical verification**. Students should be taught to calculate the **Percent Error** to evaluate the accuracy of their results:

Percent Error = [|Experimental Value - Theoretical Value| / Theoretical Value] × 100%

Furthermore, understanding **Precision vs. Accuracy**through the use of standard deviation (<2• allows students to assess the reliability of their repeated trials. This data-driven approach prepares them for higher education in STEM fields.

Comparison of Measurement Tools

Instrument	Measurement Parameter	Precision/Sensitivity	Common Application
Analytical Balance	Mass	0.0001 g	Stoichiometric weighing
Graduated Cylinder	Volume	0.5 mL	General liquid measurement
Digital Multimeter	Voltage/Current	0.01 V / 0.001 A	Ohm's Law experiments
Vernier Caliper	Length/Diameter	0.02 mm	Density and volume of solids

Case Study: Overcoming Common Experimental Failures

In a classroom setting, experiments often yield unexpected results due to **systematic errors** or **random errors**. Analyzing these failures is a critical part of the educational process.

Failure Mode: Inconsistent Results in Thermal Conductivity

Observation: Students measuring the thermal conductivity of different metals provide widely varying data points that do not match the known coefficients.

Root Cause Analysis (RCA):

- Inadequate Insulation: Heat loss to the surrounding environment (convection) was not accounted for.
- Thermal Interface Resistance: Poor contact between the heat source and the metal rod.
- Sensor Calibration: Thermocouples were not zeroed before the start of the experiment.

Proposed Solution:

Instructors should implement a **Standard Operating Procedure (SOP)**that includes the use of thermal paste to reduce interface resistance and the application of fiberglass insulation to ensure one-dimensional heat flow. This technical adjustment transforms a "failed" experiment into a lesson on engineering constraints.

The Role of Digital Integration: Data Loggers and Simulations

While the "75 Experimentos" manual focuses on physical manipulation, modern technical writing in education must address **Digital Data Acquisition (DAQ)**. Sensors for pH, CO ,, dissolved oxygen, and force can be interfaced with software like Logger Pro or Arduino-based systems. This allows for real-time graphing, which helps students visualize **Linear Regression** and **Correlation Coefficients (R^2)** during their analysis.

Digital vs. Analog: A Technical Comparison

- Analog: Better for teaching the fundamental mechanics of reading a scale; lower cost; no power requirement.
- Digital: Higher sampling rates (essential for rapid reactions); easier data export for statistical analysis; reduced parallax error.

Synthesis of Educational Outcomes

The strategic implementation of a high-volume experimental curriculum like the one proposed by Fernando Antolín Morales serves a dual purpose. First, it democratizes access to scientific inquiry, providing a standardized set of procedures that can be replicated across different socio-economic environments. Second, it bridges the gap

between abstract theory and industrial/academic application.

By engaging with these 75 experiments, students do not merely learn about science; they practice the role of the scientist. They navigate the complexities of equipment calibration, the frustrations of experimental error, and the satisfaction of empirical discovery. For the bilingual sections, this also involves mastering a specialized lexicon, ensuring that they are capable of communicating complex technical ideas in multiple languages—a prerequisite for the global scientific community.

Ultimately, the value of the "75 Experimentos en el aula" framework lies in its scalability and its rigorous adherence to the scientific method. Whether it is calculating the acceleration due to gravity through a simple pendulum or observing the osmotic pressure in plant cells, these experiments form the bedrock of a robust technical education. As educators and technical writers, our goal is to ensure these protocols are documented with the precision required to foster the next generation of engineers, doctors, and researchers. The transition from the classroom to the laboratory is a journey of precision, safety, and persistent inquiry.

Tags: #Science Experiments #Classroom Methodology #STEM Education #Laboratory Safety #Pedagogical Framework