CASCADE WATER ALLIANCE

Water Systems Teacher Fellows Program
Community Curriculum Case Study

Wastewater Engineering and the Properties of Matter

Middle School Physical Science - NGSS

Problem Statement

How can we flush the toilet and get clean water in 12 hours?

Teacher Design Team
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Grade 8, Physical Science
Pine Lake Middle School
Issaquah School District, WA

About the Water Systems Teacher Fellows Program

Teacher Fellows (grades 6-12) are paid a stipend over a 12-month period to develop new or refine existing problem-based curriculum that integrate water supply, wastewater, and stormwater management systems. Fellows integrate classroom rigor with community impact while advocating for district-wide adoption of the methods and resources they develop. Fellows are selected from the Lake Washington, Bellevue, Issaquah, and Tukwila School Districts. The Program is funded by Cascade Water Alliance and facilitated by Sustainability Ambassadors.

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About Problem-Based Learning

Problem-based learning (PBL) is experiential learning organized around the investigation and resolution of messy, real-world problems. Teachers coach student thinking and guide student inquiry as a co-investigator. PBL increases student motivation through the pull of problem dissonance, intrinsically inspiring students to take on more and delve deeper as they make a personal investment in the outcome of their inquiry. Coupled with cognitive coaching strategies, PBL calls upon critical and creative thinking by suspending the guessing game of: "What's the answer that the teacher wants me to find?" PBL promotes metacognition and self-regulated learning as students generate strategies for defining problems, gathering information, analyzing data, building and testing hypotheses, comparing strategies with those of other students and mentors, and sharing results with real-world stakeholders. Source: http://bie.org/about/why_pbl

School District Context

The Issaquah School District has a stated goal of "building a culture of sustainability." The district Sustainability Coordinator facilitates both curricular and extracurricular programs to advance this goal. The district Resource Conservation Manager tracks and reports annual energy, water and waste conservation efforts. Every school in the district has a student Green Team with an assigned Faculty Advisor. All middle school and high school Green Team leaders attend a kick off leadership training in the fall to develop annual work plans and a Community Sustainability Summit each spring to report results across generations and community sectors. The district website features a sustainability link on the home page.

City Context / Sammamish Plateau Water

Sammamish Plateau Water (SPW) is committed to sustainability through their robust Conservation Program. SPW provides support to residences, business, and schools within their service area through participating in technical studies, providing technical assistance, and supporting conservation education programs at no cost to participating schools. SPW also conducts numerous public outreach events to help their consumers better understand their water supply and how to use this limited resource efficiently and sustainably, which is especially important given the tremendous growth the service area is experiencing.

Wastewater Engineering and the Properties of Matter

NGSS - Middle School Physical Science

Problem Statement

How can we flush the toilet and get clean water in 12 hours?

Classroom Context: This problem based unit was taught to 195 eighth grade students across six periods in a Physical Science Class at Pine Lake Middle School in the Issaquah School District. The wastewater context was integrated with our school district's standard **"Properties of Matter"** curriculum. Although one or two labs were created to specifically support the wastewater context, and the order of the lessons was changed to align with the NGSS standards, most of the lessons were done as written in the school district's standard curriculum.

Students learned that the way they use water in their homes and at school affects the health of the Puget Sound. The water they use is diverted from the natural water cycle and used for many purposes such as drinking, cooking, showers, dishes, laundry and toilet flushing. In the process it is mixed with sewage, soap, cleaners, and chemicals. This "wastewater" needs to be treated before it re-enters the ecosystem and becomes a part of the water cycle again. Treating wastewater uses knowledge of the properties of matter to separate the mixtures created in our homes to return clean water to Puget Sound.

Project Summary *(Thematic Thread over 15 Weeks)*

Introduction: The unit began with a group analysis of the problem "How can we flush our toilet and get clean water in 12 hours?" After a discussion about where their waste goes, students show their thinking through a scientific model that reveals what they thought happened to wastewater once it left their homes. They drew diagrams, labeled parts, shared and defended their ideas on a sheet of large poster paper with room for three versions, the other two versions to be completed as they refined their understanding throughout the unit. After sharing their initial ideas, students were given the challenge of engineering an ideal system for treating wastewater.

