

GOALS & OBJECTIVES

- Develop a modular, interdisciplinary middle school unit, consisting of a series of four subject area modules that:
 - support deep student understanding of standards-based content and processes in Social Studies, Mathematics, Science, and English Language Arts;
 - use real-world data across the disciplines, allowing students to engage in key aspects of data literacy both within and across the disciplines; and
 - are based on recent and robust findings in cognition and instruction, and specifically address the notion of transfer across the curriculum.
- Create a flexible unit structure and materials that can be adapted and localized for individual communities, while having broad applicability.
- Employ a curriculum creation process that includes teachers, students, principals, and content experts.
- Create a set of assessments that measure student growth in data literacy as well as unique disciplinary approaches to it.
- Pilot test the modules and materials with middle school classes for formative evaluation and revision.
- Field test the modules and professional development materials with teacher teams from three middle schools, culminating in a quasi-experimental study of their effectiveness.
- Work with teachers to create a professional development program designed to develop teachers' data literacy and help them master the pedagogical approach our unit employs, while ensuring that it matches teachers' professional needs and expectations.

ACCOMPLISHMENTS TO DATE

DESIGN

- Identified data literacy context appropriate to 7th grade Social Studies, Mathematics, Science and English Language Arts -- proportional reasoning.
- Identified cross-curricular knowledge, skills, and attitudes (KSAs) related to data literacy (from a proportional reasoning perspective).
- Established real world context for TWD unit -- water availability and use in the Tigris/Euphrates watershed and six US watersheds.
- Found and cleaned real world data for watershed countries (Iraq, Syria, Turkey) and US watersheds.
- Developed and revised assessment instruments based on feedback and analyses that assess student development across the TWD unit and Math and Science content within units.
- Developed draft two-week modules for Social Studies, Mathematics, Science, and English Language Arts.

