

2016

Student preconceptions of arid, urban watershed management and how experiential learning might contribute to conceptual change.

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Student preconceptions of arid, urban watershed management and how experiential learning might contribute to conceptual change



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Rachel Aliyah Thomas

Committee
Dr. Vanessa Svihla, Chair
Dr. William M. Fleming
Mr. Kevin Gant

A Professional Project Proposal Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Water Resources
Water Resources Program
The University of New Mexico
Albuquerque, New Mexico
July 2016

Committee Approval

The Master of Water Resources Professional Project Report of **Rachel Thomas**, entitled **Student preconceptions of arid, urban watershed management and how experiential learning might contribute to conceptual change**, is approved by the committee:



Vanessa, Svihla, Chair

2016/07/13

Date

Date

Date

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Acknowledgments

- A debt of thanks goes to former Director of WRP, **Dr. Michael Campana**, for initially encouraging me as an Environmental Science Undergraduate to pursue this program.
- I owe a massive debt of gratitude to **Dr. Bruce Thomson**, the more recent former Director of the WRP, serving as my Director in my time in the program. **Bruce** offered countless hours of fielding my questions on the technical / mathematical problem sets, general guidance in navigating through the program, as well as pointing me in the right direction for solutions to every challenge I found myself facing, be it course material, initiating a Professional Project and the everyday nuts and bolts of managing a job and family outside of school – **Bruce** even offered to babysit my one year old son, Logan!
- I send a big thanks to **Annamarie Cordova**, our WRP Administrative Assistant, who jumped me through all the administrative hoops and was willing to field my never-ending questions, replete with some great conversations along this oftentimes lonesome path pursuing a masters degree as a non-traditional student.
- I owe a tremendous thanks to **Judi Svihla**, the amazing mother of my outstanding advisor, **Dr. Vanessa Svihla**, who actually DID end up babysitting my new son, Logan. This enabled me several hours on a few occasions to make precious progress towards this meaningful personal goal. Thank you so much, Judi. How can I ever repay you?!
- **Logan, my son**, provided me his supportiveness by simply being “my good, little guy” as an infant, now a toddler, through a good part of this process. He inspired me to provide us with a solid future based on pursuing and achieving higher education as a means to attain big dreams. I aim to be an example he can be proud of.
- Big thanks to **my friends: Tamara Couture, Cindy Wilson, Jeff Worthington**. I can say with raw honesty that I’m not sure this could have happened without them. They each provided their unique brand of friendship. **Tamara** babysat Logan countless times, always reminding me for the express purpose of allowing me the time to finish my degree. With all my friends love and support, they ‘cheer-led’ me through this most challenging chapter of my life, attempting a masters degree while working, single parenting a newborn and living in my recently purchased fixer upper home that’s often ‘falling down.’ My friends kept my spirits up when I was at my lower points along this demanding journey, always reassuring me that I can do this!
- I owe my deceased **Father, Jon Thomas-Weger**, appreciation for instilling in me a love of reading A LOT and educating oneself on the truths of the world. I believe he would be proud of me for furthering my education. I owe my **Mother, Maria Wilson**, a huge thanks for unexpectedly blowing into town on the wind, just in time to offer some babysitting of Logan, enabling me to throw myself into one last big push to make this happen on time in the last few weeks leading up to the deadline to graduate. I wish to thank my **Stepmother, Roxie Weger**, for believing in me - that I could do this.
- **Kevin Gant, Professional Master Mentor Facilitator**, project-based learning expert, I wish to thank endlessly for his guidance in facilitating me in the highly

- innovative, yet rather complex, project-based learning methods. I will be seeking your ongoing mentoring for years to come in the education field.
- I owe **Dr. Bill Fleming** infinitesimal thanks for ALWAYS being supportive of my ideas and plans, no matter how outlandish and implausible ! You helped encourage me to think BIG! And to be sure to try out my plans in the real world, such as your work in Nepal.
 - Finally, an enormous debt of gratitude goes to my brilliant **advisor, Dr. Vanessa Svihla**. In tandem with her bedazzling adeptness, she provided what I would call unconditional support the entire duration of this Professional Project process. Even when I would drop off the radar due to parenting issues of a newborn, or some crisis unfolding with my fixer upper, 'falling down home,' **Vanessa** exhibited the patience of many saints. She stuck with me, and was willing to pick up where we had left off, and carry forward with this academic odyssey. In a metaphor, she acted as my professional guide in climbing Mt. Everest. And all because of her skillful guidance, we conquered the summit. It is **Dr. Vanessa Svihla** to whom I owe my future, after surviving the most arduous journey of my academic life. I lived to tell the story of the data I sought for the purpose of my Professional Project.

