



Thinking With Data Suggested Best Practices for Teaching the TWD Curriculum

Executive Summary

This document contains recommended approaches for teaching the TWD unit as a whole as well as each individual module, based on the additional analysis of collected data as part of Activity 2.1 of the NSF TWD supplement funding. In short, we recommend that teachers do the following:

TWD Unit

1. *Facilitate students' conceptual understandings and development of problem-solving strategies.*
2. *Facilitate students retaining and building upon their learnings from previous modules.*

Social Studies Module

1. *Discuss module fit in the overall unit.*
2. *Focus on problematizing and contextualizing.*
3. *Teach students how to work with data.*
4. *Prepare students for learning in mathematics.*

Mathematics Module

1. *Discuss module fit in the overall unit.*
2. *Focus on targeted preparation for and learning of proportionality.*
3. *Use productive ways for sharing student solutions.*
4. *Use data to focus on proportionality.*
5. *Use data in arguments.*
6. *Prepare students for learning in the other modules.*

Science Module

1. *Discuss module fit in the overall unit.*
2. *Teach how to obtain relevant data from real data sources to answer questions.*
3. *Share student solutions.*
4. *Use data to focus on proportionality.*
5. *Use data to work through arguments.*

English Language Arts Module

1. *Discuss module fit in the overall unit.*
2. *Focus on argumentation.*
3. *Emphasize the use of data to support an argument.*
4. *Provide opportunities for dialogue surrounding students' persuasive speeches.*

All of the recommendations above are explained in more detail on the pages that follow this summary.

TWD Unit

1. *Facilitate students' conceptual understandings and development of problem-solving strategies*

The TWD unit is focused not on the specific facts but rather on how to go about grappling with complex problems. Research in Learning Sciences has shown that an important part of learning is the struggle that a learner goes through.

2. *Facilitate students retaining and building upon their learnings from previous modules*

Teachers should:

- review the unit overview document to understand the focus of all four modules.
- remind students in each module of what they did in prior modules, and how the current module fits into the big picture without “giving away” the main ideas students should struggle with. For instance, in Math, teachers can say “this module will help you with understanding how to make a fair treaty, and in understanding how to analyze water quality”, **not** “this module will teach you how to use proportionality to make a fair treaty.”
- provide students with a way to keep all TWD materials together as they go from class to class. Some teachers have found three-ring binders to be effective.
- make sure that if students are doing a significant amount of work on computers, all teachers know how students access the materials and any of the student-created files.

Social Studies Module

Recommended approaches for teaching the TWD Social Studies Module with associated teacher actions and practices:

1. Discuss module fit in the overall unit

The SS module is a tricky one, as its role is to prepare students for learning in the subsequent modules, but at the same time does not provide real answers. Therefore, it is extremely important that teachers spend some time discussing the overall TWD unit and how the SS module fits into the unit. Specifically, this needs to be done in Part 1 of the SS module, using the provided module graphic.

In addition, teachers should make connections to math, science, and ELA where necessary and appropriate (but without giving away the answers; i.e. they cannot tell students that they will be learning about proportional reasoning in math. Because of the importance of these links, SS teachers should have at least a basic understanding of PFL, the module as a whole, and the content of each individual module.

2. Focus on problematizing and contextualizing

The majority of activities in the SS module focus on problematizing (i.e. making students aware of the fact that water availability and access are crucial issues in the Middle East), and contextualizing (providing a context for water issues in the Middle East), as the purpose of this module is to prepare students for learning in mathematics, science, and ELA. It is essential that students get a solid understanding of the region's geography, its history, and the importance of water. Besides making sure that the module's content gets covered, teachers should arrange for plenty of time for group work and discussion.

3. Teach students how to work with data

The second major focus of the SS module is data, more specifically how to *interpret and graph* data as well as how to *use data to answer questions* (country water profile and water summit).

