Abstract Title Page

Title:
Examining the impact of using the Science Writing Heuristic approach in learning science: A cluster randomized study.

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Abstract Body

Limit 4 pages single-spaced.

Background / Context:

Description of prior research and its intellectual context.

The U.S. began a new national standards movement in the area of K-12 science education curriculum reform in the 1980s known as “Science for All” to develop a population that is literate in economic and democratic agendas for a global market focused on science, technology, engineering, and mathematics (STEM) (Duschl, 2008). The National Research Council (NRC) report, Rising above the Gathering Storm (RAGS, NRC, 2007), describes four areas of needed proficiency for science students: generate and evaluate scientific evidence and explanations; know, use, and interpret scientific explanations of the natural world; understand the nature and development of scientific knowledge; and participate productively in scientific practices and discourse. To this end, pedagogical skills in science education have moved from teaching students how to memorize what they need to know from science textbooks to developing an understanding of the knowledge-building process by learning how to develop explanations and predictions about our world (Erduran, Simon, & Osborne, 2004).

Purpose / Objective / Research Question / Focus of Study:

Description of the focus of the research.

The Science Writing Heuristic (SWH) approach shifts teaching from memorizing facts about science to focusing on argumentation as a means of learning the big ideas and theories of topics studied. This method, developed by Hand and Keys (1999), focuses on the student’s ability to construct and critique ideas by actively participating in negotiating questioning, claims and evidence. This approach uses argumentation, with an emphasis on language, as a central component of learning science. It consists of a framework to guide activities as well as metacognitive support to prompt student reasoning about data.

The importance of such an approach is emphasized in the Next Generation Science Standards (NGSS, 2012), where students are required to pose questions, design activities to generate data, construct claims, and use evidence to support claims. One of the critical features of the NGSS is argumentative reasoning. This forces students to go beyond a transfer of argumentation skills, to a transfer of understanding of scientific practice (Cavagnetto, 2010). This leads to students who can engage in both reasoning and critical thinking to construct knowledge and to be able to transfer these practices to new situations.

Setting:

Description of the research location.

Our study was conducted with 48 elementary schools in the United States state of Iowa with students in grades 3-5; 24 school buildings randomly assigned to treatment and the 24 other buildings to control. Nearly all the schools were located in rural areas throughout the state of Iowa. These schools ranged from single section grade levels to schools with five sections per grade level. Two of the sites were located with larger population centers, thus providing a balance between small rural schools and larger more urban locations. A description of the SWH study by letter, followed by an in-person meeting, was completed in the summer of 2009 with school district superintendents in Iowa to obtain permission for participation by elementary school buildings in the study. After obtaining consent from the district superintendents, the schools were recruited into the study. Geographic clusters of schools were formed to control for differences in free and reduced lunch populations as well as concentrations of minority populations.

Population / Participants / Subjects:
Description of the participants in the study: who, how many, key features, or characteristics.

The population is 3rd-6th grade students who attended one of the 48 elementary schools recruited into the study for at least one academic school year between 2006-07 and 2011-2012. There were 26,723 students who fit this criterion. Some students did not have scores from all four grades due to the limited time frame which led to a slightly unbalanced data set with a total of 59,172 complete observations (~1.5% missing).

Intervention / Program / Practice:
Description of the intervention, program, or practice, including details of administration and duration.

The project was focused on introducing the Science Writing Heuristic approach as the central pedagogical approach used to teach science within the treatment schools. There was a focus on aligning learning to teaching, organizing the curriculum around big ideas, and requiring the students to negotiate ideas of science through construction and critique process that involved them posing questions, gathering data, and make claims supported by evidence.

All teachers from schools that were randomized to the intervention group were trained in the Science Writing Heuristic (SWH) technique starting in the summer of 2009 at workshops held at four geographic regions of Iowa. This training took part over three days and included specific training on the SWH approach including how to foster argumentation and science inquiry skills for students in the classroom. Training also took place the following summer, and training days were held within the school year and for two days prior to the beginning of classes in the respective schools. SWH teachers were trained to foster both cooperative and individual learning by requiring student groups to examine science problems and think of solutions through both intergroup and intragroup discourse. In addition, students learn to write down discussion ideas and why they may or may not work, and then formulate their own hypothesis and test it, thereby assisting them to develop skills in science, mathematics, and English writing. All 48 selected schools currently remain in the study.

Research Design:
Description of the research design.

A cluster randomized experimental design was employed, with random assignment of participating elementary school buildings to SWH treatment (24 schools) or control condition (24 schools). The treatment schools were involved in a 2-year workshop and implementation program to use the SWH approach as the primary teaching and learning approach for the teaching of science.

Data Collection and Analysis:
Description of the methods for collecting and analyzing data.

Standardized test scores were obtained for all students from the years immediately prior to the start of the SWH study. These scores included all composite scores and a subgroup score in science as well as demographic information about individual students.

The results reported in this presentation focus on 3,801 students across the 48 schools who were tested with the Iowa Tests of Basic Skills (ITBS), later called the Iowa Assessments (IA), in both the 2009-10 and 2011-12 school years. Only students having at least one full year of exposure to the SWH approach were included in the analysis. The main dependent variable (scores on the Iowa Assessments, formerly known as the Iowa Tests of Basic Skills) is administered on a date determined by the individual schools. As a result, the test results correspond to dates ranging from October through April. To account for this broad time frame, the number of quarters of exposure to the SWH approach was used as a predictor in the model. A student who was administered the Iowa Assessment exam in the fall quarter had received 3 quarters of exposure. Students in the sample had 3, 4, or 5 quarters of exposure to the SWH approach.