Learning Target 1 - *"I can model elements, molecules, compounds and their extended structures"*

Students began their learning by deeply understanding water. We did this by separating water into hydrogen and oxygen through electrolysis. This helped them understand that water is a molecule made from elements with completely different properties. They explored 20 of the 115 elements on the periodic table to learn each element's unique qualities and how their placement on the periodic table relates to their properties and their structure. Students then explored how

the elements combine to form molecules. They used atom kits to build 3D models of molecules and learned how and why elements bond. This led to an understanding of the polarity of water. We continued our exploration of molecules and extended structures by introducing polymers. We used the atom kits to physically make polymers, explored synthetic materials and researched the positive and negative consequences of synthetic substances on society and the environment. Students brought in cleaning products from home that would end up their wastewater, researched the synthetic ingredients in the products and identified their impact on the environment.

Learning Target 2 - "*I can describe substances in terms of their properties and explain how thermal energy affects those properties"*

Students continued their learning by observing physical properties of matter. Students conducted a series of labs exploring density, floating and sinking, phase changes and how adding thermal energy affects those properties. Our focus was on water, but their learning extended to other substances as well. After Learning Target 2, students revised their wastewater treatment models on the original large poster paper provided in order to assess, reflect on, and refine their deeper understanding.

Learning Target 3 - *"I can evaluate and model the interaction of substances to determine if a chemical reaction has occurred"*

Students explored what happens when substances interact. We began with understanding the difference between a pure substance and a mixture. This led to the idea that when substances are mixed, the pure substances that make them up keep their properties. We then explored solubility and the process of dissolving to see if it is a chemical reaction. This learning reinforced the importance of understanding the polarity of water (from Learning Target 1) and how this might be related to wastewater treatment. We analyzed readings about the difficulty of getting soluble substances removed in the wastewater treatment process and the effects that has on the marine ecosystem in Puget Sound. Next, we did a series of reactions, so that students can see that when substances react, the properties of the reactants change as new products are produced. Students were introduced to the key indicators of chemical reactions, learned how to write chemical reactions and used models and equations to understand conservation of matter. Students connected this to the wastewater treatment process when learning about how bacteria are used to break down solid waste into biogas and biosolids. We discussed the long-term sustainability principles of engineering wastewater into resources.

Engineering Project

Students applied their new knowledge to design, build and test a system to clean wastewater. They were given water contaminated with sand, salt, rice, paper, BB's, and plastic beads and were tasked with solving the problem of separating all substances from each other and producing clean water in 30 minutes. This experience culminated in a video-based virtual tour of a wastewater treatment facility and a final revision of their model. Students returned to the

original problem statement, “How can we flush the toilet and get clean water in 12 hours?” for a final analysis of and appreciation for the volume of water that is treated 24/7 by our local wastewater treatment facility.

Call to Action / Pledge Campaign

Armed with their new science and engineering knowledge of how wastewater is treated, each student facilitated an outreach “Pledge Campaign” using digital media to share information and encourage behavior changes at home and among their neighbors, their parents contacts and social networks, that enable the treatment process to be as efficient, cost effective, and as environmentally friendly as possible. Aggregated data from the Pledge Campaign was shared with all participants, other community stakeholders, and archived as a benchmark for future classes.

Students reviewed the King County Wastewater Treatment Division’s Strategic Plan: “Vision, Mission, Values, and Goals” to clearly establish how their own knowledge and the pledges they collected from the community align with the County’s goals: http://www.kingcounty.gov/environment/wtd/About/Vision.aspx

Extensions and Integration with Other Content Areas

Victoria BC’s Big Problem: Students analyze the current economic, political and environmental challenge of the City of Victoria BC that continues to dump untreated sewage straight into Puget Sound. Students apply their own model of a wastewater treatment facility to propose an actual solution for Victoria. http://www.victoriasewagealliance.org/index.htm

