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Model My Watershed: Connecting Students' Conceptual Understanding of Watersheds to Real-World Decision Making

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ABSTRACT

The Model My Watershed (MMW) application, and associated curricula, provides students with meaningful opportunities to connect conceptual understanding of watersheds to real-world decision making. The application uses an authentic hydrologic model, TR-55 (developed by the U.S. Natural Resources Conservation Service), and real data applied in selected communities in southeastern Pennsylvania. The study investigates whether MMW is an effective tool for increasing students' understanding of watersheds and the impact of human decisions on local watershed conditions. While statistically significant learning gains were measured, most students failed to reach the highest levels of watershed understanding. Further refinement of the MMW curricula is needed to help students trace water along multiple pathways and to enable them to trace the connections among groundwater, surface water, and atmospheric water vapor. © *2014 National Association of Geoscience Teachers*. [DOI: 10.5408/12-395.1]

Key words: place-based, problem-based, environmental, geospatial, cyberlearning

INTRODUCTION

For most of human existence, we, like other organisms, have been subjected to the natural variations that have typified the evolution of Earth's environment. However, in the last half century, we are no longer just objects affected by our changing planet; we are now major agents of that change (Williams, 2005). Through the extraction of materials to support industrial production, the building of cities to house our growing population, and the feeding of multitudes, we have altered Earth's surface. We are no longer simply passengers but are now, truly, engineers on Spaceship Earth. Furthermore, our identities are often linked to the places where our societies have evolved and where our cultures have imbued meaning into the places we call home. As planetary engineers, it behooves us to understand Earth dynamics and to evaluate the potential impacts of our actions as part of our decision-making process. As social beings, we must also respect indigenous knowledge and link natural conditions to cultural understanding of the places we occupy. This understanding and evaluation must begin in K–12 classrooms (BOSE, 2011, p. ES-1).

Students should be given problems—at levels appropriate to their maturity—that require them to decide what evidence is relevant and to offer their own interpretations of what the evidence means. This puts a premium, just as all science does, on careful observation and thoughtful analysis. Students need guidance, encouragement, and practice in collecting, sorting, and analyzing evidence, and in building arguments based on it. However, if such activities are not to be destructively boring, they must lead to some intellectually satisfying payoff that students care about (AAAS, 1989, p. 148).

THE MODEL MY WATERSHED APPLICATION

Meaningful learning about our changing Earth requires a pedagogy that provides opportunities for the learner to explore their role as planetary engineers in an authentic way. Place-based projects where students investigate their own surroundings provide such authenticity. Using students' "home turf" as the object of exploration provides context and relevance that enhance engagement and promote meaningful learning (Powers and Duffin, 2004; Semken and Butler-Freeman, 2008). Having a "place" is the first step; having "tools" to explore that place is the second step. Model My Watershed (MMW) (NSF DRL ITEST #0929639; http://wikiwatershed.org/model.html) is a visually engaging, free, Web-based application, currently available for areas in southeastern Pennsylvania. It invites students to explore and evaluate the health of their local watershed.

MMW is a Web-hosted application that is freely accessible through all major Web browsers. It allows students the ability to explore, model, and modify their local watershed using an authentic model and real data, thus providing them with the opportunity to draw scientifically valid conclusions. Upon entering the MMW Web site, students are greeted with a familiar interface. Built on a Google® base, the MMW Web application allows students the ability to locate their home simply by searching their address. The geographic information systems (GIS) program then displays the watershed boundaries and gives students the ability to manipulate data with a click of a mouse. (While currently only available for southeastern Pennsylvania and northern Delaware, the application has the capacity to be expanded to include all areas of the globe.) Within the MMW Web site, students can explore a variety of data from a single map as the integrated data layers, which can be toggled on and off, appear as overlays on the map. In addition to land-cover information, these data include: water

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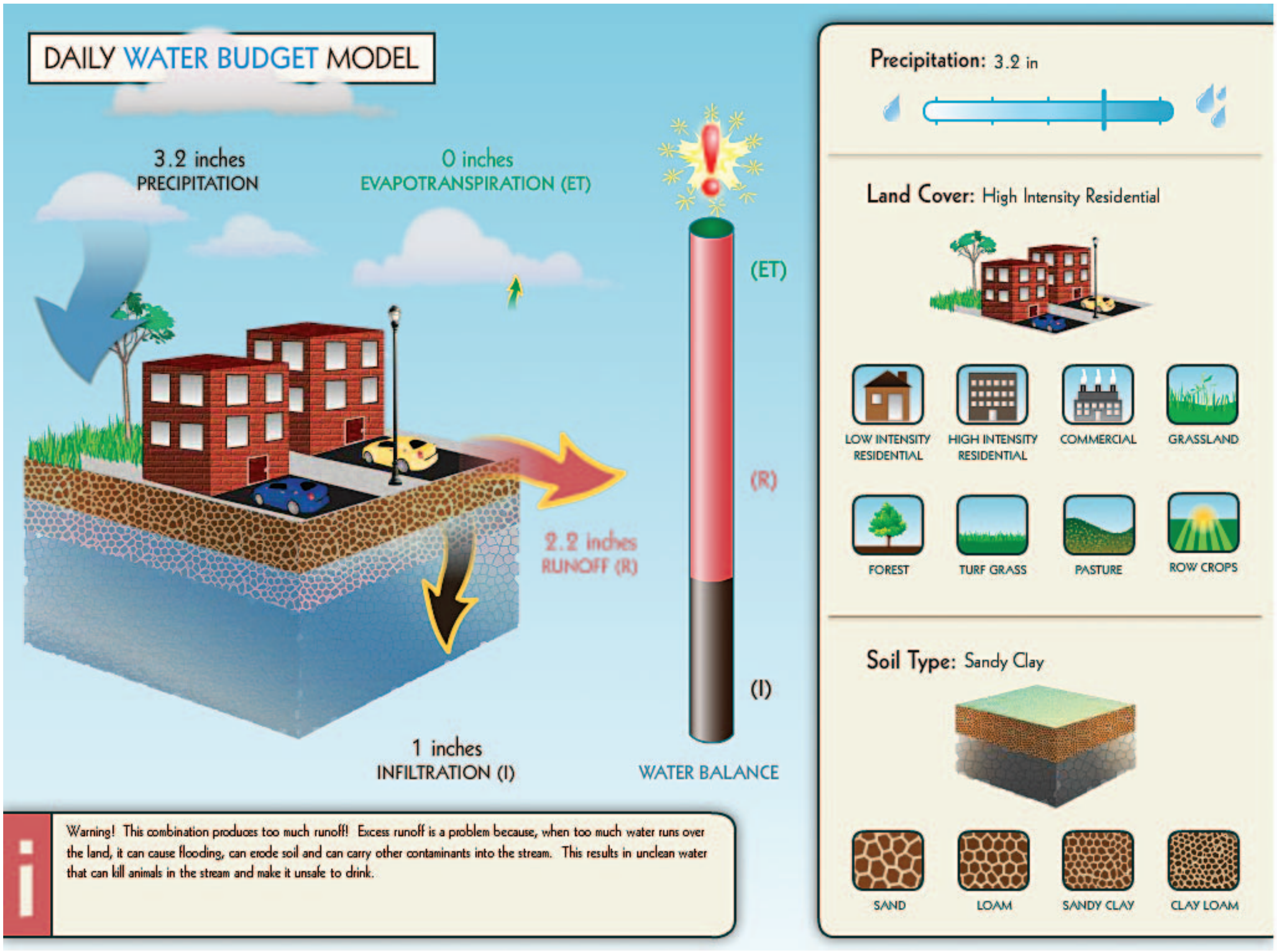