Interpreting and graphing data: During our field implementation, students (and some teachers) seemed to struggle with this, even at basic levels. Before students can adequately use data to answer questions they need to understand the data itself, be able to transform data tables into graphical representations, and be able to explain what these representations mean. The key here is for students to get the basics down, regardless of the software package being used (the SS module uses Excel). Therefore, it is essential that the teacher has a solid understanding of data and spreadsheets, and how to create a variety of graphical representations from data tables. In addition, it is important that students have ample time to practice graphing and explaining what various graphs represent, both individually/small groups, and as a class.

Using data to answer questions: This is an important skill that students will use throughout all four modules. The first time students have to use "data" to answer questions is in Part 2, where they are given primary sources to try to come up with an initial solution for dividing up the water in the Tigris-Euphrates basin. This activity is a good indicator of the level of understanding that students have before they are exposed to the spreadsheets and graphing activities in Part 3. It is important that the full activity is done, including the sharing of answers at the end.

When students create their country water profiles and posters in Part 4, it is essential that the teachers evaluates them carefully and provides detailed feedback to students *before* they enter the water summit. Students should edit their country water profiles and posters *before* they share them with their classmates. As we saw in the field implementation, students often did not focus on data/evidence to back up an answer.

4. Prepare students for learning in mathematics

Towards the end of the SS module, it is normal if teachers and students feel some sense of frustration, due to a lack of closure. This is where the module reflection in Part 6 can help. Following individual time for completion of the student reflection sheet, teachers should lead a class discussion during which students can share their answers. The focus here should be on what students learned about water issues in the Middle East, what kind of treaty they were able to come up with given the resources (data) they had, and what may have been missing (without telling students about proportional reasoning). Finally, teachers should re-emphasize the connection of SS with math and the rest of the TWD unit here, using the same unit graphic they showed students in Part 1 of the SS module.

Mathematics Module

Recommended approaches for teaching the TWD Mathematics Module with associated teacher actions and practices:

1. *Discuss module fit in the overall unit*

The math module fills several roles in the unit as it:

1. helps students make sense of the issue of “fair sharing” that they studied in social studies.
2. teaches proportional reasoning in the context of fair sharing.
3. introduces students to relevant uses of proportional reasoning in science, such as salinity.
4. provides a way for students to think about data-based argumentation.

Each of these roles also helps students understand that mathematics can be used to help answer important societal problems. The role of math in answering these questions should be highlighted to students. However, it should also be clear that the mathematical answer isn't the only way of thinking about a problem, and that other concerns also matter (such as scientific feasibility, cultural sensitivities, etc.).

Throughout the module, teachers should make connections to social studies, science and ELA as much as possible and appropriate. These connections are found in the teacher materials, and reinforce the idea that the mathematics module is part of the larger effort. In general, when students are analyzing data from Iraq, Turkey, and Syria, they should be reminded that this was the region they studied in social studies (and it may be helpful to have them recall some of the issues they raised in social studies). When students are analyzing salinity, teachers can tell them that salinity is important for drinking water and crop growth, and they will study salinity in science. When students are engaging in the last two lessons on data-based argumentation, they should be informed that this form of argumentation will be used in science and in ELA.

2. *Focus on targeted preparation for and learning of proportionality*

Through the social studies module the key issues for students should already have been *problematized*: that is, students should be aware that water availability and access are crucial issues in the Middle East. In social studies students have also been *prepared* to create a fair water treaty. In mathematics we then build on this to:

1. *continue to prepare* students for specific learning activities: students work on key problems designed to highlight the important mathematics. Students don't learn the mathematics during these preparation activities, but they develop an appreciation for a mathematical solution. Students may struggle and become slightly frustrated during these activities.
2. *share* student solution attempts. As in *preparation*, these solution attempts will typically not be fully correct. It is important for teachers to emphasize that students are sharing their current thinking, the goal is to see what parts of each solution “work”, and where each may fall short (done through the teacher's and classmates' constructive criticism). The goal is for students to see different ways of thinking about the problem and to further appreciate the characteristics of a correct mathematical solution.
3. *teach* students the key mathematical concepts in what we call the *formal learning* activities.