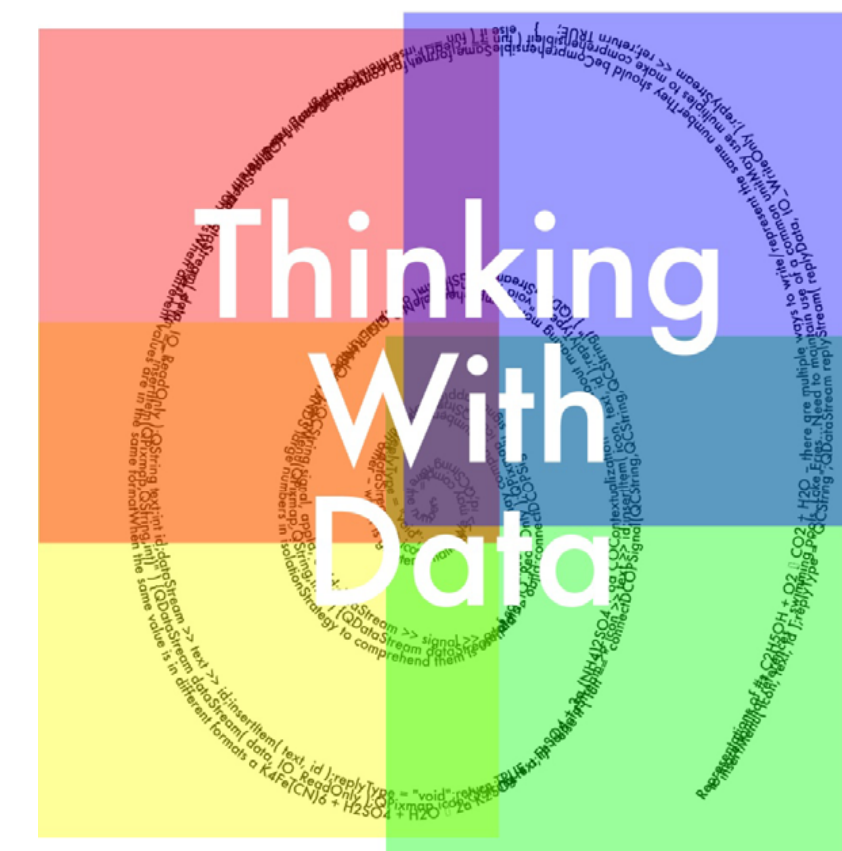
PILOT

- Piloted our initial unit with two teachers across all four content areas.
- Analyzed observational data from pilot implementation, and interview data from teachers and students.
- Administered and analyzed pre- and post-test data from the pilot study.
- Held two Advisory Board meetings (6/07, 6/08) and incorporated member feedback into module and assessment development and refinement.
- Provided ongoing and flexible teacher professional development for pilot and final implementation teachers and incorporated teacher feedback into module and assessment development.
- Made significant revisions to each of the two-week modules based on multiple iterations of observations and feedback from participating teachers, Advisory Board members, our evaluator, and colleagues.
- Modified modules so that they incorporate watersheds throughout the US, allowing teachers to customize the units based on their location.
- Completely revised the data literacy pre/post assessment to reflect a Preparation for Future Learning (PFL) focus.
- Created a website that allows teachers, students, and interested educators to access all TWD instructional materials (www.rcet.org/twd/index.html).

IMPLEMENTATION

- Completed in-school implementation and quasi-experimental study using the revised unit:
 - Teachers from two middle schools implemented the unit with approximately 150 7th graders;
 - Unit pre-test and post-tests were administered to all 7th graders in both schools (with comparison condition = approximately 580 students).
- Shared our work through
 - presentations at DR-K12 meetings, at national and regional conferences, and to education classes and interested community groups;
 - print materials and local news stories;
 - our website.

Thinking with Data: A Cross-Curricular Approach to Data Literacy



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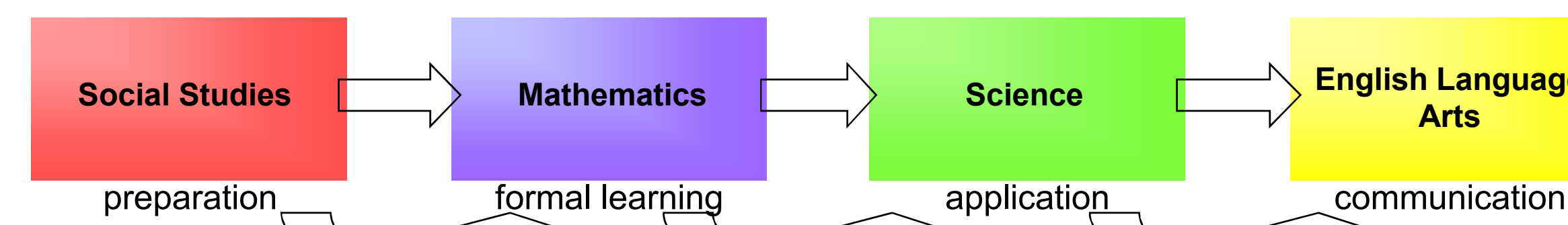
"We use data every day—to choose medications or health practices, to decide on a place to live, or to make judgments about education policy and practice. The newspapers and TV news are full of data about nutrition, side effects of popular drugs, and polls for current elections. Surely there is valuable information here, but how do you judge the reliability of what you read, see, or hear? This is no trivial skill—and we are not preparing students to make these critical and subtle distinctions."
-- Andee Rubin

Thinking with Data (TWD) is an **Instructional Materials Design (IMD)** project which developed and tested a cross-curricular unit designed to cultivate middle school students' deep understanding of data literacy. The TWD unit consists of four, 2-week replacement modules for interdisciplinary implementation in 7th grade Social Studies, Mathematics, Science, and English Language Arts. The modules address issues of data representation, proportional reasoning, and data-based argumentation using real data in discipline-specific, problem-solving contexts aligned with relevant subject area standards.

The context for the TWD modules is a compelling one: world water issues. Activities and materials are designed around student investigations of water issues in the Tigris/Euphrates basin and in six US watersheds using real world data. Data manipulation across the unit centers on the notion of **proportional reasoning**, an important part of middle school curricula and the foundation for higher mathematics. In **Social Studies**, students use existing data to explore water availability and usage in Turkey, Syria, and Iraq, and try to devise fair ways of sharing available water. In **Mathematics**, they learn techniques of proportional reasoning to expand on their Social Studies work and develop data-based solutions and arguments for fair use. In **Science**, they learn about the science behind water issues in the Tigris/ Euphrates basin, beginning with how the water cycle manifests itself in the region, and how that and ditch irrigation contributes to soil salinity. Students then explore water issues in six US watersheds. In **English Language Arts**, students develop reports on the US watersheds and present possible solutions to problems affecting them as persuasive arguments, in multimedia formats supported by data-based evidence, and present these to a larger audience.