Precipitation: 3.2 in

Land Cover: High Intensity Residential

Soil Type: Sandy Clay

Warning! This combination produces too much runoff! Excess runoff is a problem because, when too much water runs over the land, it can cause flooding, can erode soil and can carry other contaminants into the stream. This results in unclean water that can kill animals in the stream and make it unsafe to drink.

FIGURE 1: The Simple Hydrologic Model allows students to manipulate variables, such as storm intensity, land-cover type, and soil texture, and to view the water budget, which partitions the rainfall into evapotranspiration, runoff, and infiltration.

bodies, municipal boundaries, school districts, legislative districts, and environmental justice areas, as defined by the U.S. Environmental Protection Agency (2013). In addition, elevation and soil-group data appear as averages for a given location. While having multiple streams of data from different government agencies accessible on a single map is exciting, the truly innovative feature of the MMW portal is its ability to "model" the local hydrology. The application has incorporated TR-55, the hydrologic model used by the National Resources Conservation Service (NRCS), and it integrates enhanced curve numbers for urbanized areas, based on the research of Robert Pitt (1999). The data that support the modeling effort are from the National Land Cover Database, the United States Department of Agriculture (USDA) Soil Survey, and the United States Geological Survey (USGS) elevation data set, from which slope is derived. In addition, the model incorporates climate constants for summer temperature and relative humidity, thus allowing it to calculate regional evapotranspiration (ET). The model does not calculate peak flows or flow paths, but rather it partitions precipitation into a water budget, where the distributions of infiltration, runoff, and evapotranspiration are compared to pre-Columbian conditions.

The MMW web-hosted application consists of four toolsets: The Simple Hydrologic Model, Show My Watershed, Modify My Watershed, and The Teacher Interface.

To introduce users to the basic concepts of the model, MMW includes the Simple Hydrologic Model, which allows users to manipulate the amount of rainfall, the land-cover type, and the soil texture irrespective of place (Fig. 1). By comparing various combinations, a user can see the impact to the water budget of different combinations of land-cover type, soil texture, and rainfall intensities.

The Show My Watershed Module (Fig. 2) places users in the landscape and allows them to select a location to investigate in one of several ways. They can search for a specific address, or select various levels of USGS HUC (Hydrologic Unit Code) basins. They can also designate a flow point, and the model will identify the area that drains water through that point. Finally, users can free-draw an area on the map. Once the user has defined an analysis area, the model will display the existing land cover and calculate

