USING AN ARGUMENT-BASED INQUIRY APPROACH TO LEARN SCIENCE: YEAR 1 RESULTS OF THE SCIENCE WRITING HEURISTIC (SWH)

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### Overview of the Grant

<table>
<thead>
<tr>
<th>Program:</th>
<th>Mathematics and Science Education</th>
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<tbody>
<tr>
<td>Title:</td>
<td>Efficacy of the Science Writing Heuristic (SWH) Approach</td>
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<tr>
<td>Year:</td>
<td>2009</td>
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<td>Investigators:</td>
<td>Brian Hand (PI), Bill Therrien (Co-PI), Mack Shelley (Co-PI)</td>
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<td>Grantee:</td>
<td>University of Iowa</td>
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<td>Goal:</td>
<td>Efficacy</td>
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<td>Award Period:</td>
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Purpose of the Study

- Basic scientific literacy, knowledge, and skills are needed in order to participate effectively in a society increasingly shaped by science and technology.

- Current study tests the efficacy of an inquiry approach
  - Helps build students’ science content knowledge, argumentation skills
  - Interest as a foundation for scientific literacy with elementary school students
Sample and Setting

- **Setting:** Participating schools are located in urban, suburban, and rural districts in Iowa.

- **Population:**
  - Students and their teachers in Grades 3 to 6
  - 48 elementary schools
  - Low socioeconomic backgrounds

- **Dependent Measures**
  - Iowa Test of Basic Skills (ITBS) – Math, Reading, Science, plus subscales
  - Cornell Critical Thinking Test (CTT) – Overall scores plus subscales
Research Design and Methods

- **Block-randomized design**
  - 48 elementary schools (24 treatment; 24 control)
  - Treatment: SWH approach in science instruction
    - Professional Development: 7 days – summer, 3 – school year

- **Instructional Sessions**
  - 20% videotaped
    - 10% stratified by month, teacher, and study condition
    - Randomly selected for viewing and coding
    - Fidelity of implementation will be measured by the Reformed Teacher Observation Protocol (RTOP) and the Classroom Protocol of Effective Teaching (C-PET)
Intervention: The Science Writing Heuristic (SWH) approach

- **Argument-based Inquiry**
  - Students set their own investigative agenda
  - Students are encouraged to make explicit and defensible connections between questions, observations, data, claims, and evidence.

- **Learning by immersion**
  - Argument used within the context of the topics for which they have to build understanding
  - The concept of argument is not separated from how knowledge is constructed in science
  - Students learn about language, while they learn through language while experiencing language (Halliday, 1975).
Intervention: The SWH approach

- **Learning**
  - An active negotiation of meaning (Vygotsky, 1962)
  - Conceptual frameworks & big ideas
  - Existing knowledge

- **Language**
  - Personal explanations and observations are tested against the perceptions and contributions of other students in the class
  - Represent knowledge in multiple ways – reading, writing, oral language, visual representations

- **Pedagogy – Enactment of theoretical orientations**
<table>
<thead>
<tr>
<th>Student Template</th>
<th>Teacher Template</th>
</tr>
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<tbody>
<tr>
<td><strong>1</strong> Beginning ideas</td>
<td>1. Exploration of pre-instruction understanding through individual or group concept mapping or working through a computer simulation.</td>
</tr>
<tr>
<td><strong>2</strong> Tests</td>
<td>2. Pre-laboratory activities, including informal writing, making observations, brainstorming, and posing questions.</td>
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<tr>
<td><strong>3</strong> Observations</td>
<td>3. Participation in laboratory activity.</td>
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<tr>
<td><strong>4</strong> Claims</td>
<td>4. Negotiation phase I - writing personal meanings for laboratory activity.</td>
</tr>
<tr>
<td><strong>5</strong> Evidence</td>
<td>5. Negotiation phase II - sharing and comparing data interpretations in small groups.</td>
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<tr>
<td><strong>6</strong> Reading</td>
<td>6. Negotiation phase III - comparing science ideas to textbooks for other printed resources.</td>
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<tr>
<td><strong>7</strong> Reflection</td>
<td>7. Negotiation phase IV - individual reflection and writing.</td>
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<tr>
<td><strong>8</strong> Writing</td>
<td>8. Exploration of post-instruction understanding through concept mapping, group discussion, or writing a clear explanation.</td>
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</table>
Cornell Critical Thinking Test Results
Overall