STUDENT PRECONCEPTIONS OF ARID, URBAN WATERSHED MANAGEMENT AND HOW EXPERIENTIAL LEARNING MIGHT CONTRIBUTE TO CONCEPTUAL CHANGE

By

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ABSTRACT

Voting-aged, freshman-level university students attending college in urban Southwest US cities are living in what is considered one of the most “climate-challenged” regions of the entire country. Such students may not understand the issues and ways to manage an urban watershed. For instance, the Southwest faces climate change drought predictions and naturally occurring water scarcity. Urban populations continue to climb, pushing up demands on already scarce water resources. Urban watersheds present specific challenges, such as impermeable surfaces. Students need to understand these urban watershed management challenges and climate change stressors. I conducted a study in an introductory environmental science class at an urban, very high research university in the arid Southwest. I used a pre / post design to assess student preconceptions about their urban campus watershed. The post-test was administered following a brief, experiential learning exercise, carried out over two instructional class periods. I developed a coding scheme to analyze the pre- and post-test responses. Results showed that students held both normative and non-normative preconceptions. There was minor growth in students’ conceptual understanding between the pre-test and post-test, and this growth was significant, ($t(33) = -2.25, p < .05$), with a small to medium effect size, $d: -0.393$. This finding

supports the use of experiential learning as a means to teach students about water resources. Understanding students' preconceptions of arid, urban watersheds can assist in how to better design curriculum. Improvements in curriculum design can empower students with more accurate knowledge to make better decisions about urban watersheds. This knowledge will help students make more informed voting decisions related to water resources policy for the Southwest.

Introduction

Statement of the Problem

There is limited information about student preconceptions about watershed management, especially in urban, Southwest desert environments. Because we don't know enough about student preconceptions, it can be challenging to design effective instruction to build on their ideas and help students understand the importance of water conservation.

Understanding the significance of water conservation in the watersheds of the urban Southwest has never been more urgent, given climate change and the concomitant uncertainty with future climate. Adding to this, the Southwest urban centers continue to see upward trends in population growth, not only increasing overall water consumption, but also driving up energy demand (coal-fired electricity production requires water) compounding the stressors on water resources.

Research Objectives

The objectives of this study are to:

- (1) identify the preconceptions students enrolled in an introductory environmental science class have about specific watershed management topics and to
- (2) understand how a particular experiential learning activity could help them learn about specific watershed management topics. The specific topics focused on in this study relate to aquifer recharge, barriers to water infiltration, and actions organizations and citizens can take to enhance water infiltration.

Research Questions

RQ1: What preconceptions do students who attend a university in an urban setting within an arid, Southwest desert environment hold about specific watershed management topics?

RQ2: How might an experiential learning watershed makeover activity help students understand specific watershed management topics in an arid, urban, Southwest desert environment?

Methodological Approach

These research questions were addressed by first designing a pre- and post-test to assess student preconceptions. I then designed a short experiential instructional intervention to teach students about urban watershed management. I developed and refined a coding scheme based on student responses, and coded data. I report descriptive statistics about these coded data, and conducted a paired samples t-test to compare pre- and post-test scores.

Literature Review

In this review, I briefly describe preconceptions and attitudes students bring to new learning opportunities related to water resources, and how these preconceptions / attitudes can affect learning outcomes. I discuss the definition of experiential learning and some background about the effectiveness of this learning method. Additionally I review research on water resources education, which is somewhat limited in scope. Thus, I also look at closely related areas of research, such as sustainability education and environmental education. Finally, I include a brief review of research on effective urban watershed management techniques for an arid Southwest environment; this final section helps the reader understand the context of the study, which focuses on this topic.

Misconceptions, Alternative Conceptions, Preconceptions?