Many teachers want to jump directly to *teaching* in the *formal learning activities*. While both the *preparation* and *sharing* activities may seem counter-intuitive to learning, these steps are very beneficial to the learning progress; they make the *formal learning* activities more impactful, as they present a

solution to the *students'* problem (i.e. the *preparation* and *sharing* lead to student ownership of the problems, and thus more invested in any solutions).

Research has shown that this type of learning is more effective than traditional learning activities, because students are better able to apply and remember solutions to problems they “own” rather than problems that come simply from a textbook.

3. *Use productive ways for sharing student solutions*

A significant part of the math unit involves students sharing their solutions with others. Some teachers have found it productive to have students present the work of other students during this time. That is, students (or groups) work on a solution and then trade with another student (or group) for the class presentation. When this is done the teacher should take the following steps:

- Inform students in advance that this trading will take place.
- Discuss what is necessary for one group to be able to share the work of another (e.g., all diagrams clearly labeled, abbreviations defined, numbers labeled, processes explained, etc.).
- Provide time for students (or groups) to “finalize” their solution so that another student (or group) can successfully share the solution.
- The first few times this type of sharing takes place, support students both in sharing the work of others and in making sure that the work is ready for sharing.
- Ensure that all critiques are constructive. Critiques should point out what aspects of the problem are addressed by the solution and what aspects of the problem are not fully addressed.

This form of sharing can be particularly productive for a variety of reasons. Students who know that somebody else will present their solutions are more likely to create clear solutions. Students who are presenting somebody else’s solution are more likely to be open to critique.

4. *Use data to focus on proportionality*

The math module uses data to teach the creation of proportional measures. Proportionality is key to middle school math, and the use of measures and units is key to mathematical and data literacy. Even so, the TWD approach to data and proportionality is quite novel to many teachers and students.

A primary learning goal is that students learn to distinguish between an *absolute* measure (such as the total amount of water in a country) and a *proportional* measure (such as the amount of water per person).

For instance, in the TWD unit we see that the country with the most water and highest population (Turkey) also has the highest per capita water availability: this may lead students to believe that the initial water allocation is “fair”. However, comparing the per capita water availability among countries shows that Turkey has significantly more water *per person*, and students can see that a fair distribution still has Turkey receiving the greatest amount of water, but with the *same* per capita water availability for each country.

5. *Use data in arguments*

The last part of the math module focuses on using data in arguments. It is important for students to work through the arguments themselves and to understand key aspects of data-based arguments. Data is often used to mislead people, and this section is an attempt to help students identify such misuses of data.

Of course, not all arguments can be resolved through the use of data, and this is true in this unit: While math can provide insight into arguments about water distribution, other considerations (history, culture, etc.) must also be taken into account.

6. Prepare students for learning in the other modules

Some teachers will have students take what they learned in math and bring it back to social studies to revisit the treaties they made. This use will make a direct link between mathematics and the potential solution to a significant societal problem. Even if students do not bring their work back to social studies, they should understand how the mathematics can be used as part of a solution.

At the end of the module teachers should re-emphasize the connection between math and the rest of the TWD unit. When students leave mathematics class they should feel prepared to apply their new understandings to other subject areas.

In science, which follows the math module, students build upon their math experiences with data-based argumentation to create and justify arguments about causes of poor water quality. Specifically, students use their understanding of proportional reasoning in their investigations into the impact of salinity on crop growth, as salinity is a proportional measure.

After science students go on to English Language Arts, which focuses on data-based argumentation. In ELA, students build upon argumentation structures, using data in traditional persuasive essays. Key to the accuracy of their arguments is the way in which students use data in these essays.