The TWD unit is grounded in a **Preparation for Future Learning (PFL)** pedagogical approach (Bransford & Schwartz, 1999). It investigates how **preparing** students to learn in one curricular context (Social Studies) with **formal learning** occurring in another (Mathematics) can improve students' deep understanding of data literacy. The project further explores extending the PFL approach to include **application** and **communications** activities common to traditional transfer sequences in still other curricular contexts (Science/ELA), leading to our calling the approach PFL+. Initial field testing of the approach suggests it enhances middle school students' data literacy, strengthening claims that PFL uncovers a general mechanism of transfer. Findings also advance the field's understanding of how Mathematics and Science can be meaningfully integrated throughout the curriculum.



The TWD unit was subjected to both pilot testing (2007-2008) and field implementation phases (2008-2009). Formative evaluation during these phases guided the improvement of materials. Summative evaluation focused on four questions, listed below with associated findings:

- Are teachers able to effectively implement the TWD modules?
 - Yes, as long as there is sufficient administrative support and associated professional development.
- Do students who engage in the TWD modules increase their understanding of data literacy?
 - Yes; students who were exposed to the TWD curriculum had a pre/post test gain score that was three points higher than comparable students in the same school who did not engage with the TWD materials. This difference was statistically significant: $t(156.273) = 10.750, p < .001$, with Cohen's $d = 1.24$ (very large effect).
 - When considering questions individually, student scores improved the most on those items that required higher order thinking skills such as data interpretation across multiple tables and calculation of proportional data, providing support for the argument that the TWD materials and the PFL approach aid in the development of data literacy skills among middle school students.
- Do students who engage in the TWD modules also increase their understanding of disciplinary content, particularly in Mathematics and Science?
 - Yes; pre/post testing in Math and Science showed statistically significant gains in learning disciplinary content. Due to inconsistencies in test administration, only two items could be scored on the Math test for School 2; both items showed statistically significant gains, with $Z = 3.16, p < .001, d = .23$ (small effect), and $Z = 4.70, p < .001, d = .35$ (small effect) respectively. Students in School 2 showed statistically significant gains across the entire Math test, $t(24) = 4.899, p < .001, d = .56$ (medium effect).
 - In Science, students in both schools showed statistically significant gains too, with $t(84) = 12.665, p < .001, d = 1.36$ (very large effect) for School 2; and $t(27) = 4.441, p < .001, d = .83$ (large effect) for School 1.
- Can we expect, based on teacher and principal input, that this program can be scalable to a wide number of schools?
 - Yes; with the exception of Social Studies, teachers felt that the TWD unit fit into the 7th grade curriculum.
 - There were concerns about the tensions created when modules are taught using PFL, especially at the end of the Social Studies module (lack of closure).
 - A small number of teachers were concerned that some of the materials were too advanced for their students, and these concerns are addressed in our final set of materials by including alternative options for lower-achieving students.
 - Finally, teachers expressed the importance of staff development, working as a team of teachers so each knew what the other three were doing in their modules, and alignment with content standards.



