

# Research on the Integration Model of STEM Curriculum and Teaching Skills Innovation Competition for Pre-service Teachers: A New Pathway for Cultivating Science Education Professionals

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**Abstract:** This study establishes a deep integration system between science education programs and STEM Teaching Skills Innovation Competitions through the "promoting teaching through competition, advancing learning through competition, and fostering innovation through competition" framework. The three-tier competition structure (foundation-core-transformation) and dual-track mechanism (technical implementation/pedagogical transformation) incorporate engineering practice capabilities and teaching conversion competencies into evaluation standards. The resulting cultivation pathway-"contextualized task-driven learning, scaffolded technical support, and pedagogical adaptation"-effectively resolves the disconnection between technical practice and teaching application among pre-service teachers.

**Keywords:** STEM, Pre-service Teachers, Science Education, Teaching Skills, Innovation.

## 1. Introduction

The global STEM education movement drives systemic reform in basic education. According to the Ministry of Education[1], interdisciplinary course adoption in primary/secondary schools increased by over 300% in three years. However, teacher capacity building lags behind curricular demands: only 28.6% of science teachers independently conduct electronics-based STEM projects, 73.4% of pre-service teachers report technical courses "overemphasize theory while lacking pedagogical guidance"[2], and 62% of teacher training institutions' lab courses remain verification-based. These issues originate from three fractures in traditional discipline-siloed training:

Knowledge fragmentation appears through the disconnect between technical courses (circuit design, programming) and pedagogical courses (lesson plan theory)[3]. Analyses indicate only 15% of technical course cases involve teaching adaptation, while merely 8% of pedagogical content integrates modern technology.

Practical deficiency stems from insufficient engineering design training. Most lab courses prioritize textbook theory verification over implementing "design-build-optimize" project cycles[4], with pre-service teachers engaging in <1.2 authentic engineering projects per semester.

Evaluation gaps cause imbalanced competency assessment. Traditional written tests fail to measure teaching transformation abilities, creating a "skilled in exams but ineffective in teaching" paradox[5]. Only 42% of top-performing pre-service teachers in written assessments effectively organize interdisciplinary inquiry.

Teaching skills innovation competitions offer a breakthrough solution[6]. Exemplary cases include physical teaching aid projects requiring concurrent scientific verification (lever principles), technical debugging (soldering precision), and engineering optimization (range extension). Industrial prototype transformations (e.g., dimming systems to "paper cup lamp" experiments) demonstrate three core

functions: catalyzing curriculum reform through authentic projects, incubating pedagogical innovation via technical adaptation, and establishing multidimensional competency benchmarks[7]. Provincial data confirms 41.7% higher STEM teaching competency among graduates from sustained competition participants.

## 2. Integration Framework: Three-Tier Dual-Track Competition System

### 2.1. Three-Tier Structure

Based on "knowledge integration-technical practice-pedagogical transformation" progression[8]:

Foundation Tier: STEM knowledge integration. Tasks like buoyancy-based densitometer construction prioritize conceptual accuracy (30%) and procedural standardization (20%), requiring articulation of Archimedes' principle-measurement technique connections[9].

Core Tier: Technical engineering practice. Projects like IoT weather stations emphasize system stability (40%) and innovation (20%), demanding end-to-end solutions with sensor calibration and 72-hour reliability testing[10].

Transformation Tier: Age-appropriate pedagogical design. Tasks such as junior-high "dimmable lamp" lessons enforce material simplification, functional visualization, and operational safety principles. Exemplary entries establish "phenomenon observation → problem posing → solution design → verification" inquiry chains.

### 2.2. Dual-Track Mechanism

Technical Implementation Track: Functional prototypes. Eco-material vehicles challenge lightweight design (<50g), energy conversion optimization, and environmental adaptability testing, necessitating materials science and fluid dynamics applications.

Pedagogical Transformation Track: Age-appropriate technical simplification. Industrial robotic arm programming adapted to K-12 "tea-sorting games" exemplifies progression: magnetic grippers (elementary), ultrasonic obstacle

avoidance (middle school), and machine vision (high school)[6]. One team's "Robotic Arm Primer Kit" reduced student error rates by 65% across 30+ schools.

### 2.3. Four-Dimensional Evaluation

Comprehensive assessment covers: Technical integration (circuit design, programming logic); Pedagogical design (inquiry questions, contextual authenticity); Engineering thinking (iteration frequency, cost control); Artistic expression (structural aesthetics, interactive experience) The "classroom recording + reflective defense" model evaluates student-led inquiry time ( $\geq 60\%$  for excellence), technical troubleshooting efficiency, and natural interdisciplinary integration[3]. Defense sessions require pedagogical justification, e.g., explaining titration-to-colorimetric analysis simplification in water quality projects.

