Evaluating the Efficacy of Engineering is Elementary® for Student Learning of Engineering and Science Concepts

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Abstract

Using the data from a randomized-controlled trial (RCT), we evaluated the efficacy of Engineering is Elementary® (EiE), an elementary engineering curriculum intervention grounded on the principles of inquiry and project-based learning. We assessed intervention effects with intent-to-treat analyses. The results showed that the intervention curriculum was particularly effective for improving student learning of science concepts required to understand the problems and processes of engineering.

What is EiE?

Background

Engineering has been incorporated into K-12 science standards in the U.S. In the past several years, there has been a growing need for high-quality curricular materials for engineering instruction in elementary schools. EiE is an elementary engineering curriculum developed by Museum of Science, Boston, to increase children's engineering knowledge and skills and support teachers' pedagogical development in engineering education.

Critical Components of EiE

EiE consists of 20 units that introduce a variety of engineering fields. Each unit is designed to build on and apply science content through the design and development of a related technology. Grounded on the principles of inquiry and project-based learning, EiE incorporates the following critical components:

- the problem is introduced in a relevant, interesting context
- students learn about and use the engineering design process
- engineering challenges specify a challenge and constraints and permit many possible solutions
- students use science and math to design solutions
- students use failure constructively and design iteratively
- students work collaboratively

Current Study

Using two cohorts of data from a large-scale RCT project implementing four engineering units (electrical, environmental, geotechnical, and package engineering) with the treatment (EiE) or control (E4C) curriculum, the current study:

a. Examined the baseline equivalence of intervention and comparison groups to assess to what extent randomization was successfully implemented

b. Evaluated the impact of EiE on student learning of engineering and related science concepts and processes by conducting an intent-to-treat analysis

Method

Recruitment & Randomization

- Contacted principals of schools in MA, MD, & NC to recruit
- Selected 359 teachers from 244 schools out of 613 eligible teachers
- Randomly assigned schools to EiE or control (E4C), and then teachers in EiE to one of 4 EiE units and those in E4C to one of 4 comparison units
- Randomly assigned half of 252 volunteer teachers to implement an extra unit (civil engineering) as a second dose

Teacher Training

Teachers attended a 3-day professional development workshop in the summer and a 1-day follow-up session in the spring. Training included:

- introduction to engineering & hands-on sessions on the assigned unit
- modeling curriculum-specific pedagogy, class management, & activities
- preparation for data collection by reviewing protocols & requirements

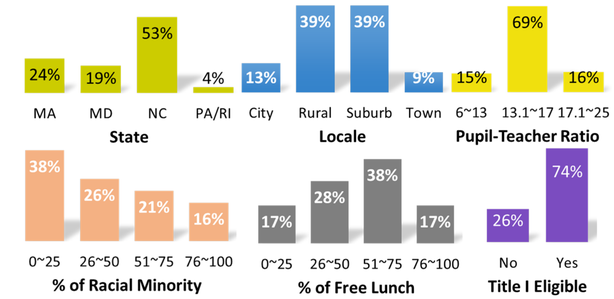
Curriculum Implementation & Data Collection

- Student pretest and demographic data were collected prior to intervention
- Teachers then implemented their science curricula and engineering unit, each with approximately 10 hrs of content over 8-10 lessons
- Upon completion, teachers collected posttest data from students
- All unit-specific engineering & science assessment instruments were developed by the project team and tested for validity and reliability

Attrition & Final Analytic Samples

- 5% & 15% of school attrition during 1st and 2nd year, respectively
- No different attrition rate b/w EiE and E4 schools; no significant differences in school characteristics b/w those retained and dropped; and no significant treatment-by-attrition on school characteristics
- See table below for final analytic sample size for each engineering unit and graphs below for characteristics of all schools in the samples

Unit	Schools			Classrooms			Students		
	Total	EiE	E4C	Total	EiE	E4C	Total	EiE	E4C
Electrical	39	18	21	134	52	82	2908	1208	1700
Environmental	54	29	25	191	92	99	4370	2135	2235
Geotechnical	35	18	17	107	46	61	2439	1007	1432
Package	46	23	23	139	63	76	3026	1367	1659



Analysis & Result

Baseline Equivalence

- Examined the baseline equivalence of the treatment and control groups at the school, classroom, and student levels to determine whether randomization was successful using independent sample *t*-tests and chi-square tests
- Found little significant difference in baseline demographic characteristics and pretest scores b/w the two groups

Impact of EiE Intervention

- Employed 3-level hierarchical linear modeling to conduct intent-to-treat analyses of the impact of EiE
- Adjusted for student gender, race, pretest score, and free/reduced lunch status; classroom grade level, cohort and an extra unit implementation; and school location, school average pretest score
- Table below presents the results of the analyses

Unit	Assessment Outcome	Estimate (SE)	Effect Size
Electrical	Circuits[e]	-0.06 (0.25)	-0.03
	Energy[s]	0.13 (0.17)	0.07
	Electricity[s]	-0.12 (0.19)	-0.07
Environmental	Pollution[e]	0.05 (0.12)	0.03
	Read foodwebs[s]	**0.26 (0.11) ***	**0.17**
	Analyze foodwebs[s]	**0.19 (0.11) †**	**0.10**
Geotechnical	Foundation[e]	0.28 (0.34)	0.11
	Landforms[s]	**0.63 (0.22) ******	**0.22**
Package	Plants[e]	0.01 (0.07)	0.01
	Package Design[e]	**0.33 (0.19) †**	**0.14**
	Plant Structures[s]	**0.37 (0.23) †**	**0.20**
	Needs for Plants[s]	**0.18 (0.08) ***	**0.18**

Note. ** $p < .01$, * $p < .05$, † $p < .10$; "e" superscript indicates engineering domain and "s" superscript indicates science domain

Conclusion

Findings & Discussion

- Found significant or marginally significant effects of EiE on 5 out of 7 science assessment outcomes, and 1 of 5 engineering assessment outcomes
- Given the short period of curriculum implementation, the findings provide good evidence for the efficacy of the EiE intervention, particularly for science
- Both treatments addressed the same engineering objectives using different pedagogies, so lack of significance of factual engineering outcomes unsurprising
- The EiE curriculum was designed to apply science concepts. Both groups learned the same science content but those using EiE had improved science outcomes.

Next Steps

- Conduct moderating analyses to examine if EiE effects would differ depending on student- and class-level characteristics
- Conduct treatment-on-the-treated analysis to examine the mediating role of fidelity of implementation (FOI)

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