Science Module

Recommended approaches for teaching the TWD Science Module with associated teacher actions and practices:

1. Discuss module fit in the overall unit:

The science module fills several roles in the overall unit; it:

1. Provides students opportunities to access data from a variety of real world contexts to inform and extend the problem-solving activities begun in social studies.
2. Reinforces the concept of proportional reasoning begun in math.
3. Introduces students to relevant science concepts of the water cycle, the effect of climate on water distribution, and using laboratory experiments to answer questions.
4. Provides an opportunity for students to use their research skills to gather data and information about a watershed area of the United States.
5. Provides a context for students to engage in data-based argumentation.

Throughout the module teachers should make connections to social studies, math and ELA. Social studies develops the initial context in which the students are working in the science module. Math establishes the importance and skills needed to make sense of numbers through proportional reasoning, as well as the structure of data-based arguments. In ELA, students will create a set of arguments to support a solution for a problem they have been investigating. These arguments must be based on factual evidence and sound reasoning.

One of the suggested changes is to provide teachers with specific connections specified in the overall synopsis of the goals and activities of each section of the module. This overall description is provided as a one-page handout, as well as detailed in the teacher materials. Using these references will allow teachers to make connections whenever appropriate with content from other areas.

The science module is an opportunity for students to dig deeper into the science behind the water crises in Syria, Iraq, and Turkey, as well as to apply that learning to understanding the issues faced by US watersheds.

2. Teach how to obtain relevant data from real data sources to answer questions

The essence of data-based reasoning is to use relevant information from the real world to develop explanations and inform solutions to real problems. It is important that the teacher emphasize that students must support any of their ideas, conclusions, or solutions with the evidence they have garnered individually or collectively. Students have many opportunities to gather and reason from multiple data sources in the unit.

Students use real geo-climate data represented in GIS maps, data tables, bar graphs, and maps. It is important that the teacher supports the students in learning how to obtain data from this variety of resources. This is an academically critical skill as well as an important tool for functioning as a well-informed citizen.

Within the science unit, it is also important that students make connections between:

- the amount of rain shown by GIS data and altitude in the area.
- the relative amounts of rain and the water cycle.
- the geographic location of the three Middle Eastern countries and their access to fresh water.
- their laboratory investigation and the degree to which an increase in soil salinity can inhibit plant growth.

- irrigation practices and soil salinity.
- their investigation of water issues in the Middle East with watershed problems for states in the United States.

3. *Share student solutions:*

A significant part of the science unit activities involves students sharing their solutions with others. Sharing is important for several reasons: allowing students to see how other students have worked toward solving some problems, introducing techniques, prompting an advance organizing of their ideas, presenting their information in such a way that it clearly makes sense to others, and allowing them to rethink their original ideas. Some teachers have found it challenging to fit in all of the activities designated for sharing. Nonetheless, it is a very important part of the activity. It is especially important to not just have students present but for other students and the teacher to challenge their explanations. This encourages students to back up their ideas with evidence, a very important concept in science. Other forms of sharing include:

- Students may share quickly with other table members.
- Two or more tables may share with each other.
- Students may work at home on a visual to share.
- Students may share at home with parents or siblings. Parents could leave written comments on their son's or daughter's sharing activity.

4. *Use data to focus on proportionality:*

The math module uses data to teach the creation of proportional measures. Proportionality is key to understanding many of the concepts in science, and the use of measures and units is key to science, math and data literacy. The idea of proportionality will be used through the student's academic career and beyond. Even so, the TWD approach to data and proportionality is quite novel to many teachers and students.

Students will use their sense of proportional reasoning when considering how much rain is available to the people within each country (Iraq, Syria, and Turkey) investigated. The idea that rain is ultimately distributed to people, to the land for the irrigation of crops, to the air through evaporation (water cycle), and finally to the ocean must be explored in terms of related variables: i.e. water per capita, water per farmable land acreage, amount of water available for use vs. water lost to the environment. Proportional reasoning is particularly important in the salinity and plant growth experiment because it is key to comparing growth across plantings.