## 3. Core Competency Cultivation: From Technology to Pedagogy

### 3.1. Interdisciplinary Integration

Contextualized tasks like "Campus Microclimate Monitoring" integrate: Science: Urban heat island analysis via temperature differentials

Technology: Three-point sensor calibration; LoRa transmission

Engineering: Wind-resistant enclosure fluid dynamics simulation

Mathematics: Temperature-humidity modeling through least-squares regression

Disciplinary mapping tools prevent superficial integration. In solar streetlight lessons: light measurement (science), angle-energy modeling (math), bracket design (engineering), and servo programming (technology). Pre-service teachers' mapping templates have been adopted for provincial teacher training.

### 3.2. Technical Capacity Building

Tiered framework: Basic: Mixly + Arduino projects (e.g., light-controlled lamps) enable non-engineering students to master fundamentals in 8 hours.

Advanced: Python + Raspberry Pi (e.g., plant disease recognition) develops data processing skills.

Innovation: AI kits (e.g., TensorFlow Lite engagement analyzers) facilitate machine learning deployment.

Virtual simulation platforms overcome constraints via circuit failure simulation, current thermal imaging, and real-time debugging. Adoption increased experimental efficiency by 68%, reduced component costs by 92%, and raised complex circuit success rates from 63% to 95%. VR soldering modules reduced errors by 80% through gesture-capture immersion.

### 3.3. Pedagogical Transformation

Technical simplification model: Professional prototypes (industrial sensors/C programming) → Teaching aids (simulated devices/Scratch) → Student kits (household materials/magnetic circuits). Water quality monitoring progression illustrates: spectrometers → colorimetric cards → tea-infusion color observation. Localized contextualization emphasizes: Regional themes (e.g., "canal monitoring" in Jiangnan water towns). Life-based problems (e.g., community environmental issues). Traditional-modern integration (e.g., traditional steelyards with modern sensors).

The "Ancient Brewing STEM Course" combined microbial science, sensor-optimized processes, and artisans' oral histories.

## 4. Implementation Effectiveness and Development

### 4.1. Empirical Competency Gains

Longitudinal study of 428 pre-service teachers shows significant improvement: Pedagogical design ability increased 57.3% (58.1 → 91.4), technical application 43.9% (62.3 → 89.7), and interdisciplinary integration 79.4% (47.5 → 85.2). Key mechanisms: 89.2% attributed gains to "authentic project-driven knowledge integration," 76.5% to "pedagogical tasks reshaping technical cognition."

Exemplary outcomes: Wearable photosynthesis monitors: Miniaturized chlorophyll sensors convert spectral data to "plant health indices," winning national teaching awards. Color changes demonstrate photosynthesis for elementary students; light-efficiency analysis suits secondary levels.

Poetry-mechanics theaters: Servo-controlled lotus mechanisms recreate classical poetry scenes, increasing humanities-background student participation by 45%.

### 4.2. Challenges and Solutions

Faculty development employs tripartite mentorship: technical experts (prototyping), pedagogy mentors (lesson plans), practicing teachers (classroom feedback)[3]. One institution increased mentors' interdisciplinary competency from 35% to 82%.

Resource adaptation tailors solutions: Urban: Arduino + 3D printing (e.g., traffic monitoring)

Rural: Low-cost ESP32 + recycled materials (e.g., soil-moisture irrigation)[9]. Kits include substitution guides like gypsum-board humidity sensors (5% industrial cost).

Evaluation reform uses blockchain for immutable progress tracking. AI-generated diagnostics (e.g., "excellent circuit design but inadequate learner analysis") trigger personalized resources[5]. Pilots show 3.2× efficiency gains and 88% resource targeting accuracy.

## 5. Conclusion: Competition-Education Ecosystem

### 5.1. Contributions

This model drives triple transformation: Curriculum restructuring integrates authentic projects (e.g., 20% credit for IoT development). Teacher competency evolution shifts practitioners from technical operators to educational designers. Resource ecosystems develop shared repositories, with 47 provincial-awarded lesson plans exceeding 20,000 annual downloads.

### 5.2. Recommendations

Policy: Incorporate competition outcomes into teaching certification; establish STEM teaching standards per Science Education Guidelines. Technology: Develop AI lesson analyzers assessing interdisciplinary integration, technical difficulty adaptation, and activity optimization. Ecosystem: Forge university-school-enterprise collaboration: curriculum R&D, implementation validation, and technical support (e.g., simplified APIs). Educational innovation thrives through transformative practice. When pre-service teachers contemplate cognition while soldering circuits or design

inquiry while debugging programs, they reshape education's DNA. Teaching competitions ignite reform's flame—where engineering and humanistic care converge, guiding "teaching for the unknown, learning for the future". As one participant reflected: "The competition taught bridging science and education, not just technology."

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