Misconceptions—or misunderstandings—are found in every field of science across all age groups in education (Fremerey, Liefländer and Bogner, 2014). Some researchers have opted to use the term *misconception* in their work, yet offer no definition of misconception for the context of their work (e.g., Helm, 1980). However, the term *alternative conceptions* is preferred by others (e.g., Calik & Ayas, 2005, Fremerey et al., 2014). The argument for the use of alternative conception over misconception is that students' ideas are not always entirely wrong, but can be spontaneously generated misrepresentations, with some elements of truth within.

Researchers have long debated the use of misconception, which, according Hogan and Maglienti (2001) shows a deficit perspective (as cited in Leonard, Kalinowski and Andrews, 2014). This idea of a “cognitive deficit” (Leonard et al., 2014, p. 180) considers the student flawed in his / her ability to understand, thus placing blame on the learner.

Maskiewicz and Lineback (2013) claim that the use of misconception is outmoded in the Learning Sciences and Science Education research; however, Leonard et al. note that the

term misconception can still be found “regularly” (though they fail to define “regularly” or provide a count) in the literature, based on their review of articles published in 2013. If authors insist on using the term misconception, they should provide an explicit working definition of misconception for the context of their work (Leonard et al., 2014).

Researchers who take a constructivist stance usually opt for the term *alternative* conception (Leonard et al., 2014). According to constructivism, there is no deficit or flawed knowledge. Students’ knowledge is constantly being reshaped by new knowledge and experiences. Others have suggested terms such as *naive conceptions* and *preconceptions* (Maskiewicz and Lineback, 2013). Preconception are ideas students hold before instruction, and thus may or may not be misconceptions (Clement, 1993).

I prefer the term preconception because this most accurately describes the experience an instructor faces: students arrive with various ideas prior to our instruction. For clarity, I refer to preconceptions even when authors use other terms. For the context of my study, it is the conceptions that students *previously* held that interested me, and how those preconceptions could change via a brief experiential learning intervention.

Students’ Preconceptions of Environmental Issues

The hallmark of environmental science is its interdisciplinary nature; thus, there are many potential preconceptions students may hold. I delimit the focus to two areas most relevant to my study: water resources and pollution effects.

Researchers have investigated students’ preconceptions in the environmental sciences related to the subfield of water resources. For instance, Saylor, Prokopy and Amberg (2011) studied a phenomenon commonly misunderstood by American undergraduate students: that bottled water is safer and purified to higher standards than is municipal tap water. This misunderstanding lies in students’ limited knowledge of drinking water standards. Stringent federal regulations apply to public municipal drinking water, in the

US, but also in many other countries, such as Germany (Fremerey et al., 2014). US public water drinking supplies are held to the Safe Drinking Water Act standards, monitored by the Environmental Protection Agency (epa.gov) whereas bottled water is under the purview of the FDA, which has enacted lesser standards on the bottled water industry (Olson, 1999). And even under the regulations enforced by the FDA, Gleick (2010) reported that these enforced regulations only apply when the bottled water becomes interstate commerce. Often, as much as 60–70% is sold within the boundaries of the state in which that bottled water was sourced. Therefore municipal tap water can be expected to be of higher quality than bottled water, with a minute number of exceptions (Olson, 1999). Saylor et al. showed that American undergraduate college students have preconceptions that bottled water is safer than municipal tap water. But Fremerey et al. found preconceptions held by German students were more accurate compared to American students. The population surveyed in the German study included advanced 10th grade biology students and university undergraduates. These German high school and undergraduate students responded with greater levels of correct understanding than did American students of their municipal drinking supply regulations as compared to regulations that govern bottled water. However, the German students also held inaccurate preconceptions about where German drinking water was purified; they overwhelmingly believed their water was treated at a sewage treatment facility, when in reality, their drinking water is treated in a water utility plant (Fremerey et al., 2014).

Student preconceptions about environmental pollution were studied by Rodriguez, Kohen and Delval (2015), who used their results to enhance environmental education program development. Their findings suggested that environmental educators need to attend to temporal, spatial and causal relationships. For instance, they noted that how pollutants interact chemically within the environments that they are introduced can be

challenging for students to understand. Likewise, they noted that temporal, spatial and causal relationships and the inferences necessary to understand these in an environmental system need more focus in teaching. Understanding temporal, spatial and causal relationships can be particularly challenging when phenomena are not observable, i.e. polluting receiving waters within a watershed.