5. *Use data to work through arguments:*

The purpose of the science unit is to steep the student in gathering and thinking about relevant data pertaining to the use of water, watersheds, as well as some basic science concepts of the water cycle and experimentation. For instance, based on the students' research, a student will be able to analyze fundamental issues with United States watershed areas. They may ascertain whether or not there are scarcity issues due to climate, or pollution issues, or distribution issues. Having the background to access this data is critical to be able to identify the important issues that inform arguments about fair use of water for specific locales. This body of facts and evidence will constitute the evidence that students will use in ELA to construct their arguments and solutions.

English Language Arts Module

Recommended approaches for teaching the TWD English Language Arts Module with associated teacher actions and practices:

1. Discuss module fit in the overall unit

English Language Arts (ELA) is the culminating module of the Thinking with Data (TWD) unit and completes the PFL framework. Students transfer what they have learned in previous modules and apply data representations to support persuasive arguments surrounding water-related issues in the United States. The ELA module brings together the varying aspects of argumentation explored in the preceding modules and provides a context for students to transfer and apply the skills they have learned in social studies, math, and science for both data literacy and argumentation. Because of the role of the ELA module in the PFL framework and the TWD unit, it is important that teachers have at least a basic understanding of the PFL framework. Because of the emphasis on transfer and application of skills for data literacy and argumentation, teachers should also have an understanding of the content of each of the previous modules (social studies, math, and science) in order to be able to refer students back to specific skills learned in those modules.

2. Focus on argumentation

A primary focus of the ELA module is argumentation. In the ELA module, students use data to create a fair argument regarding issues and solutions affecting their watershed region. The ELA module brings together the varying aspects of argumentation explored in the preceding modules and provides a context for students to transfer and apply the skills they have learned in those previous modules for both data literacy and argumentation. Consequently, the ELA teachers should also have an understanding of how argumentation was addressed in each of the previous modules (social studies, math, and science) in order to make relevant connections for students. For example, students come to the ELA module having had the experience in social studies of attempting to create an argument that provides for a “fair” distribution of water in the Middle East. In the math module, students were introduced to formal argumentation methods focusing on evaluating and formulating mathematical arguments. The ELA module provides a context for students to transfer and continue to build on methods for argumentation with a new focus that emphasizes the use of data in written, verbal, and visual communication of a persuasive argument.

3. Emphasize the use of data to support an argument

The second major focus of the ELA module is the use of data to support an argument. The module is designed to provide a context for transferring students’ understanding and use of data as evidence while also engaging students in the use of accurate, appropriate, and meaningful representations as evidence to support an argument. As the culminating activity of the ELA module, students host a *Youth Water Forum* in which they present a persuasive speech on specific issues related to U.S. watersheds. To build their argument, students revisit the research they conducted in the science module to look for patterns in the data that reveal specific themes and issues. Based on the data, students create a persuasive argument regarding their issue, apply data representations to support their argument, and communicate their findings using digital media. In order to guide students through this process, it is essential that the ELA teacher is familiar with the research conducted in the science module. It is also important that the ELA teacher is familiar with content in the math module in order to refer students back to relevant points there, should they need assistance in calculating specific measures for their data.

4. Provide opportunities for dialogue surrounding students’ persuasive speeches

To fully engage students in the argumentation process, it is important for the ELA teacher to approach the persuasive speeches in a way that allows for not only simple student presentations of their persuasive pieces but also provides opportunities for debate, discussion, agreement, and disagreement. Just as the students presenting the persuasive speech had to interpret data and data representations in order to formulate conclusions regarding their issue, students listening to their peers' speeches should be prompted to question, interpret the data and data representations, and to draw their own conclusions. To prepare students for such dialogue, the ELA teacher should remind students to use the *Water Forum Discussion Guide* to take notes on each speech. Further, it is essential for the teacher to scaffold a discussion following each presentation to guide students to focus on points of agreement, points of disagreement, and other questions they might have regarding the issue presented.