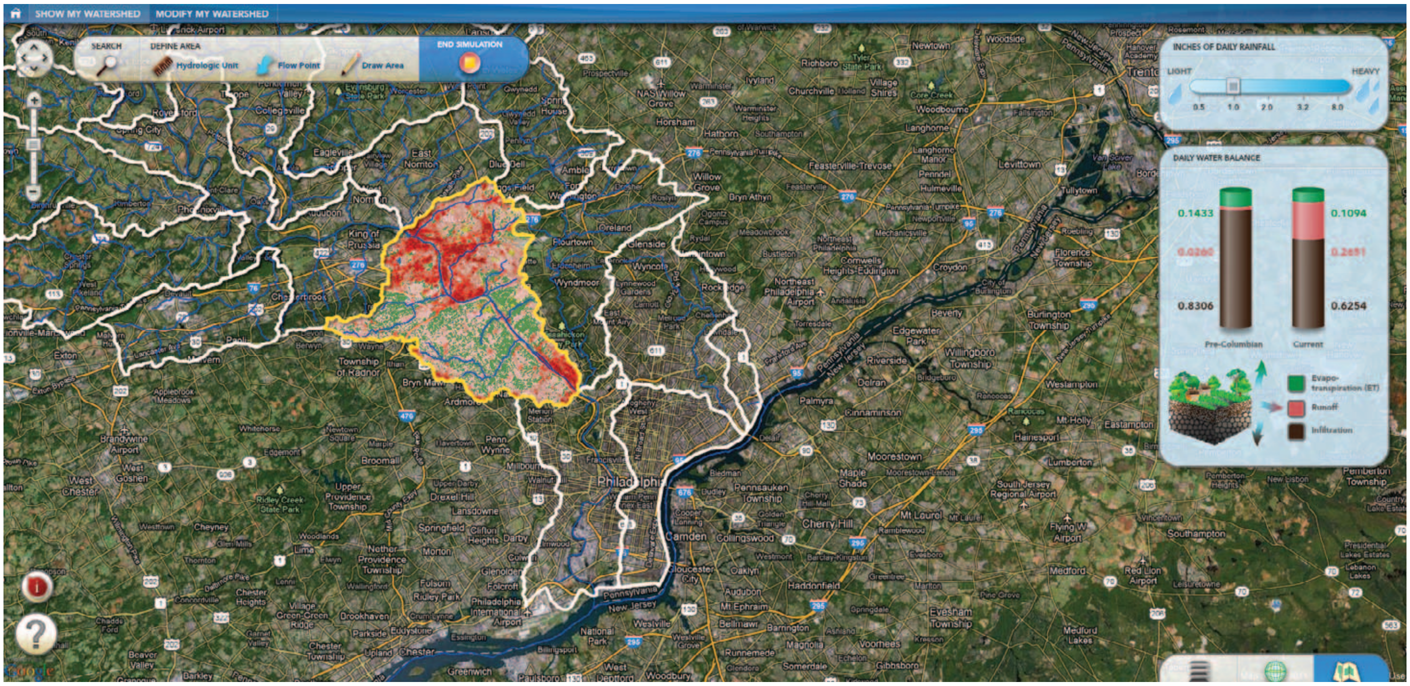


FIGURE 2: The Show My Watershed module allows students to identify an area on the map by identifying a USGS HUC Basin, defining a flow point, or drawing an area. Once the area is defined, the student can run the model and compare the water budget for the current land use to the water budget during pre-Columbian conditions.

both the area and percentage in each land-use category. When the user then chooses a storm intensity, depicted in inches of rainfall, and activates the "start simulation" button, the model runs the simulation and returns a water budget that depicts infiltration, runoff, and ET for that area based on current land-cover type and the storm magnitude that the user selected. This water budget is compared to one based on pre-Columbian conditions, the U.S. EPA's target for site hydrology.

In the Modify My Watershed Module (Fig. 3), the user can make changes to the area previously defined in the Show module. S/he can change the land-cover type to any

FIGURE 3: Once the student has defined an area and modeled it in the Show My Watershed module, s/he can then modify the area by changing the land-cover type or implementing best-management practices such as green roofs, vegetated infiltration basins, and no-till farming.

that is depicted in the model or can implement selected best-management practices, such as green roofs, vegetated infiltration basins, or porous pavement. S/he can also elect to make changes that average improvements over larger areas, such as the implementation of rain gardens or cluster housing. The model uses an algorithm to integrate those changes within the area defined by the user (e.g., 10% of homes have rain gardens, or houses are clustered to provide the number of housing units equal to high density but open space equal to medium density). The resulting output shows before and after modifications in the water budgets. It also calculates a hydrology score, a water quality score, and a social impact score, based on the perceived human disruption caused by the change, as ± percentage scores. Finally, it keeps track of the approximate financial costs associated with each modification. By trying to keep a reasonable balance on costs, as well as social and environmental impacts, users can weigh the various options and make informed decisions on trade-offs that are necessary when seeking solutions to complex problems. (The underlying formulas and metrics used to calculate those scores are available via the teacher interface. Teachers can utilize this information in classroom instruction.)

MMW also includes a Teacher Interface, where teachers can enroll students by section, assign scenarios, and track time-on-task. Teachers can also develop their own scenarios and curricula and share them with peers, if they wish. For example, they can challenge students, either individually or in teams, to improve the hydrology of their schoolyards or try to minimize the environmental impact of a local shopping center. The teacher can define explicit goals and set a budget as well. Once students have completed their assignments, the teacher can export results to an Excel spreadsheet for grading purposes.

PROJECT-BASED LEARNING APPROACH

As stated already, every child lives in a watershed, and every child is Earth's essential steward. MMW is unique in that it allows the student to vividly see the impact of human action on his/her watershed. It also permits students to engage in land-planning exercises that allow them to immediately see the potential impact of new changes to their watershed. By linking processes that act at the local, familiar scale to conditions that occur at a larger scale, the MMW Web application seeks to provide participants with a cognitive anchor that will allow them to link their own observations to data and to the models, thus helping learners to comprehend the integrated and complex nature of environmental science.

This project is based on broad problem-based learning (PBL) models. The central tenet of PBL methodology is that information is mastered when it is taught in the context in which it will be used (Donner and Bickley, 1993). "A project is meaningful if it fulfills two criteria. First, students must perceive the work as personally meaningful, as a task that matters and one that they want to do well. Second, a meaningful project fulfills an educational purpose. Well-designed and well-implemented project-based learning is meaningful in both ways" (Larmer and Mergendoller, 2010, p. 34). In MMW, we promote the use of scenarios that describe a local watershed problem as a vehicle to move students from the theoretical application of ideas to active problem solving (Farley et al., 2005; Beddoe et al., 2009); MMW fulfills both criteria for meaningful PBL. The scenarios developed and included in the application present students with real issues and ask them to develop strategies, based on what they have learned, and apply those strategies to develop plans to address them. What makes this approach such an effective way to engage students is the emphasis on solving real problems as a team in a collaborative setting; students participate in every step of the process by: (1) defining the key challenges of the problem; (2) deciding who the stakeholders are and what issues affect them; and (3) analyzing data and discussing potential solutions. This makes the science engaging and relevant to real life. It also models the interdisciplinary approach that environmental decision making takes in professional settings while developing communication and collaboration skills.

The National Center for Case Study Teaching in Science (NCCSTS, 2013) has compiled an impressive set of examples of how this format can be adapted to science education at every level. The scenarios for MMW are developed as dilemma/decision cases, as defined by NCCSTS (http://sciencecases.lib.buffalo.edu/cs/collection/).

MMW SCENARIOS

MMW scenarios are incorporated into the application through the teacher portal. These problems are situated in a range of settings from urban through suburban to rural areas. In each case, users are asked to seek solutions that not only address the stated problems, but are also tasked to forge a solution that considers cultural, social, economic, and social-justice issues. Next, we present a summary of scenarios that are currently included in the MMW application.