My study focused on student preconceptions of local watershed management and the water resources therein, and how a learning experience might impact their preconceptions in this area of environmental concern.

How might preconceptions prevent students from learning from instruction?

Students' preconceptions, which may not align with the scientifically correct ones, can be anchored quite firmly in a student's mind and can prove resistant to change (Fremerey et al., 2014). Without knowing where students' misunderstandings lie, we, as instructors, may waste time reteaching already well-understood topics or neglect areas of spotty comprehension. Having a detailed understanding of what those preconceptions are is important for facilitating conceptual change (Fremerey et al., 2014). This allows instructors to meet students where their current understandings are rooted, and to use these starting points to build upon or deconstruct preconceptions.

Fremerey et al. cite other authors who emphasize not just identifying the preconceptions, but also suggest interventions to bring about conceptual change. One study confronted students with their preconceptions to help students develop more scientifically accurate ones using both indoor and outdoor activities (Sellman and Bogner 2012). Franke and Bogner (2013) found that presenting students with preconceptions they bring can positively affect their interest in the topic. These studies speak to the importance of designing learning experiences that can bring about conceptual change. One approach to promoting conceptual change is experiential learning.

What is experiential learning and how might it support conceptual change?

Experiential learning is self-explanatory through the term itself; it is learning through experience, or learning by doing. John Dewey was a leader in the progressive education movement, the antithesis of traditional, didactic delivery of information. Dewey emphasized learning *by doing* (Mayhew and Edwards, 1936). For instance, he described a young student who was not just painting a prescribed object in a specified style as a means to acquire a skill, but rather, was painting the backdrop of a set for a school theater production portraying an historical event being studied. The student was learning the sensation of painting, as an artist might feel, as well as *feeling* the historical context presented in the play. Such learning experiences can emerge later as a memory to be reflected on and can be built upon to bridge the once unfamiliar world to the familiar. Kolb (1984) proposed a working definition of experiential learning as “the process whereby knowledge is created through the transformation of experience” (p. 38).

In order for experiential learning to be an effective process, the experience must be deliberately designed and include a reflection point. Experiential learning happens when reflection on the experience happens (Reeves, T., Reeves, P., & McKenney, 2014). In other words, experiential learning does not just happen simply by doing stuff, such as the generic field trip. It must be a deliberately designed experience with reflection points designed into the experience. Dewey wrote that brief interval reflection periods should be provided to allow the student to mentally organize what was gained through overt physical activity, or hands-on learning, built into a learning design plan (1938).

Experiential learning can be found in both informal and formal educational settings (Fenwick, 2000) and more recently, due to technology, in virtual settings. It can run the gamut from kinesthetic activities in a classroom to workplace trainings with a facilitator, and from organized social activism to team-building projects in the wilderness. It typically occurs

in the physical world, but with new technologies, can also occur in the virtual world (Reeves et al., 2014).

My study tests an experiential learning experience within a formal university course setting.

Examples of Experiential Learning in Environmental Education and Water

Resources Education

Campana (2010) encouraged students to learn water resources by *doing*, fulfilling the broader definition of experiential learning. The students carried out this learning in a Honduran community in dire need of a sanitary water delivery system. This effort served as the field methods capstone course for the Water Resources Program at the University of New Mexico (UNM). Campana concluded that his students demonstrated ingenuity that he found inspiring as an instructor in this experiential learning experience.

In a study with graduate students, a participatory approach was used to help students connect their prior knowledge to learn about water and sustainability (Missingham, 2013). Missingham presents a framework for this that includes asset-based instruction, participatory learning, problem-posing pedagogy, and knowledge construction. Asset-based instruction, in contrast with deficit models, would seek to build on students' prior and everyday experiences. Participatory learning is similar to experiential learning and typically involves working in small groups. Likewise, his description of problem-posing pedagogy aligns to experiential learning approaches that place the onus of learning on the student. Knowledge construction aligns to theoretical views of constructionism, in which students build understanding through designing. Constructionism is based on constructivism, with students constructing their own knowledge through meaningful experiences, producing tangible, publicly shareable products of learning (Papert & Harel, 1991).

