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A K20 Center Research Brief

STEM Design Lab: Building Critical Thinking and Collaboration

Evrin Baran, Sedef Canbazoglu Bilici, Canan Mesutoglu, and Ceren Ocak
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Introduction

Growing global interest in STEM education has prompted researchers and policymakers to look beyond the traditional classroom. Formal school settings often constrain STEM instruction to individual content-area courses, limiting students' ability to see connections across science, technology, engineering, and mathematics disciplines. Time demands and formal curriculum requirements further restrict opportunities for the kind of hands-on, interdisciplinary problem-solving that research suggests builds authentic STEM competencies. Out-of-school learning environments, such as summer camps, science museums, robotics leagues, and university-based workshops, offer important alternatives. These informal settings allow students the freedom to explore STEM ideas in authentic contexts, engage in engineering design, and develop technology and inquiry skills that may not surface in traditional coursework. Research has demonstrated that participation in out-of-school STEM programs positively affects students' academic achievement, interest in STEM fields, and career aspirations.

Despite a growing evidence base, challenges remain. Time constraints in short-term programs, inconsistent evaluation frameworks, and limited data on underrepresented student populations make it difficult for decision-makers to assess program value. There is a particular need for theoretically grounded models of out-of-school STEM programs implemented in systematic ways.

The authors of this study designed a university-based, out-of-school STEM education program grounded in a conceptual framework emphasizing authentic learning contexts, engineering design processes, and content integration across all four STEM disciplines. The study aimed to measure if participation in this program changed secondary students' attitudes toward STEM disciplines and STEM career pathways and to understand the mechanisms through which those changes occurred.

Methodology

Research Design

The study employed a quantitative pretest-posttest design. Researchers examined changes in students' attitudes toward STEM and STEM careers before and after participation in an



out-of-school STEM program. The design allowed the authors to measure shifts in attitudes associated with program participation but did not include random assignment or a comparison control group.

Sample

The study was conducted in an informal learning context rather than a regular classroom.

- Number of participants: 40 sixth-grade secondary students (25 male, 15 female)
- Grade level: Sixth grade (ages 10 to 12)
- Recruitment: Invitations were sent to public school administrators and city science centers. Seventy students expressed interest; 40 were selected based on enrollment in different schools, a sixth-grade academic level, and no prior experience in a STEM education program
- Schools represented: 24 different secondary schools that did not offer a formal integrated STEM course

Intervention Descriptions

The STEM education program was a university-based, out-of-school initiative designed specifically for sixth-grade secondary students. The program was grounded in a conceptual framework with three core components: authentic learning contexts, an engineering design process, and content integration across all four STEM disciplines.

The program opened with a welcoming session for students and parents to explain the program's scope and goals. This was followed by a visit to the university's Science Museum, where students explored three exhibits: an Applied Science Center, the History of Science, and Technology and History of Transportation. Museum exhibits included science demonstration experiments, group discussions, and science contests.

The remaining days of the program were devoted to 14 STEM modules, which included:

- Egg-drop
- Scaled model of the solar system
- Application inventor
- Design of a vacuum cleaner
- Enduring buildings
- STEM commercial video
- Pot-kin car design
- Design of a high-speed train
- Time to investigate, calculate, build, and test
- Design of a wind turbine
- We are building our own structures
- Interrogate and learn: force and motion with probes



- Cryptology and Egyptian number systems
- Design of a kaleidoscope

Dosage

The program was implemented across three consecutive weekends for a total of 5 days and 40 hours. The intervention included 14 STEM modules, each addressing different science and engineering practices.

- Total number of sessions: 14 STEM modules delivered across 5 days
- Session length: Each module lasted 90 to 180 minutes; 2 to 4 modules were conducted each day
- Daily schedule: Sessions ran from 9am to 5pm each day, with a 15-minute large-group debrief following each module
- Total duration: 3 consecutive weekends, 5 days total
- Total instructional time: 40 hours (as stated in the study)

Data Analysis

Researchers analyzed data by comparing pre- and post-intervention survey responses measuring students' attitudes toward STEM and STEM careers. Statistical analyses were used to determine whether observed changes were statistically significant. The focus was on identifying overall attitude shifts following program participation.

Results

Key findings reported in the study include:

- Students demonstrated statistically significant improvements in their attitudes toward STEM.
- Students also showed more positive attitudes toward STEM careers after participating in the program.
- Results suggest that out-of-school STEM experiences can support students' perceptions of STEM as engaging, relevant, and attainable.

The findings indicate that informal STEM learning environments may play an important role in complementing school-based instruction by fostering positive attitudes that support long-term engagement in STEM pathways.

Application into Practice

This study suggests that out-of-school STEM programs can serve as valuable tools for schools and districts seeking to improve student attitudes toward STEM learning and careers.

Action Steps for Schools and Districts

1. Develop or partner with out-of-school STEM programs that focus on integrated STEM learning.



2. Target students in secondary school, which is a critical period for shaping STEM attitudes.
3. Prioritize hands-on and career-connected STEM experiences.
4. Use attitude surveys to measure shifts in student perceptions before and after participation.
5. View out-of-school programs as supplements, not replacements, to in-school STEM instruction.

Work Cited

Baran, E. (2019). The impact of an out-of-school STEM education program on students' attitudes toward STEM and STEM careers. *School Science and Mathematics*, 119(4).
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