- The Mill Creek neighborhood is located in West Philadelphia, PA. When William Penn first designed the street layout for his "Greene Country Towne," between the Delaware and Schuylkill Rivers, he envisioned a grid pattern with a green square at the center and one in each quadrant. In the early 19th century, Philadelphia expanded into the agricultural area west of the Schuylkill River. This area included streams, many of which powered local mills. Rather than considering the natural topography and hydrology, the city planners simply imposed the existing grid pattern over the landscape. Streams, like Mill Creek, were originally used as open sewers but were eventually buried in pipes and became part of Philadelphia's sewer network. As do so many buried streams, Mill Creek did not stay confined in its pipe. In the mid-1900s, there were two dramatic collapses that undermined houses and even swallowed a car. The decline of the buildings mirrored the decline in the socioeconomic status of the neighborhood's residents. Although the creek was not the only cause of neighborhood decline, it did exacerbate the situation. Despite redevelopment during the 1960s, the neighborhood continues to be economically depressed and subject to periodic collapses (Spirn, 2005). The MMW scenario asks students to redevelop the neighborhood around a park that represents the former channel of the stream. They are advised to incorporate best land management practices such as tree plantings and infiltration basins within open space; to provide commercial and employment centers; and to build sufficient housing to provide for all current residents. Their plan must reduce storm-water runoff that causes Philadelphia's combined sewers to dump raw sewage into the Delaware and Schuylkill Rivers (Philadelphia's water-supply sources) during even moderate rainstorms. They must also maintain community integrity and provide needed local resources.

- Valley Forge National Historic Park is located at the confluence of the Valley Creek and the Schuylkill River. In the winter of 1777, General George Washington and nearly 3,000 troops wintered at Valley Forge, Pennsylvania, 20 miles (32 km) north of Philadelphia. At the time, the land was actively farmed. Today, the area surrounding Washington's Headquarters is part of Valley Forge National Historical Park, which maintains much of the rural character it had during Washington's encampment. However, the headwaters of Valley Creek have been developed with condominiums and apartment developments that cause increased storm-water runoff and regularly cause flash flooding. Even moderate rainfall causes the National Park Service personnel to place sandbags around Washington's Headquarters to prevent damage to the structure. Specifically, this scenario asks students to outline a plan to: (1) reduce the amount of overland flow that reaches the creek during storm events by implementing best-management practices and (2) stabilize downstream, flood-prone areas such as Washington's Headquarters using riparian plantings. In their plan, students must not only protect George Washington's Headquarters, they must also maintain the integrity of the headwater community (number of households, commercial and employment centers) to minimize the impact to current residents.
- Lancaster County, PA, is known for its rich, limestone soils that support the agriculture of the Plain Sect (Amish and Mennonite) farmers. Despite the tourist industry that has grown around the picturesque Amish farmsteads and buggies, the Plain Sect residents are an endangered culture. Suburban sprawl threatens their productive farmland, which could soon sprout houses rather than corn. In this scenario, users are asked to preserve prime farmland to protect the Plain Sect culture. The users compare four local land areas: (1) the farmland surrounding their schoolyard; (2) a recently constructed housing development; (3) an urban marketplace; and (4) a forested area. Using best-management practices, users model ways to best manage community growth.

In all of these scenarios, students are asked to justify their decisions and to discuss how they are addressing local societal and economic issues in a culturally sensitive way. Depending on the grade level, they may be asked to discuss some or all of the following questions as they prepare their plans. The level of complexity and detail expected from students will, of course, vary with grade level.

1. *Who are the local stakeholders?* Students are asked to identify all of the groups who are affected by the problem or who will be affected by the proposed solutions. They also need to identify economically and culturally vulnerable populations. For those stakeholders who may not be actively engaged in local decision making (e.g., Plain Sect farmers or underrepresented minorities), they should also define a strategy for incorporating them into the planning process. This could include Web-based research on how these populations have responded to similar problems. It could also include face-to-face interviews with group representatives, if possible.
2. *What are each stakeholder's concerns/issues?* Once the student or team has identified all of the stakeholders, they should then outline any stakeholders' concerns or issues that would relate to any proposed solution. Once they have done that, they should identify areas of potential conflict that will need to be addressed. Each stakeholder concern should be categorized. For example, is the concern economic, cultural, religious, ideological, political, etc. This will be important to identifying those concerns on which stakeholders may be able to compromise and those where little or no compromise is possible.
3. *Where are there direct conflicts and where can trade-offs be accommodated easily?* Students are asked to identify areas where they believe compromise is possible and where trade-offs can address conflicting viewpoints. For example, would one group be willing to accept the proposed changes in exchange for walking and bicycle trails?
4. *Where there are no easy compromises, how should conflicting viewpoints and interests be resolved?* Students should consider how local land-use decisions get made and how they should be made. Would they propose a public meeting? If so, how would that be managed? Is there another alternative way to make decisions?
5. *Ultimately, how should decisions get made and by whom?* Students should discuss how difficult environmental decisions should be made in a democratic society and how minority interests should be addressed.

RESEARCH ON EFFECTIVE WATERSHED INSTRUCTION

Improving watershed instruction is not as simple as merely implementing compelling scenarios into the learning process. Designing effective instruction must build upon students' current understanding of water. Students' initial ideas about water and watershed topics are often naive and unconnected, but there is hope for change. Gunkel et al. (2012), Endreny (2010), and Ben-Zvi Assaraf and Orion (2005a, 2005b, 2010) provide evidence that children have the capacity to develop more connected, sophisticated, and systems-oriented ideas about water through instruction. However, compelling evidence suggests that students' conceptual understanding of scientific topics, including environmental topics, bears little impact on the actual decisions they make on real-world issues (Allum et al., 2008; Nisbet and Scheufele, 2009). Similarly, in classroom settings, students typically make few connections between the content and their decisions (Zohar and Nemet, 2002; Sadler, 2004; Raved and Ben-Zvi Assaraf, 2011; Rose and Barton, 2012). To improve watershed understanding, curriculum must be purposefully designed to provide students meaningful opportunities to connect conceptual understanding of watersheds to real-world decision making. The National Research Council (NRC) Framework emphasizes scientific practices including developing and using models, analyzing and interpreting data, engaging in arguments from evidence, and obtaining, evaluating, and communicating information. The MMW project is based on the premise that this barrier between students' conceptual understanding of watershed content and their real-world actions can be bridged by the enactment of a curriculum that teaches watershed content using real data, scientific models, and local places. The MMW project allows students to actively explore their own watershed. To assess the effectiveness of the MMW curriculum, a research study was conducted to investigate the following questions.

1. What is the impact of the MMW curriculum on students' conceptions of the watershed?
2. Are students able to apply watershed content learned through the MMW curriculum to real-world problems?
3. What misconceptions about the watershed persist after instruction?