Camkin and Neto (2013) adapted Paulo Freire's (1970) pedagogy of problem-posing to design an experiential learning approach they referred to as the "co-learning methodology." They designed college-level short-courses. Their goal was to prepare future water professionals who could identify water resource problems and come up with new solutions in global integrated water resource management. Their method leveraged the varied strengths of the students, who were college science students from around the world; they asked the students to use their prior knowledge and experiences to contribute ideas about solving water resource problems. The students worked collaboratively on these problems with guest speakers, who were water professionals. Having students share their relatively novice personal experiences with the formal knowledge of the professional experts allowed them to see their perspectives as valued and valuable, instead of simply accessing knowledge from the water professionals. This speaks to the idea of allowing students to make meaning through a participatory process.

Ballantyne and Packer (2009) conducted a study looking at interview responses and observational data of students in 12 environmental programs in Queensland, Australia. The intent was to learn the outcomes of experiential learning as compared to teacher-directed. The students had been exposed to teacher-directed instruction (e.g., worksheets, teacher presentation, teacher-led group discussion). These same students then participated in experiential learning activities (e.g., interpreted walks, field investigation and reflective response). Students were then asked what helped them most to engage in learning. Students reported that the most engaging learning occurred in experiential learning activities (p. 254). Emotional responses to the different teaching types—teacher-led or experiential—were also surveyed. Students reported greater incidents of negative emotional responses such as "bored" or "felt nothing" with teacher-directed learning and higher incidents of "feeling happy" and "calm" responses with experiential learning activities (p. 255).

An example of a virtual field trip, G-Camp for Teachers, is a Texas outreach program made available to 30 different classrooms, grades 4th-12th, over a two week duration. G-Camp has the goal of teaching Earth science experientially through providing that virtual exhilaration factor, virtually the same excited feeling about learning that many experiential, exploratory field trips can offer. G-Camp does this by initially building interest and excitement in participating students by using social media outlets such as Facebook and a blog to connect involved teachers and students. GPS mapped sites visited on the virtual field trip updated at regular 10 minute intervals in real-time. Visual observation data of the sites being studied were uploaded to G-Camp's Facebook page continuously. Through virtual mimicry of a field trip such as G-Camp, experiential learning can happen (Gamache et al., 2010).

Past Research on Water Resources, Sustainability and Environmental Education

The scope of research literature on teaching and learning water resources is limited; thus, I also review research on related topics, such as sustainability and environmental education. The findings of my study also prompted further research of students' preconceptions specifically in the area of pollution and its effects on / in a given environment, such as a watershed / basin.

One example of a water resources education effort described a project that took students to Honduras to set up a water delivery system for a small community (Campana, 2010). They emphasized the need to include a focus on sustainability in water systems.

In another example, Welker, Wadzuk, and Traver (2010) report on their experience using water resources education campus-wide. Students sought to improve their urban campus stormwater management as a short term goal. Stormwater management in an urban watershed can improve the overall health of that watershed; it can mitigate non-point

source pollution, prevent erosion and enhance groundwater aquifer recharge. Effective stormwater management can be achieved in part with techniques that are also classed as 'green infrastructure,' such as wetlands, raingardens, pervious pavements and green roofs. Welker and colleagues claimed that their stormwater management project succeeded in educating not just the students, but also water professionals and community public partners. The project included a web presence and educated through the design, construction and study of stormwater controls; this included providing on-campus tours of the project, including features such as a wetland, raingardens and porous asphalt.

A study with a focus on constructivist teaching methods, such as Freire's problem-posing, used experiential learning methodologies in water resources education. The end goal was to bridge existing tensions between the water professionals' realm and the relatively novice, informal, bottom-up watershed stakeholders' perspectives, whose perspectives would be similar to freshmen in an introductory environmental science class. Both the professionals and the students benefited by the exchanged knowledge and experience. Furthermore, this study's authors reported that an emotional involvement of the professional presenting on their area of expertise in a real-world example facilitated the students in making learning connections in the technical areas. Thus, co-learning can help relative novices to develop the capacity to deal with the complexity of water resources issues in a new world of uncertainty—climate change. Supporting bridge building between these disparate communities—water professionals and students / relative novice stakeholders—through alternative modes of learning can lead to more effective water resources policy (Camkin and Neto, 2013).

