Examining the Efficacy of Foundations of Science Literacy: Exploring Contextual Factors

Overview
- **Foundations of Science Literacy (FSL)**
  - Comprehensive professional development for preschool
  - Emphasizes development of scientific thinking
- **Purpose of talk**
  - Evidence of program efficacy
  - Causal mechanisms underlying development of scientific thinking

Outline of Talk
1. **Foundations of Science Literacy (FSL)**
2. Causal Framework
3. Instruments
4. Efficacy of FSL
5. Summary and Conclusions

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Foundations of Science Literacy (FSL)

- Comprehensive professional development program
- Introduces teachers to latest thinking about early science learning
- Supports application to classroom practices through
  - 42 hours of instruction
  - Group & individual mentoring
  - Performance-based assignments

FSL: Study Design

- Random assignment at program level
  - 60% to FSL
  - 40% to control group
- Research objectives: Impact of FSL on
  - Classroom practices in teaching science
  - Children's science concepts and scientific thinking skills

Analytic Sample

<table>
<thead>
<tr>
<th></th>
<th>Classrooms</th>
<th>Children</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSL</td>
<td>40</td>
<td>270</td>
</tr>
<tr>
<td>Control</td>
<td>32</td>
<td>186</td>
</tr>
<tr>
<td>Total</td>
<td>72</td>
<td>436</td>
</tr>
</tbody>
</table>

FSL: Science Content

- Physical science concepts
  - Water flow
  - Properties of liquids
  - Sinking and floating
  - Balls and ramps

- Scientific thinking skills
  - Solving challenges in the case of constraints
  - Testing and revising hypotheses
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Causal Framework: Misconceptions

Misconceptions about the physical world
- Often arise from intuitive theories based on experiential thinking (Carey, 1985; Keil, 1989)
- e.g. Small things aren’t strong enough to float...

How is it that children advance beyond their intuitive ideas about floating and sinking?

Causal Framework: Overview

Intuitive theories about physical world → Shift to scientific thinking → Hypothesis revision based on experience

Experience with physical world → Executive functioning capacity

Foundations of Science Literacy

Causal Framework: EF Capacity

- As we gain executive control, we learn how to inhibit intuitive, but incorrect, responses
- EF capacity: ability to represent and process hierarchical rule systems (Zelazo et al., 2006)
- Hypothesis Revision (Gropen et al., in press)

What Happened: Action → Observed Outcome ≠ What They Thought Would Happen: Action → Predicted Outcome
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**Causal Framework: INUS Example**

- Oxygen
- Lightning
- Fire
- Energy Source
- Lit Cigarette

**Causal Framework: INUS Applied**

- Exposure to Scientific Phenomena
- FSL
- Hypothesis Revision
- PAS
- Stimulating Home Environment
- Executive Function Capacity
- DCCS

**Instruments: Overview**

- **Preschool Assessment of Science (PAS)**
  - Assesses scientific thinking
  - Performance-based
  - Four prediction tasks
  - Two challenge tasks
  - Cronbach’s alpha = 0.729

- **Dimensional Change Card Sort (DCCS)**
  - Assesses cognitive flexibility
  - Sorting task
  - Cronbach’s alpha > 0.90

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Instruments: **DCCS**

**Color Game:**
- Here's a blue star and here's a red truck.
- In the color game, all the blue ones go here...
- and all the red ones go here...
- 6 trials with test cards
- Continue if at least 5/6 correct

**Shape Game:**
- Now we're going to play the shape game.
- In the shape game, all the stars go here...
- and all the trucks go here...
- 6 trials with test cards
- Passing if at least 5/6 correct

Instruments: **PAS** Floating & Sinking Prediction Task

**Prediction:** "If we put these 3 blocks in the water, two of them will float and one of them will sink. Which one will sink?"

**Observation:** "Let's see what happens. Put all the blocks in the water. Ok, now watch me put all the blocks in the water."

**Confirmation/Revision:** "If we put these 3 cylinders in the water, two of them would float and one of them would sink. Which one would sink?"

---

**Instruments: Convergent Evidence**

<table>
<thead>
<tr>
<th>Children whose initial prediction was incorrect</th>
<th>N=451</th>
<th>PAS Incorrect Revision</th>
<th>PAS Correct Revision</th>
<th>( \chi^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCCS Switch</td>
<td>131</td>
<td>57</td>
<td>27.298***</td>
<td></td>
</tr>
<tr>
<td>DCCS +Switch</td>
<td>118</td>
<td>145</td>
<td></td>
<td></td>
</tr>
</tbody>
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Efficacy of FSL: Framework

Exposure to Scientific Phenomena

Hypothesis Revision

Stimulating Home Environment

Executive Function Capacity

Efficacy of FSL: Results

Fixed effects

<table>
<thead>
<tr>
<th>Covariate</th>
<th>Estimated Coefficient (SE)</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept, $\gamma_{00}$</td>
<td>0.05 (0.34)</td>
<td>0.15</td>
</tr>
<tr>
<td>Child-level covariates (df = 332)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall revision score, $\gamma_{10}$</td>
<td>0.36 (0.26)</td>
<td>1.36</td>
</tr>
<tr>
<td>Age (in months), $\gamma_{20}$</td>
<td>0.12 (0.03)</td>
<td>3.51**</td>
</tr>
<tr>
<td>Gender (Female = 0), $\gamma_{30}$</td>
<td>-0.03 (0.25)</td>
<td>-0.13</td>
</tr>
<tr>
<td>IEP status, $\gamma_{40}$</td>
<td>-0.43 (0.41)</td>
<td>-1.05</td>
</tr>
<tr>
<td>Language of testing (Eng = 0), $\gamma_{50}$</td>
<td>-1.14 (0.35)</td>
<td>-3.27***</td>
</tr>
<tr>
<td>Maternal education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (Less than HS), $\gamma_{60}$</td>
<td>-0.22 (0.49)</td>
<td>-0.45</td>
</tr>
<tr>
<td>High (BA or above), $\gamma_{70}$</td>
<td>0.02 (0.43)</td>
<td>0.05</td>
</tr>
<tr>
<td>Cognitive flexibility (High = 0), $\gamma_{80}$</td>
<td>-0.08 (0.58)</td>
<td>-0.14</td>
</tr>
<tr>
<td>Classroom-level predictor (df = 61)</td>
<td>1.14 (0.42)</td>
<td>2.74**</td>
</tr>
</tbody>
</table>

Cross-level interactions (df = 202)

| FSL * Maternal education, $\gamma_{90}$ | 0.07 (0.65) | 0.11 |
| FSL * High maternal ed., $\gamma_{10}$  | -0.05 (0.88) | -0.06 |
| FSL * Cognitive flexibility, $\gamma_{11}$| -0.05 (0.55) | -0.06 |

*** $p < .001$, ** $p < .01$, * $p < .05$, † $p < .10$
Summary of Main Results

• FSL supports young children’s ability to revise scientific hypotheses under relevant circumstances

• Efficacy of FSL is greater for:
  o Children with sufficient cognitive flexibility to switch dimensions on the DCCS
  o Children whose mothers have less education

Conclusions

• Shows how an educational intervention affects student outcomes through
  o cognitive and
  o contextual mechanisms

• Builds towards an explanatory and predictive theory of educational mechanisms
  o “why” and “for whom”

Acknowledgements

• Institute of Education Sciences, U.S. Department of Education

• We gratefully acknowledge the contributions of our colleagues:
  Janna Fuccillo
  Cindy Hoisington
  Donna Dervishian