Research Design

An investigation of the Lancaster County, PA, scenario was piloted in the fall of 2012 with two secondary Earth Science teachers, six classrooms, and approximately 150 students in a rural Lancaster County High School. In this pilot, each teacher used the MMW curriculum with two of their classes and their traditional curriculum with one of their classes. This pilot study suggested that students' struggled to connect the concepts of runoff and land management to the larger water cycle. Still, students reported enjoying using the MMW portal, but they often missed potential learning opportunities available in the application, suggesting that the curriculum needed increased scaffolding to lead students through the application. The results of the pilot were used to refine the MMW curriculum and analysis instruments. A full-scale study was then conducted in the spring of 2013. Four teachers from two rural school districts in Lancaster County, two 7th grade life science teachers, and two high school environmental science teachers implemented the MMW curriculum in 16 classrooms. The MMW curriculum was designed to address local issues and was adapted for the age of the students. The 7th grade life science teachers chose to investigate a 1 square mile area (1.6 km^2) surrounding their rural school campus. Using a carefully scaffold curriculum that guided students through the Simple Model and Show My Watershed applications, students assessed the watershed health of their "school yard." The students then compared the schoolyard environment to a 1 square mile area (1.6 km^2) surrounding the "city market" in downtown Lancaster, PA. The high school classrooms utilized a similar scaffold curriculum that expanded the investigation to include five areas in Lancaster County: the schoolyard, a housing development, a local farm, a forested area, and the city market. In the high school curriculum, students were guided through the Simple Model, Show My Watershed, and Modify My Watershed. Model My Watershed Curricula developed by various teachers who used MMW are available at http://wikiwatershed.org/curricula.html.

Research Instruments

The study used a mixed-method design that involved the simultaneous collection and analysis of both quantitative and qualitative data. The instruments used in this study included: a 14 question content knowledge test, the Draw My Watershed (Shepardson et al., 2007) assessment, and semistructured interview protocol for focus groups.

The content knowledge test was developed by the research team, which included watershed scientists, science education researchers, and project evaluators. The content knowledge test was administered online to students before and after instruction. The content knowledge questions were integrated into a larger survey that included questions about interest in science, technology, engineering, and mathematics (STEM) and future career interests. The "Draw My Watershed" assessment was created by Shepardson et al. (2007). This assessment asks students to draw a picture of a watershed and to describe their drawing in a paragraph response. This assessment is scored using a study-designed rubric that assesses students' watershed understanding according to the scale developed by Gunkel et al. (2012).

All students in the study completed a pre- and postunit quantitative/qualitative test of watershed content knowledge and a pre- and postunit qualitative "Draw My Watershed" (Shepardson et al., 2007) assessment. After the completion of the unit, each of the four teachers in the study chose six to eight students to participate in a focus group using a semistructured interview protocol designed by the research staff.

RESULTS

Data collected from the quantitative portion of the pre/postunit content knowledge survey show a statistically significant gain in content knowledge for students in all classes (Table I).

Pre- and post-test data were collected from the Draw My Watershed Assessment (Table II). Using the four categories of watershed understanding outlined by Gunkel et al. (2012) as a guide, the Draw My Watershed Assessment (Shepardson et al., 2007) data were analyzed with a rubric that rated students' watershed understanding. The rubric consisted of a five-point scale, where 0 = no/incorrect understanding and 4 = comprehensive understanding. Examples of answers for each level appear in Figure 4.

All classes showed statistically significant improvement in understanding, yet few achieved the highest levels of understanding.

Data from the qualitative survey item and an analysis of the Draw My Watershed instrument show that students' understanding of watersheds increased, especially in their understanding of large-scale connections of water, i.e., streams to rivers. However, students were still lacking in their understanding of microconnections related to the "hidden sources" of water, e.g., groundwater and water vapor. In addition, while many students recognized many

TABLE I: Data collection.

Research Question	Instrument	Data Type
1. What is the impact of the MMW curriculum on students' conceptions of the watershed?	14 question survey that investigates students' watershed content knowledge and their ability to apply this knowledge to real-world problems (pre/post).	Quantitative and qualitative question
2. Are students able to apply watershed content learned through the MMW curriculum to real-world problems?	Qualitative questions from content survey (pre/post) and student focus group (postinstruction only).	Qualitative
3. What misconceptions about the watershed persist after instruction?	Draw My Watershed assessment (Shepardson et al., 2007). This instrument asks students to draw a picture of their watershed and to explain in words what a watershed is (pre/post).	Qualitative and quantitative

TABLE II: Pre/postcontent knowledge survey.

Teacher	Pretest	Post-Test	Difference	*t*-Test[1]
All ($n = 270$)	5.1 (2.5)	8.5 (2.1)	3.3	19.8**
7th grade teacher A ($n = 112$)	4.4 (2.1)	7.1 (2.9)	2.7	10.8**
7th grade teacher B ($n = 59$)	5.1 (2.5)	8.5 (2.3)	3.4	7.7**
High school teacher A ($n = 44$)	4.7 (2.1)	9.1 (2.1)	4.4	11.0**
High school teacher B ($n = 55$)	6.8 (2.3)	11.1 (1.4)	4.3	13.3**

[1] Mean (standard deviation) difference between pre- and postinstruction and *t*-test ($** = p < 0.01$).