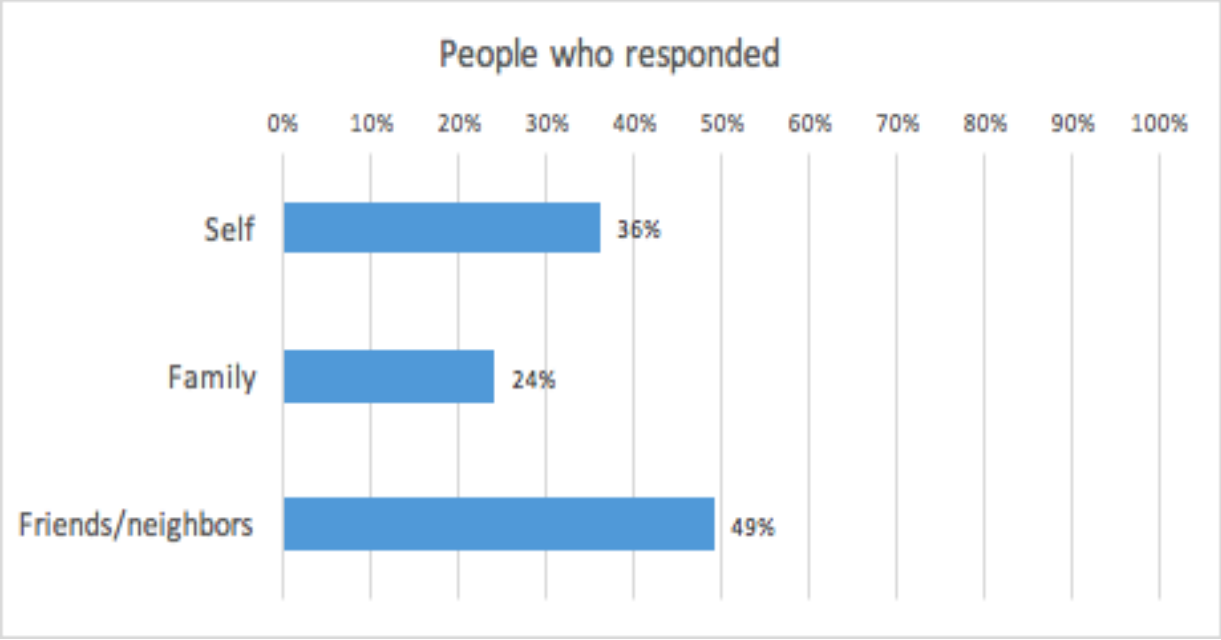
Singapore Leads the Future: Students analyze the current economic, political and environmental solutions in the small island nation of Singapore where the government is pursuing an integrated management approach to harvesting rainwater, recycling wastewater, desalinating seawater, and creating vast inland reservoirs that double as beautiful water recreation opportunities for their citizens. http://aseaniwrm.water.gov.my/iwrm-in-singapore/

A Living Building: Students analyze the integrated water systems in the Bullitt Center, the greenest commercial office building in the world, to determine how to achieve a system for “net zero water” independent of traditional regional water systems infrastructure. http://www.bullittcenter.org/

