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Scaling STEM-ID: Engineering Curriculum Implementation Supported by an NSF DRK-12 Project

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Introduction

Broadening access to high-quality middle school engineering education remains a national priority, particularly as districts seek to scale evidence-based STEM curricula beyond pilot contexts. The STEM-ID project, supported by the National Science Foundation's DRK-12 program, is explicitly focused on understanding what it takes to scale rigorous, engaging middle school engineering instruction while maintaining the integrity of core pedagogical commitments. Building on prior NSF-funded development work, the STEM Innovation and Design (STEM-ID) curriculum consists of three grade-level, semester-long middle school engineering courses organized around contextualized design challenges that integrate the engineering design process (EDP) with core mathematics and science learning.

As implementation has expanded to include a growing number of teachers, schools, and instructional contexts—spanning sixteen middle schools across multiple cohorts of teachers—the project's research agenda has increasingly centered on questions of scalability and sustainability. In this paper, scaling is understood not simply as increasing the number of classrooms using the curriculum, but as examining how critical components of the curriculum are taken up, adapted, and sustained across varied contexts. This paper reports illustrative findings from ongoing implementation research examining how key components of the STEM-ID curriculum are enacted at scale, the nature of teacher adaptations as implementation broadens, and factors that influence successful and sustainable use of the curriculum. This paper reports illustrative findings from ongoing implementation research examining how key components of the STEM-ID curriculum are enacted across settings, the nature of teacher adaptations, and factors that influence successful and sustainable implementation.

Conceptual Framework

This work is guided by the Innovation Implementation Framework [1], which conceptualizes curricular innovations as componential and enacted within complex educational systems. The framework distinguishes between *structural components*—including procedural and educative features of the curriculum—and *interactional components*, which focus on the behaviors and practices of teachers and students during enactment.

Drawing on earlier development and implementation studies, the research team identified a set of critical components essential to achieving the intended outcomes of the STEM-ID curriculum (Table 1). These include organization around contextualized challenges, use of curriculum materials and supports, facilitation of student engagement in the engineering design process, integration of mathematics and science, use of advanced manufacturing technologies, and collaborative group work. Consistent with the Innovation Implementation Framework, this study focuses on how these components are used in practice rather than strict fidelity to an idealized model.

Table 1

STEM-ID Critical Components

<table>
<tr><td colspan="2">Structural – Procedural Component</td><td colspan="2">Structural – Educative Component</td></tr>
<tr><td colspan="2">1. Course organized according to contextualized problem-based challenges.</td><td colspan="2">2. Utilization of STEM-ID Materials including:

Teachers’ Edition, materials and supplies related to design challenges, challenge overviews, information on related Math and Science standards, instructions for preparing and utilizing technology (3-D printers, LEGO Robotics, CAD software), digital Engineering Design Logs</td></tr>
<tr><td colspan="4">Interactional Components</td></tr>
<tr><td>Component Area</td><td colspan="2">Teachers</td><td>Students</td></tr>
<tr><td>Engineering Design Process</td><td colspan="2">3. Teacher Facilitates Student Engagement in the Engineering Design Process</td><td>4. Students Engage in the Engineering Design Process</td></tr>
<tr><td>Math/Science Integration</td><td colspan="2">5. Teacher Facilitates Integration of Math/Science and Engineering</td><td>6. Students Apply Math/Science Content and Skills</td></tr>
<tr><td>Advanced Manufacturing Technology</td><td colspan="2">7. Teacher Facilitates Utilization of Advanced Manufacturing Technology</td><td>8. Students Use Advanced Manufacturing Technology</td></tr>
<tr><td>Collaborative Group Work</td><td colspan="2">9. Teacher Facilitates Collaborative Group Work</td><td>10. Students Engage in Collaborative Group Work</td></tr>
</table>

Methods

Implementation research drew on multiple data sources collected during the 2024–25 academic year, including classroom observations, teacher interviews, online PLC check-ins, and implementation surveys. Data collection focused on eleven teachers implementing the curriculum across ten middle schools during this reporting period, within a broader multi-year implementation that has reached sixteen middle schools.

Classroom observations were conducted using a semi-structured protocol aligned to each critical component of the curriculum and included both checklist ratings and detailed field notes. Across the project, researchers have conducted over one hundred classroom observations, with multiple observations per teacher to capture variation across challenges and instructional phases.