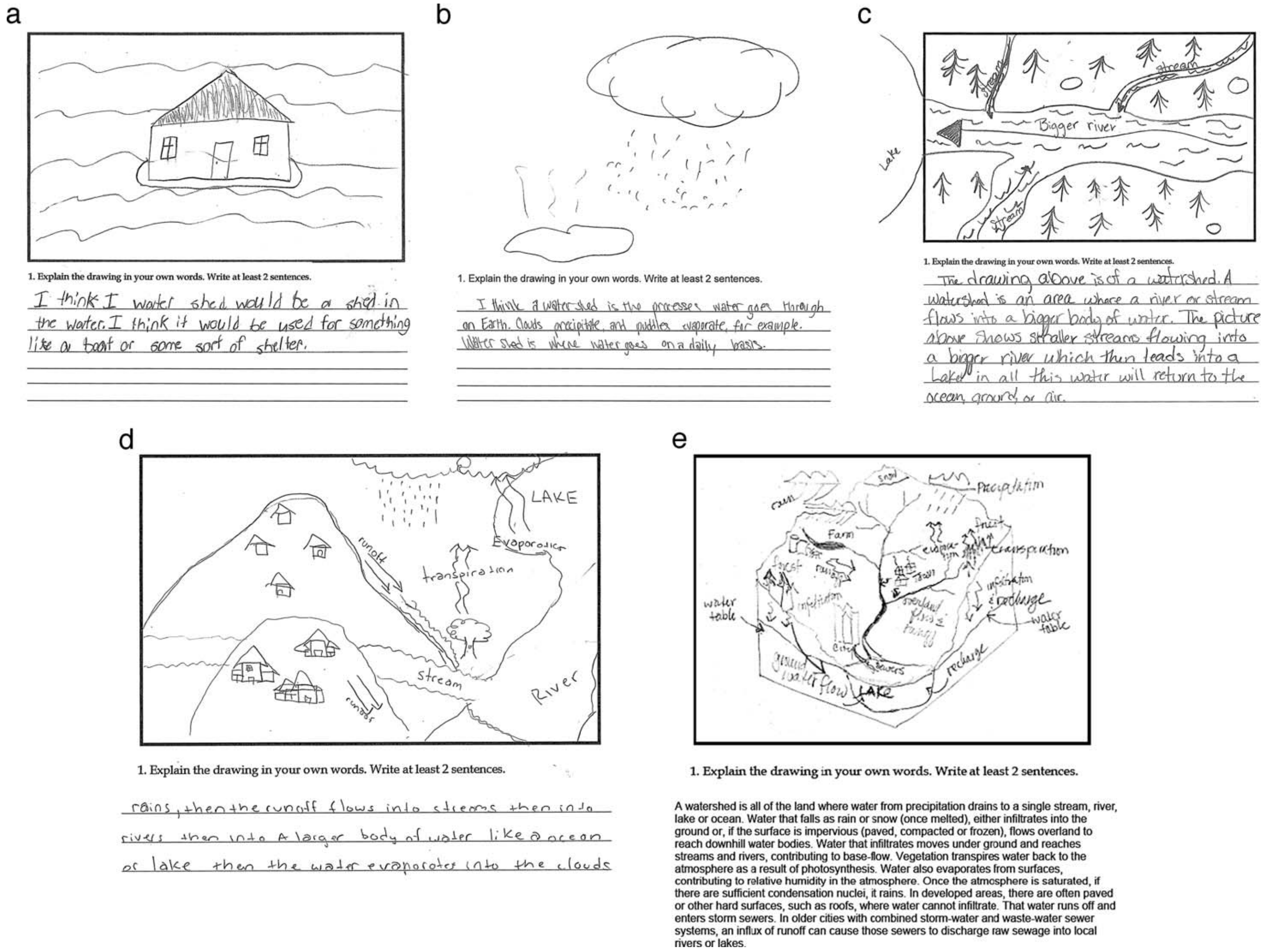
TABLE III: Draw My Watershed analysis.

Teacher	Number of Matched Pairs	Pre	Post	*t*-Test[1]
7th grade teacher A	74	0.9 (0.8)	1.3 (0.9)	2.8**
7th grade teacher B	85	0.4 (0.7)	1.1 (0.7)	6.9**
High school teacher A	80	0.7 (0.7)	2.0 (1.2)	8.4**
High school teacher A	44	0.8 (0.7)	1.8 (0.6)	7.1**
Overall	283	0.7 (0.8)	1.5 (1.0)	11.8**

[1] Mean (standard deviation) difference between pre- and postinstruction and *t*-test ($** = p < 0.01$).

water pathways, they usually failed to identify when one pathway would be more likely than another.

Four focus groups were conducted at the conclusion of the unit. Each of the teachers involved in the study assembled a purposeful selection of five to seven students to participate in a 45 min focus group. Students were chosen in order to have a range of ability levels, interest in science, and gender balance. Using a semistructured interview protocol (see Appendix A), students provided information on their experience using the Model My Watershed toolset. In the pilot study, students expressed concern that the classroom instruction did not support their use of the Model My Watershed toolset, and they saw a disconnect between the Model My Watershed maps and their local area. This information was used to create a scaffold approach for the curriculum used in the full-scale study, where the MMW toolset and classroom instruction were fully integrated through the creation of an activity guide for classroom use (http://wikiwatershed.org/curricula.html). In the full-scale study, students did not express similar concerns or curricular disconnect. The analyses of data from the four focus groups conducted in the full-scale study were carried through in several steps using NVivo to organize the developing different themes and identify critical incidents (Braun and Clarke, 2006). The analysis resulted in the identification of three themes as described in Table IV. Generally, the results highlighted that the use of technology allowed for a personalization of learning, where each student could use his or her own yard as the context for watershed study, and the MMW toolset allowed for quick and varied experimentation of differing environmental conditions. This ability to quickly test the impact of best-management practices on the local watershed was cited by students in their explanation of how best-management practices, tested in the MMW toolset, could positively impact the health of their watershed. Finally, when asked for suggestions on how to improve the MMW toolset, unlike during the pilot study, students did not offer substantive suggestions related to curriculum alignment or connections. Instead, students' suggestions were restricted to design features. Particularly, students warned against the use of text-rich descriptions or directions by directly stating that they do not read the text and that they



a

1. Explain the drawing in your own words. Write at least 2 sentences.

I think I water shed would be a shed in the water. I think it would be used for something like a boat or some sort of shelter.

b

1. Explain the drawing in your own words. Write at least 2 sentences.

I think a water shed is the processes water goes through on Earth. Clouds precipitate, and puddles evaporate, for example. Water shed is where water goes on a daily basis.

c

1. Explain the drawing in your own words. Write at least 2 sentences.

The drawing above is of a watershed. A watershed is an area where a river or stream flows into a bigger body of water. The picture above shows smaller streams flowing into a bigger river which then leads into a Lake in all this water will return to the ocean, ground, or air.

d

1. Explain the drawing in your own words. Write at least 2 sentences.

rains, then the runoff flows into streams then into rivers then into A larger body of water like a ocean or lake then the water evaporates into the clouds

e

1. Explain the drawing in your own words. Write at least 2 sentences.

A watershed is all of the land where water from precipitation drains to a single stream, river, lake or ocean. Water that falls as rain or snow (once melted), either infiltrates into the ground or, if the surface is impervious (paved, compacted or frozen), flows overland to reach downhill water bodies. Water that infiltrates moves under ground and reaches streams and rivers, contributing to base-flow. Vegetation transpires water back to the atmosphere as a result of photosynthesis. Water also evaporates from surfaces, contributing to relative humidity in the atmosphere. Once the atmosphere is saturated, if there are sufficient condensation nuclei, it rains. In developed areas, there are often paved or other hard surfaces, such as roofs, where water cannot infiltrate. That water runs off and enters storm sewers. In older cities with combined storm-water and waste-water sewer systems, an influx of runoff can cause those sewers to discharge raw sewage into local rivers or lakes.