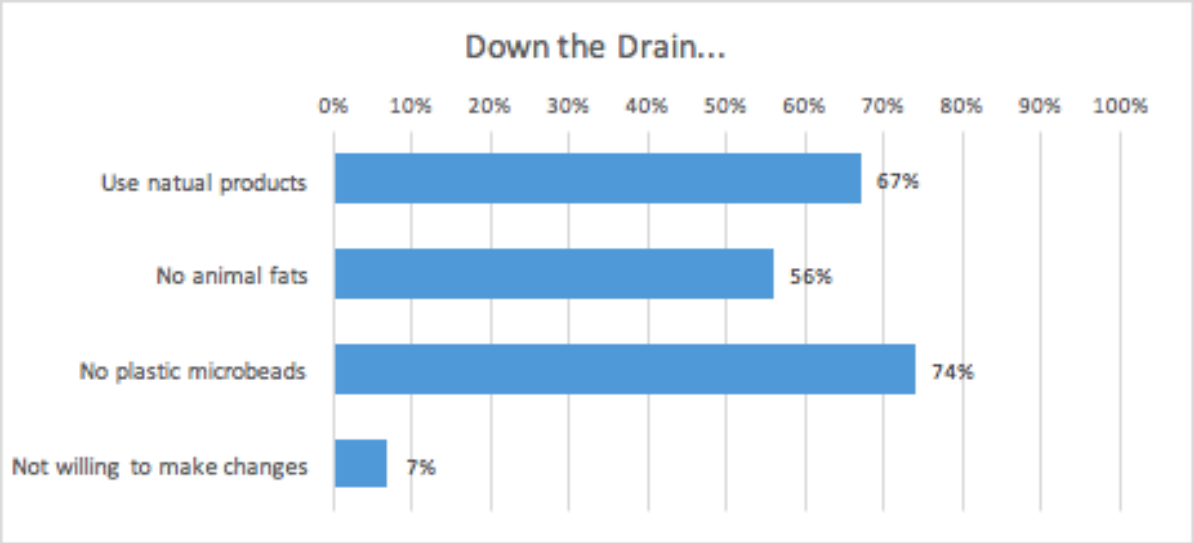
Community Impact Statement

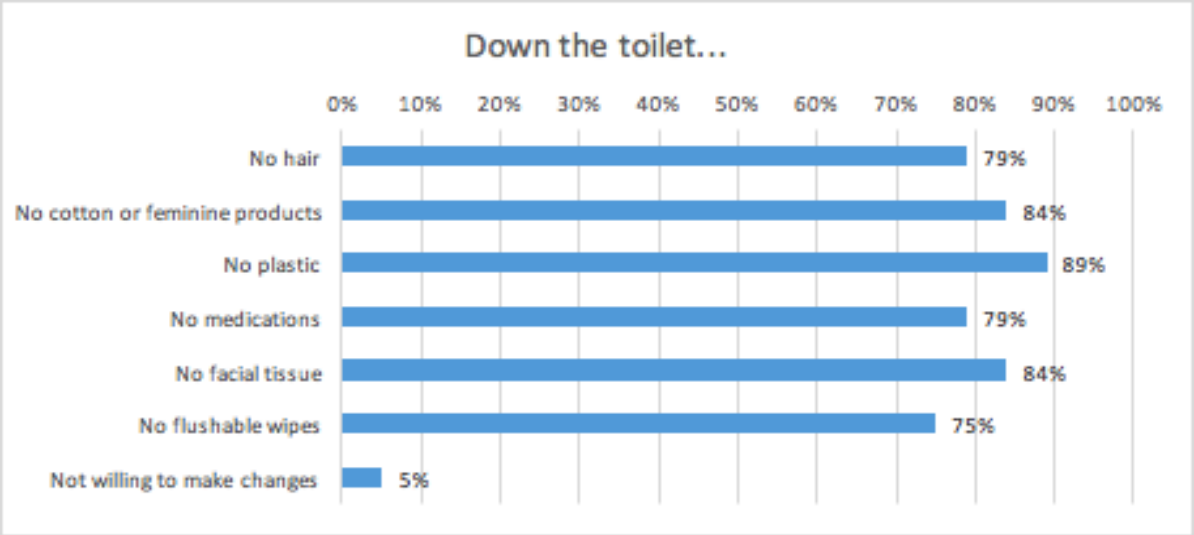
GOAL Students understand the properties and processes necessary to clean wastewater. This will lead to behavior changes, at the household level, that enable the treatment process to be as efficient, cost effective, and environmentally friendly as possible.			
Original conditions *What were the conditions before we took action?*	**Impact** *How did conditions improve as a result of our action?*	**Recommendation** *What do we think should happen next?*	**Stakeholders** *Who should know about our results and recommendations?*
Zero people pledged to change behavior related to wastewater	505 people pledged to change their behavior relating to what they put in the water	Create digital map with icons for households committing to behavior change	Parents Family members Neighbors Parent networks Clubs and civic groups

Call to Action “Pledge Campaign Results”



What they pledged to do….





Community Performance Measures

Selected from the King County Wastewater Treatment Division's Strategic Plan: "Vision, Mission, Values and Goals" http://www.kingcounty.gov/environment/wtd/About/Vision.aspx

- **Build a Sustainable and Resilient Future:** King County contributes to the long term viability and health of environmental, social, and economic aspects of our communities. We anticipate, prepare for and respond to changing conditions.

- **Educate and Engage Customers:** King County listens to and engages all customers and stakeholders, to develop an increased understanding of and satisfaction with our products, services and rates.