Giocalone, Mobley, Sawyer, Witte and Eidson (2010) identified public perceptions (similar to preconceptions in an introductory environmental science class), via a phone survey about stormwater management in South Carolina. The study's purpose was to aid in

improving on the redesign South Carolina's statewide watershed awareness campaign, "Carolina Clear." The public needs to be better educated on watershed issues as there appears to be a disconnect between watersheds and its stakeholders; for this to happen these complex issues need to be more understandable and accessible, especially at the local level. Local understanding and involvement at the local stakeholder level is integral if watersheds are to avoid disastrous outcomes with the suite of challenges faced today: population growth, rapid development, reduced federal, state and local funding for watershed monitoring, research and watershed-scale planning, political partisan gridlock preventing policy-making, [climate change uncertainties]. Negative outcomes in watershed management can usually be traced to top-down policy and implementation not working (Eidson, 2008). Myrtle Beach residents were the only participants who had access to a watershed awareness public outreach education program; more of these respondents answered the question correctly, "Do you believe that this stormwater is treated before reaching our lakes, streams and beaches?" (correct answer: no) than respondents from other areas. However, the same Myrtle Beach respondents incorrectly answered a multiple choice question about the definition of a watershed. In general, this study spotlights the need to provide watershed / stormwater awareness at more refined local scales. This would allow participants / learners to make water-landscape connections about their regional watershed and the stormwater management that occurs in their local, micro-watershed (Giacalone et al, 2010).

Urban Watershed Management in an Arid, Urban, Southwest Desert Setting

First, I will present the commonly used United States Geological Survey (USGS) definition of a watershed: "A watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel." (usgs.gov). The term watershed can be interchanged with

drainage basin, basin or catchment. A watershed, by definition, includes all surface bodies of water, such as natural streams, arroyos, and concrete stormwater channels, as well as underlying waters, which are known as groundwater or aquifer. Generally, many smaller watersheds, such as the urban Albuquerque watershed are part of much larger ones, like the regional Middle Rio Grande Basin (usgs.gov).

Urban watersheds pose myriad issues regarding the management of a healthy watershed. The most distinguishing characteristic of urban watersheds, contrasted with natural watersheds, is the prevalence of impervious surfaces, notably paved streets, parking lots and sidewalks (usgs.gov). These impervious surfaces reduce groundwater recharge and increase surface stormwater flows while compromising water quality due to vehicle pollutants, pet wastes and lawn fertilizers. But there are other concerns endemic to an urban watershed. Waterways managed by or created by humans (rivers / arroyos / concrete channels) have not evolved naturally under rapid climate change conditions; as such, they may not be designed to accommodate increased volumes of water during severe storm events, leading to devastating flooding. Land use change and development processes can result in the loss of vegetation, leading to erosion, which in turn increases runoff and sedimentation in streams and rivers, endangering water quality. Dense human population creates a need for sewage treatment systems, which discharge treated wastewater effluent into local waterways, furthering the possibility of reducing water quality. Underground septic systems can also cause water quality issues for groundwater. Local rivers and streams may be diverted to increase drinking water supplies for urban populations, which can harm riparian ecology (usgs.gov).

Urban watersheds specifically found in the arid Southwest US (including: Arizona, California, Colorado, Nevada, New Mexico and Utah) (Garfin, Jardine, Merideth, Black, & LeRoy, 2013) must additionally cope with water scarcity typical for a desert climate. Average

annual rainfall is 13 inches in New Mexico, determined from historical records dating back to the late 19th century (Sheppard, Comrie, Packin, Angersbach & Hughes, 2002).

Albuquerque average annual rainfall is 9.45 inches (noaa.gov). Due to low precipitation amounts overall in the Rio Grande Basin, Albuquerque has historically been reliant on the aquifer for drinking supply and other uses.

There are recent observations of lasting drought in the Southwest, from 2001-10. These droughts have proven extraordinarily severe compared to the droughts of the last century (Garfin et al., 2013). In recent years the San Juan-Chama Project was brought online to provide additional drinking water supply to compensate the dwindling water resources of the aquifer.

Population growth places further demand on water resources. In the past several decades, there has been rapid population growth throughout the Southwest, notably in urban centers. Concentrated areas of urban population have put stress upon regional limited water supplies (Garfin et al., 2013).