FIGURE 4: Sample drawings showing different levels of watershed comprehension. Level 4 was completed by a member of the research team. (a) Level Zero Example. Water is depicted as a literal shed or other incorrect/off-base answer. Answer shows cartoonish characterization with no connection to environmental features. (b) Level One Example. Water is visible in familiar, isolated contexts, such as rivers, puddles, lakes, oceans, faucets, or isolated water. Answer does not acknowledge hidden sources of water, such as groundwater or water vapor. Map pictures show no connection between water features. (c) Level Two Example. Answer includes some mechanisms to move water. However, human actions to move water are not stressed. Connections to hidden sources of water, e.g., groundwater and water vapor, are not stressed. Large-scale connections of water, i.e., streams to rivers are shown but microconnections, such as groundwater recharge and contribution to stream base flow, are missing. (d) Level Three Example. Answer includes all features listed above for Level 2 and includes connections to school science. Illustration traces water among many pathways but does not indicate the likelihood of one pathway over another or the reasons for those differences. (e) Level Four Example. Integrates connections in the water cycle, including when and where water will follow specific pathways, such as infiltration, evaporation, transpiration, and runoff. Links these pathways to human influences and activities in the watershed, e.g., runoff from impervious surfaces as opposed to infiltration.

find pages containing a lot of text to be boring and unengaging.

The data provide evidence that the MMW Web site and curricula are effective tools for increasing students' understanding of watersheds and the impact of human decisions on local watershed health. By using the students' local watershed as the location of exploration and learning, the MMW project connects "school science" content to real-world applications by using scientific data, knowledge, and practices to participate in evidence-based decision making about issues impacting their local watershed (Kali et al., 2003; Orion and Ault, 2007; Mohan et al., 2009; Gunkel et al., 2012). While statistically significant learning gains were measured, most students failed to reach the highest levels of watershed understanding as defined by Gunkel et al. (2012). Further refinement of the MMW curricula is needed to help students trace water among many pathways and to be able to predict the likelihood that water will follow one pathway over another and the connection between "hidden" sources of water (groundwater and water vapor).

TABLE IV: Focus group analysis.

Interview Question	Emerging Themes	Selected Quotes from Responses
I am wondering if you can tell me what you have learned about watersheds and water quality since the beginning of this unit a couple of weeks ago? What were the most surprising or interesting things you learned about?	Role of technology in the learning process	I thought it was helpful because it wasn't on paper so we could explore it and go online and click on different things to see how it changes the environment so you could see the changes. I thought that was good.
		They thought it was cool seeing their own house. "There you go, there's my own house!"
I wonder if any of you plan to do anything differently since learning about how to keep watersheds healthy in this unit? Are there realistic things you could do (or you could encourage others to do) to keep your watershed healthy?	Actions students can take	So like, before when we are learning about change how if you want a different amount of runoff. Sometimes it's hard to think about how you could change it. But some of it is clear and its right there.
		You can plant more green things, and you can have a green roof.
		Taking care when you build houses and creating green space.
Did any of you visit the WikiWatershed Web site on your own time (e.g., NOT homework)? Did any of you explore it further? If so, what did you think? [For MMW students:] Did you talk about WikiWatershed with friends who were not in this class with you? If so, what did they think?	Suggestions for improvements to the MMW interface	They don't read directions. Too many "words" gives the impression of "boring"
		I didn't read it—it just looks boring.

SUMMARY

MMW provides students with the tools necessary to investigate their local watershed with a focus on their role as agents of hydrologic change. The application is designed using problem-based learning principles implemented as a series of proposed scenarios that each present a difficult environmental problem where there are many conflicting interests. MMW provides a vehicle where environmental issues can be addressed within local social, economic, and political contexts. This is an essential curriculum design principle, as most environmental challenges are complex and imbued with issues of potential social and economic conflict. In short, there are no simple answers, but there may still be workable solutions to the issues that we face.

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Appendix

Pre/Post Content Knowledge Survey Questions

Knowledge Test and Answer Key

Q15 If you were responsible for planning a new area for housing, which is the best building design to provide everyone with a place to live while protecting the environment?

~~○ Subdivision (1)~~

○ **Apartment with Green Roof (2)**

~~○ Mansions (3)~~

~~○ I don't know (4)~~

Q19 A watershed is:

~~○ the land next to a stream or river that often floods after a large rain storm (1)~~

~~○ a building built over a spring where people collect water (2)~~

○ **the land area where all rain drains into a single river, lake or stream (3)**