Comparing Treatment (SWH) vs. Control

Two-sample t-tests conducted on the 5th grade CCT data

SWH students ($n=1,154$) had significantly higher gains overall ($p=.002$), compared to control students ($n=882$)
Comparing Treatment (SWH) vs. Control

Two-sample $t$-tests conducted on the 5$^{th}$ grade CCT data

SWH students ($n=1,154$) had significantly higher gains in levels of induction ($p=.010$) compared to control students ($n=882$)
Comparing Treatment (SWH) vs. Control

Two-sample $t$-tests conducted on the 5th grade CCT data

SWH students ($n=1,154$), compared to control students ($n=882$), did not have significantly different gains on observation and credibility ($p=.322$)
Comparing Treatment (SWH) vs. Control

Two-sample $t$-tests conducted on the 5th grade CCT data

SWH students ($n=1,154$), compared to control students ($n=882$), had significantly higher gains on deduction ($p=.004$)
Comparing Treatment (SWH) vs. Control

Two-sample t-tests conducted on the 5th grade CCT data

SWH students \((n=1,154)\) did not have significantly higher gains in deduction/assumption \((p=.191)\)
A tentative SEM (n=1,808) was estimated using maximum likelihood to assess relationships among demographic variables and student ITBS (previous year) and CCT outcome measures.

* The model results in acceptable metrics ($\chi^2=274.518$, $df=75$, $p<0.0001$; RMSEA=0.038, CFI=0.977, TLI=0.972 SRMR=0.020).

* Model results, summarized in Figure 1

  - **CT**: control and treatment designation (1=Treatment, 2=Control),
  - **CCT**: Post test Cornell Critical Thinking Score
  - **IMP**: Improvement on the CCT (Post Test – Pre Test)
  - **ALL**: the composite student achievement measure

* the other variables are as defined on the next slide
Using a SEM to account for variability and relationships between 5th grade demographics and tests scores (ITBS and CCT), accounting for SWH control/treatment (Figure 2)

SWH students have higher gains overall ($p=.001$), compared to control students

**QTR**: quarter of test administration (Fall=0, Midyear=1, Spring=2)

**ASN**: Asian, **BLK**: Black

**SED**: special education

**GAT**: gifted and talented

**FRL**: free and reduced lunch

**ELL**: English language learner

**T1L**: Type 1 language

**RC**: Reading Comprehension

**M1**: Math Concepts/Estimation

**M2**: Math Problems & Data Interpretation

**SI**: Science Inquiry (subset of Science Comprehension)

**NSI**: Non-science Inquiry

**Figure 2: Tentative SEM – Testing Effect of Treatment**
Bootstrap Test

- Treatment assigned to school buildings, not students
- Schools were blocked to control for school differences, with randomization within blocks
- Treat each school as a unit and the average improvement on the Cornell Critical Thinking Test as the measurement
The difference between average improvement between the treatment and control groups is compared to differences for 100,000 randomly assigned treatment and control structures.

- **Induction and Deduction**: Evidence of Improvement ($p < .05$)
- **Observation and Credibility**: Weak evidence of improvement ($p < .1$)
- **Deduction/Assumption**: No evidence of improvement ($p > .1$)
- **Overall**: Very strong evidence of improvement ($p < .001$)
Summary

- These preliminary results from a randomized trials experiment provide the basis for drawing potentially major implications for inquiry-based science instruction.

- Statistically significant improvements have been shown in critical thinking skills following relatively brief exposure to the SWH approach.

- These findings also provide policy implications for the interplay between science education and the evidence-based study of how student achievement is affected by structural and classroom-level shifts in instructional approaches.
Future Directions

- Refine SEM results through additional parameterization to reflect incorporation of Cornell Critical Thinking and within-subjects ITBS data

- Multilevel models, with students at Level 1, classrooms (i.e., teacher) at Level 2, and possibly building/district at Level 3
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