Between the 2010 and 2011 academic years, the standardized test traditionally administered was changed from ITBS to IA. To account for the change in exams, the subject subtest scores were first converted into a national standardized score. These standardized scores were then standardized again, so all measures have a mean of 0 and standard deviation of 1 for the analysis. Standardization occurred within a subject and within grade level. The analysis therefore examines the change in relative position among the students from year to year, and the coefficients can be interpreted as effect sizes. A multilevel linear mixed effects model was used to estimate the change in Mathematics, Reading, and Science scores with demographic information and other learning categorizations as predictors. Written in R code format, the model used is:

Year 2 Score ~ Baseline Score +Baseline TRT school+ SWH Linear effect+ Quarter Test is administer + Gender + Asian + African American + Hispanic + Special Education + Gifted and Talented + Low Socioeconomic Status + English Language Learners +SWH/Gender Interaction + SWH/Black interaction+ SWH/Special Education Interaction+ SWH/ Gifted and Talented Interaction+ SWH/ Low Socioeconomic Status Interaction + SWH/ English Language Learners Interaction + (1|SCHOOL)

All estimation was conducted using R statistical software with the help of the lme4 package. Estimates using the model for the Mathematics, Science, and Reading scores can be seen in Table 1.

Findings / Results:
Description of the main findings with specific details.

From the results in Table 1 we see that the students in schools assigned to teach using the SWH approach had a disadvantage in their test scores of roughly 0.4 of a standard deviation prior to the intervention. However, with each semester of exposure to the SWH approach, students gained one-tenth of a standard deviation against their peers in control schools. As a result, after 4 semesters of exposure the disadvantage has disappeared. There was no effect on the Science scores attributable to the SWH implementation. This may be attributed to the Science tests measuring content rather than inquiry.

All the interaction terms for the Mathematics and Reading scores should be interpreted concomitantly with the SWH linear main effect term. The interaction term for every variable except ELL is not significantly different from 0. This means that when compared to a white, traditional student learning from the traditional approach, ELL students gain 1/10 of a standard deviation for each quarter of exposure. Overall this finding indicates that the SWH approach has the potential to impact many different demographic groups in addition to ELL students, as measured by the main effects of demographic variables, as their learning disadvantages often are reduced with this approach.

Conclusions:

Description of conclusions, recommendations, and limitations based on findings.

The inquiry-based SWH approach to teaching science is associated with a demonstrable reduction in Mathematics and Reading test score disadvantages for students in many traditionally disadvantaged groups. Further, over the two years of learning about science with the SWH approach, the Mathematics and Reading scores for students in disadvantaged schools recovered to the level of their peers who were learning from a traditional approach in more advantaged schools. It is important to note that the disappearance of SWH-exposed students' initial disadvantage in Mathematics and Reading scores following the intervention was not replicated with Science scores. This finding provides useful confirmation of the transfer of benefits gained by students from their SWH-based exposure to critical thinking, as the Mathematics and Reading components of Iowa Tests of Basic Skills/Iowa Assessments more closely track with the expectations of critical thinking than is true of the Science component, which is focused more on measuring content rather than on the ability to apply students' acquired inquiry-based skills. These and other results of data analysis from the SWH project attest to the efficacy of using argumentation to foster science learning. The key result overall is the importance of the critical thinking mode of inquiry, rather than the acquisition of separate bits of content knowledge. It is crucial to emphasize the spillover benefits into other disciplinary areas from the holistic approach to learning that is fostered by students being able to apply their argumentation skills across specific content areas.

Appendices

Not included in page count.

Appendix A. References

References are to be in APA version 6 format.

Cavagnetto, A. (2010). Argument to foster scientific literacy: A review of argument interventions in k–12 science contexts. Review of Educational Research, 80(3), 336-371.

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. Review of Research in Education, (32)1, 268-291.

Erduran, S., Simon, S., & Osborne, J. (2004). Tapping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. Science Education, 88(6), 915-933.

Ford, M., & Forman, E. (2006). Redefining disciplinary learning in classroom contexts. Review of Research in Education, 30(1), 1-32.

Hand, B., & Keys, C. (1999), Inquiry investigation: A new approach to laboratory reports. Sci. Teach. 66, 27-29.

National Academy of Sciences. (2007). Rising above the gathering storm: Employing America for a brighter economic future. Washington, DC: National Academy of Sciences.

National Research Council. (2012). The next generation of science standards: A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: National Research Council. Retrieved from http:// nationalacademies.org/bose/Standards_Framework_Homepage.html

Appendix B. Tables and Figures
Not included in page count.

Table 1: Estimates from linear mixed effects models for scores on Mathematics, Science, and Reading, Iowa Assessments tests.

Variables	Mathematics	Science	Reading
Intercept	0.0295	-0.0550	0.0085
SSM	-0.3418***	-0.4563***	-0.3670***
SWH intercept	-0.4096***	-0.0024	-0.4346***
SWH slope	0.1065***	-0.0003	0.1048***
DifQTR	0.1710***	0.0247	0.1070***
GEN	-0.0144	0.0986***	0.0195
ASN	0.1255**	0.0638	0.0239
BLK	0.0094	-0.1393**	-0.0994*
HSP	-0.1140**	-0.0923	-0.0392
SED	-0.3171***	-0.2375***	-0.3113***
GAT	0.3247***	0.5302***	0.4459***
FRL	-0.1338***	-0.1117***	-0.1232***
ELL	0.2506**	0.0412	-0.0613
TRT:GEN	0.0121	0.0001	0.0058
TRT:BLK	-0.0382	-0.0061	-0.0099
TRT:SED	0.0040	-0.0370	0.0156
TRT:GAT	0.0010	-0.0048	0.0000
TRT:FRL	0.0115	-0.0023	0.0104
TRT:ELL	-0.0803**	-0.0575*	-0.0120

*$p<.1$, **$p<.05$, ***$p<.01$