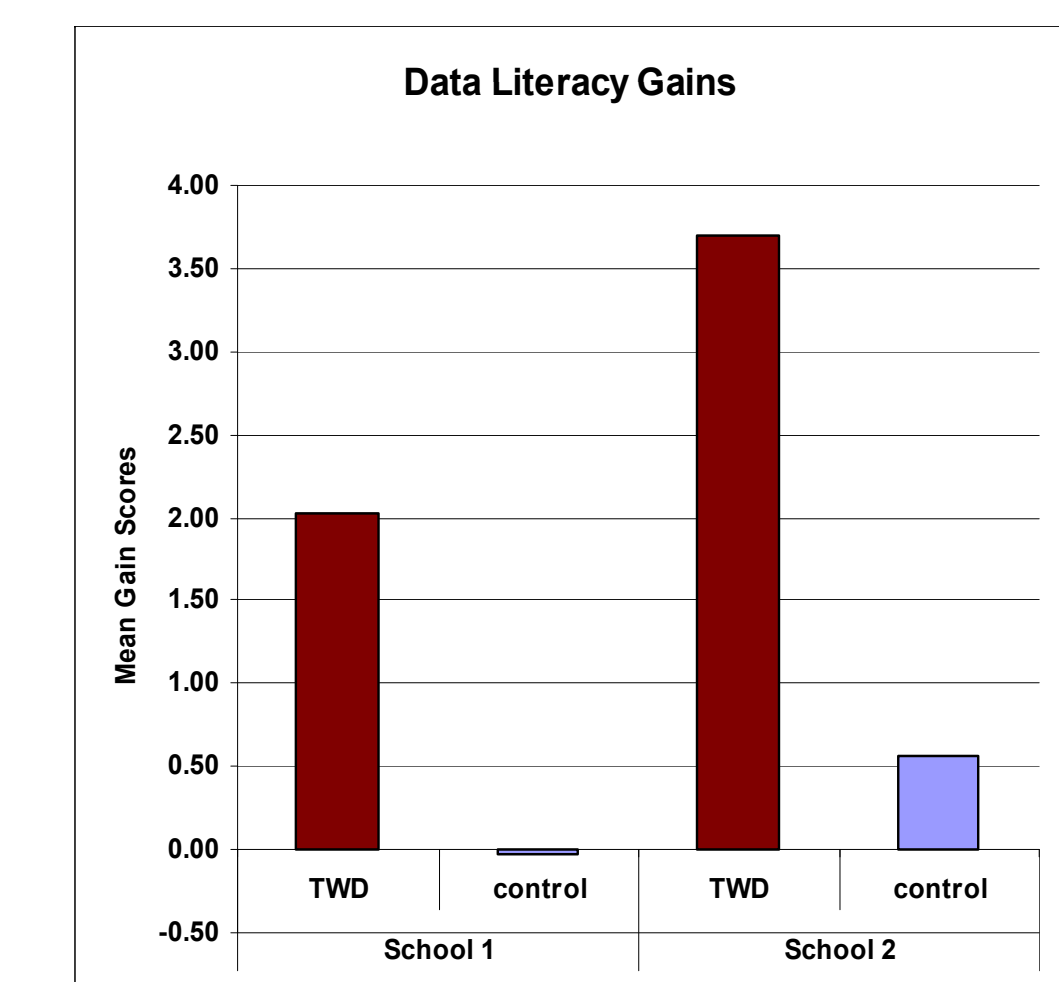
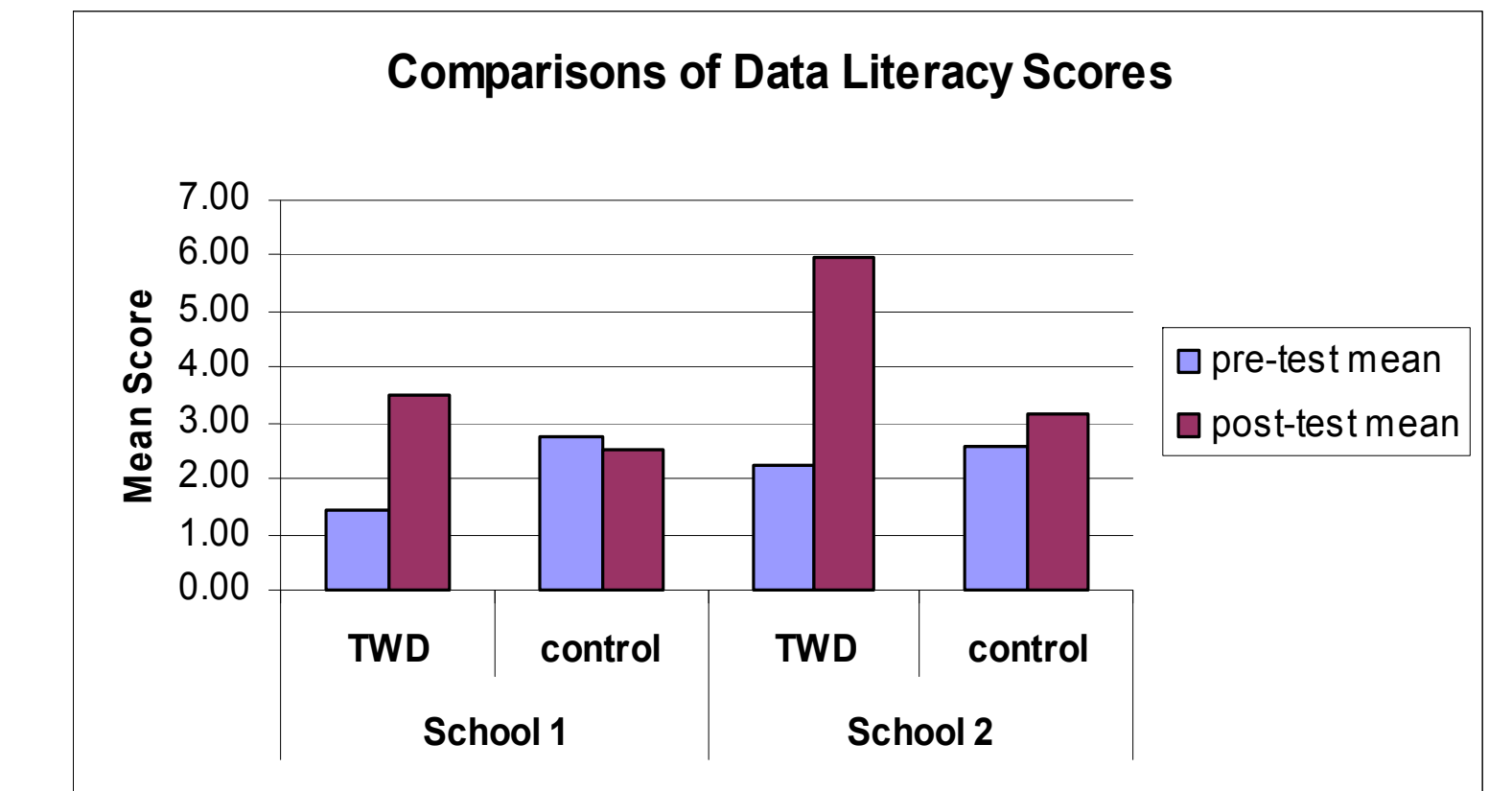
DETAILED PRE-POST TEST FINDINGS