Curriculum Rigor meets Community Relevance

Standards Assessed	Critical Content	Community Connections
MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures **Washington Standards** *Explain that* all *matter* is made of *atoms*, and give examples of *common elements*—substances composed of just one kind of *atom*. Demonstrate with a labeled diagram and explain the *relationship* among *atoms*, *molecules*, *elements*, and *compounds*. **MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.** ***Washington Standards*** Use *characteristic* intrinsic *properties* such as *density*, *boiling point*, and *melting point* to identify an unknown substance. **MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.** **Washington Standards** Demonstrate that the *properties* of a *compound* are different from the *properties* of the reactants from which it was formed. **MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.** **Washington Standards** *Apply* the *concept* of *conservation of*	**Disciplinary Core Ideas** ● PS1.A: Structure and Properties of Matter Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. ● (MS-PS1-1) Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. ● (MS-PS1-2),(MS-PS1-3) Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. ● (MS-PS1-4) In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. ● (MS-PS1-4) Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). ● (MS-PS1-4) PS1.B: Chemical Reactions Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. ● (MS-PS1-2),(MS-PS1-3),(MS-PS1-5) The total number of each type of atom is conserved, and thus the mass does not change. ● (MS-PS1-5) Some chemical reactions release energy, others store energy. (MS-PS1-6) ●(MS-PS1-4) PS1.B: Chemical Reactions Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different	Students learn where the water goes when it goes down the drain in their house and how it gets treated in a wastewater facility. . Students learn what to put in wastewater and what not to put in wastewater. Students learn what is not removed from the wastewater and its effects on the environment. Students taught friends and family about stewardship actions and conducted a pledge drive to record changes in practices

mass to correctly *predict* changes in *mass* before and after *chemical reactions*, including reactions that occur in closed containers, and reactions that occur in open containers where a *gas* is given off. **Washington Science Standards:** Separate a *mixture* using differences in *properties* (e.g., *solubility*, size, magnetic attraction) of the substances used to make the *mixture*.	properties from those of the reactants. ● (MS-PS1-2),(MS-PS1-3),(MS-PS1-5) The total number of each type of atom is conserved, and thus the mass does not change. ● (MS-PS1-5) Some chemical reactions release energy, others store energy. (MS-PS1-6) **Cross Cutting Concepts:** ● Systems and models ● Structure and function ● Energy and matter ● Stability and change **Science and Engineering Practices** ● Asking questions ● Planning and carrying out investigations ● Analyzing and interpreting data ● Using math and computational thinking ● Constructing explanations ● Engaging in argument from evidence ● Obtaining, evaluating and communicating information	

Teacher Reflection

I began this curriculum design thinking I would need to create an “end of unit project” related to wastewater management that would tie into standards. That view changed drastically when I understood how to use Problem Based Learning as the framework for teaching.

My focus quickly shifted to using wastewater management ***as the context to apply science and engineering practices*** and to teach the performance standards and DCI’s at a deeper, more relevant level. This mindset shift allowed me to plan my lessons with a progression that addressed the standards and DCI’s in a meaningful way that enabled students to continually revise their solutions to the problem, deepen their knowledge, and reflect on stewardship practices at home and in the community.

For students, having a real life context to build their learning around really transformed both their motivation for and their retention of standards-based content. They finally saw a connection between their learning, their behaviors, and how those behaviors affected the world around them. They not only understood how to address the problem, but that the behaviors they choose can either compound the problem or solve it; that it is not up to “the government” to solve it alone. By the end of the unit, students had developed novel ways to treat wastewater that were based on scientific principles and engineering practices. It was empowering for them as they pledged to change their own behavior and convinced others to do the same. This generated a virtuous cycle of awareness and action.

Student Testimonials of Learning, Motivation and Application

“The engineering projects and the various labs that we do help me learn a lot. It has also made the class enjoyable and has made me willing to learn.”

“I like doing the projects because it helps me understand the concepts better.”

“What Mr. Burgard does very well is relating this information to real life. While we read several articles that did not have a very large effect on classroom activities, but they did cover a part of learning that is thoroughly ignored by most teachers, which is showing us why what we are learning matters and how it will be helpful in our future.”

Really Helpful Resources

10-minute video talk and virtual tour of the Brightwater Treatment Facility:
http://www.sustainabilityambassadors.org/apps/videos/videos/show/18950392-wastewater-treatment-engineering-brightwater-virtual-tour

King County Resource Recovery
http://www.kingcounty.gov/services/environment/wastewater/resource-recovery.aspx