~~○ the process of water running down hill towards a stream, river or lake (4)~~

~~○ I don't know (5)~~

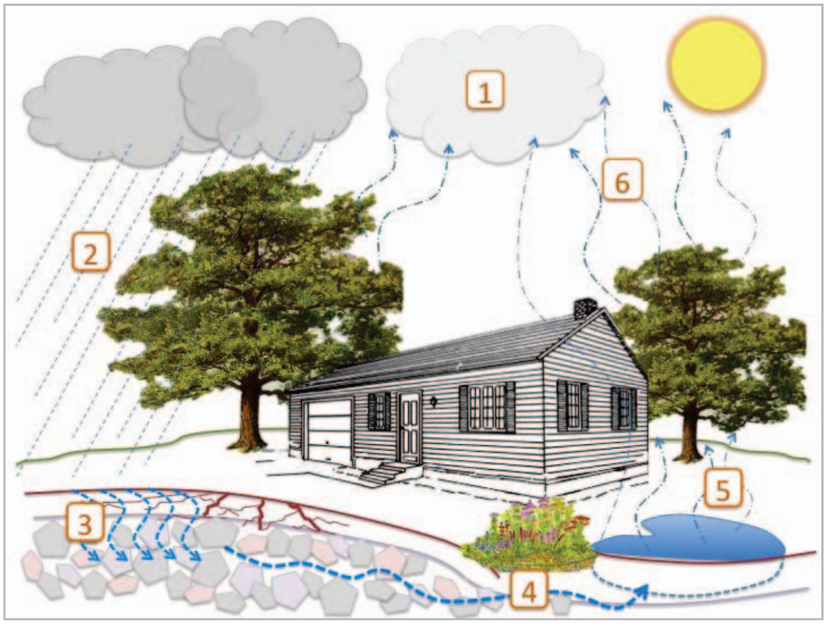
Q28 True or false? Cluster housing is way to limit watershed impact in a populated area.

○ **True (1)**

~~○ False (2)~~

~~○ I don't know (3)~~

Q30



Using the figure above, match a number to the corresponding part of the water cycle.

___**2**___ Precipitation (1)

___**5**___ Evaporation (2)

___**3**___ Infiltration (3)

Q31 Which of the following is NOT a “best-management practice”?

~~○ a rain garden (1)~~
~~○ porous paving (2)~~
~~○ green roof (3)~~
○ **storm drain (4)**
~~○ I don't know (5)~~

Q32 True or False? Water drains slower through sandy soil than through soil with lots of clay.

~~○ True (1)~~
○ **False (2)**
~~○ I don't know (3)~~

Q33 Trees and other plants take water from the soil and release it into the atmosphere. What is the name of that process?

~~○ Infiltration (1)~~
~~○ Permeability (2)~~
○ **Transpiration (3)**
~~○ Runoff (4)~~
~~○ I don't know (5)~~

Q34 Turf grass lawns have more runoff than natural grass meadows because . . .

~~○ their root structure is so dense (1)~~
~~○ the underlying soil has been compacted by repeated mowing (2)~~
○ **both of the above (3)**
~~○ none of the above (4)~~
~~○ I don't know (5)~~

Q35 Fill in the blank.
__**Hydrology**___ is the study of water and its movement on and through the earth.

Q36 Fill in the blank.
__**Sediment**____ are particles of rock and soil that are washed into a stream or river.

Q37 Which of the following land uses might cause the least amount of storm water runoff?

~~○ a baseball field (1)~~
~~○ a parking lot (2)~~
○ **a forest (3)**
~~○ a lawn (4)~~
~~○ I don’t know (5)~~

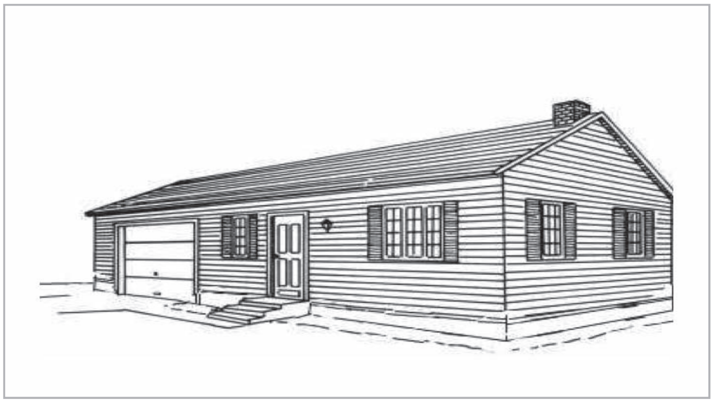
Q39 Meteorologists predict the weather by using models. Models allow scientists to understand how processes work. Which of the statements is NOT a true statement about models?

~~○ Models are representations of real objects or processes. (1)~~
○ **Models are 100% accurate. (2)**
~~○ Models use large amounts of data to make predictions of real systems. (3)~~
~~○ Models simulate large-scale experiments that would be too costly or impossible to actually perform. (4)~~
~~○ I don't know (5)~~

Q40 Briefly describe, in steps, how a raindrop that lands on your backyard could make its way to the ocean.

A raindrop would runoff of the lawn and flow to a storm drain then through the storm drains to a nearby river, or it could runoff directly into a stream. It would then follow the path of the stream directly into a creek, then into a river and eventually into the ocean

Q41



Look at the above figure. What best management practices could be added to this house or yard that would minimize storm-water runoff?

1) ~~Table with umbrella, solar panels and livestock~~
2) **Rain gardens, porous pavers and rain barrel**
3) ~~Wind turbine, green roof and submerged cistern~~
4) ~~Solar panel, rain barrel and bird bath~~
5) ~~I don't know (5)~~

Student Focus Group Questions:

Introduction:

As you might remember from when we were first introduced, we're trying to learn how a new curriculum works. Some of you were involved in a new, experimental learning software and some students learned the same content through a more traditional teaching strategy. So you might have heard that students in another class were doing something quite different. That's OK and we would like to hear about both experiences if you heard about it outside of class.

1. Did any of you visit the WikiWatershed website on your own time (e.g. NOT homework)? Did any of you explore it further? If so, what did you think? [For MMW students:] Did you talk about WikiWatershed with friends who were not in this class with you? If so, what did they think?
2. I am wondering if you can tell me what you have learned about watersheds and water quality since the beginning of this unit a couple of weeks ago? What were the most surprising or interesting things you learned about?
3. Next, I'm curious about how you feel about science? (***Note:*** This is different than what you know about science or watersheds. How you feel can include how **interested** you are in science as well as other feelings you may have.) If you can remember this far back, can you tell me a little about how you felt about science before this unit? Do you think your feelings have changed at all? Why?
4. What are your feelings about how water is managed in your community?
5. How many of you think you might want to have a science job when you get older? How do you imagine yourself using science (maybe in the ways you learned from the watershed course) in your career or just being a part of a community when you are done with your education? What do you imagine yourself doing for your career?
6. Finally, I wonder if any of you plan to do anything differently since learning about how to keep watersheds healthy in this unit? Are there realistic things you could do (or you could encourage others to do) to keep your watershed healthy?