The revised TWD unit was field-tested with 7th grade students in two schools in northeast Ohio in the fall of 2008 (September through December). Both schools were organized into grade level teams and in each school one team (consisting of a Social Studies, a Mathematics, a Science, and an English Language Arts teacher and their students) completed the TWD unit while the other 7th grade teams served as a quasi-experimental control group. In both schools, students in the experimental (TWD) team were characterized as lower than average achievers. 581 students completed pre/post data-literacy tests; 119 of these students were taught using TWD materials.

The pre/post test was a five-question, problem-based test concerned with a common issue and context. It was designed to measure students' ability to ask and answer data-based questions; to use appropriate data, data representations and data manipulation tools (proportional reasoning in particular); and to develop and evaluate data-based inferences, arguments, and explanations. It was administered to all 7th grade students in both schools at the beginning of the school year and just before winter break. Gain scores were calculated, and differences in average gain scores between experimental and control groups were explored using Multivariate Analysis of Variance (MANOVA).

The overall analysis yielded $t(156.273) = 10.750, p < .000$, with $d = 1.24$ (very large effect). The mean difference in gain scores between the experimental and control groups was about 3 points on a test with a maximum score of about 15 points, or roughly a 20% difference. This is a large difference as indicated by its associated effect size.

When looking at the schools individually we found differences between them in student performance. TWD students at School 2 seemed to have learned more than those at School 1 with mean gain scores at 3.69 and 2.03, respectively. At School 2, the mean difference in gain scores between the TWD group and their 7th grade classmates was 3.135, as compared to a mean difference of 2.270 at School 1. However, effect sizes for both schools were large (1.27 and 1.00 respectively).



When considering test questions individually, the largest differences in gain scores occurred on items that required data interpretation and synthesis across multiple tables and data manipulation involving proportional reasoning and calculation. These findings suggest that the TWD materials and their PFL approach supported the development of data literacy skills among the middle school students participating in the field test. They thus provide support for the argument that the TWD curriculum aids in the development of data literacy skills among middle school students.

BROADER IMPACTS

With its materials tested in an authentic school setting, the TWD Project

- provides a scientific basis for conducting school-based data literacy activities that cut across disciplines;
- provides a set of assessment tools that can be used to investigate students' formative reasoning as they engage in cross-disciplinary data literacy;
- provides a collection of materials and related data sets that can be used by others in the implementation of cross-disciplinary data literacy; and
- has informed the work of our Advisory Board members, who have significant influence in different areas of educational research.

TWD ADVISORY BOARD

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