Semi-structured interviews were conducted with participating teachers at the end of each semester to elicit reflections on implementation, challenges, adaptations, and contextual influences. During the 2024–25 year, a total of nineteen interviews were conducted, each lasting approximately 45–60 minutes.

Implementation surveys were completed by teachers following individual curriculum challenges and included both structured items documenting enacted practices and open-ended prompts describing challenges and adaptations. Monthly online PLC check-ins served as both professional learning opportunities and a mechanism for documenting implementation experiences across the year.

Qualitative data from observations, interviews, and PLC discussions were analyzed using a systematic coding and synthesis process informed by Miles, Huberman, and Saldaña [2]. Coding focused on identifying evidence related to the enactment of critical curriculum components, teacher adaptations, and contextual factors influencing implementation. Survey data were analyzed descriptively to identify patterns across teachers and challenges.

Findings

Overall Implementation Patterns

Across sites, implementation of the STEM-ID curriculum varied considerably. Some teachers achieved full implementation of most curriculum challenges, while others implemented a subset of activities or modified sequencing to accommodate contextual constraints. Design-focused challenges—particularly those involving robotics or extended prototyping—were most likely to be partially implemented or omitted. Importantly, years of teaching experience or prior experience with the curriculum did not consistently predict degree of implementation.

Teachers working within shorter instructional cycles (e.g., nine-week quarters) frequently developed adapted implementation plans that prioritized selected challenges or activities. These adaptations reflected intentional decision-making aimed at preserving core learning goals within constrained schedules.

Implementation of Critical Components

Despite variation in overall completion, evidence of all critical curriculum components was observed across participating classrooms. Teachers consistently facilitated collaborative group work and integration of mathematics and science concepts, even in cases of partial curriculum completion. Student engagement in the engineering design process was strongest in early phases (problem definition and ideation), with prototyping, testing, and iteration more sensitive to time and technical constraints.

Use of advanced manufacturing technologies, such as CAD and 3D printing, was a notable source of both high student engagement and implementation challenges. Technical issues, software access, and equipment reliability frequently shaped how and when these components were enacted.

Teacher Adaptations

Adaptations were common and generally aligned with project guidance encouraging responsive implementation. Most adaptations were pedagogical in nature, including the addition of scaffolding activities, reorganization of challenge sequences, or substitution of comparable engineering tasks. Teachers often described these adaptations as necessary to address pacing, assessment requirements, or students' prior knowledge while maintaining alignment with curriculum goals.

Factors Influencing Implementation

Teachers identified multiple factors influencing implementation, including curriculum scope and complexity, access to resources and technology, scheduling structures, and individual teacher characteristics such as pedagogical content knowledge and self-efficacy. Professional development and participation in the project PLC were consistently cited as key supports for navigating challenges and sustaining implementation.

Discussion

Findings underscore the importance of examining curriculum use rather than strict fidelity when studying implementation at scale. As the STEM-ID curriculum has moved beyond early implementation contexts, variability in enactment has become both expected and informative. While full implementation of a semester-long, technology-rich engineering curriculum proved difficult in many settings, teachers demonstrated substantial commitment to enacting core components and making principled adaptations in response to contextual constraints.

From a scaling perspective, these findings suggest that sustainability depends less on uniform implementation and more on the curriculum's capacity to support productive variation. Teachers' adaptations—particularly those that preserved engagement in the engineering design process, math and science integration, and collaborative problem solving—often reflected deep engagement with the curriculum's underlying goals. At the same time, recurring challenges related to pacing, scheduling, and technology point to structural features that warrant continued refinement as the project scales.

Collectively, these insights have informed ongoing efforts to streamline and modularize elements of the curriculum in ways that preserve rigor and authenticity while offering greater flexibility for implementation across diverse instructional contexts.

Conclusion

This implementation research highlights both the promise and complexity of scaling middle school engineering curricula across diverse educational settings. By documenting patterns of enactment, adaptation, and contextual influence, the project contributes to a growing knowledge base on how ambitious STEM curricula are taken up in practice. Ongoing research will continue to examine how implementation relates to teacher learning and student outcomes as the project expands to additional schools and districts.

References

[1] J., Century and A. Cassata, “Implementation research: Finding common ground on what, how, why, where, and who,” *Review of Research in Education,* vol. *38*, no. 1, pp. 169–215, 2014.

[2] M. B. Miles, A.M. Huberman, and J. Saldaña, *Qualitative Data Analysis: A Methods Sourcebook* (4th ed.). Sage. 2019.

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