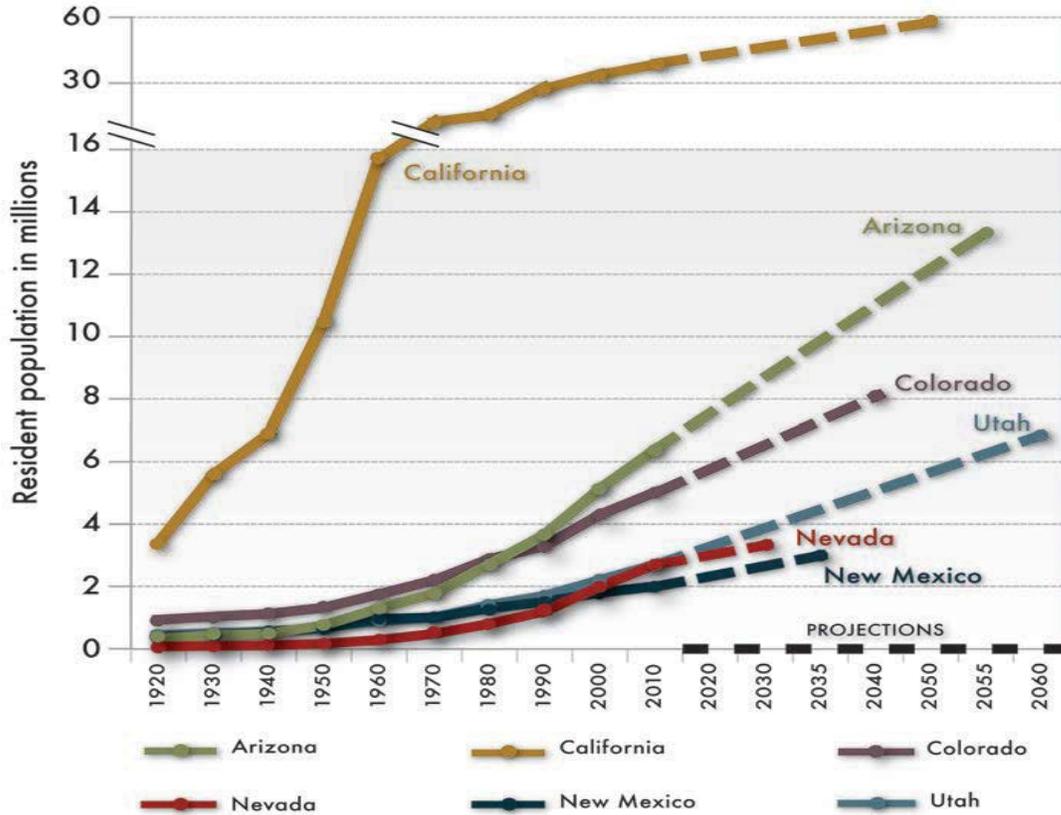


Figure 2.1. Projected Southwest US population growth (Garfin et al., 2013)

Another complication of Southwest watersheds is the North American monsoon phenomenon; New Mexico urban watersheds experience up to 50% of total annual rainfall within the monsoon season, determined by fluctuations in the North American monsoon system behavior (Garfin et al., 2013). Monsoon rains occur early July-September (Sheppard et al., 2002). These monsoonal rains bring about more flash flooding events, which are more likely to occur with impervious surfaces that are often found in a desert landscape and are ubiquitous in an urban watershed (Garfin et al., 2013).

The predictions for climate change impacts in the Southwest are still somewhat unclear. The more southern areas of the Southwest are expected to receive less rain, and the northern areas perhaps may see increased precipitation rates, but the boundary

between these regions is poorly defined. And the confidence level of the perhaps increased precipitation of the northern region of the Southwest has a medium-low confidence rating. Due to higher temperatures, resulting in less spring snowpack, the melt flows reaching the Albuquerque region are likely to be lower. Predicting monsoonal patterns is extraordinarily difficult due to the high level of resolution necessary in global or regional climate models to understand individual thunderstorm cell activity. Winter storm events are predicted to become more extreme (higher rates of precipitation), but summer storm event extremes have not yet been studied adequately to determine a prediction. Droughts will be more severe, more frequent and hotter (Garfin et al., 2013).

These climate change predictions, adding gravity to an unprecedented and rapid rate of population growth in the urban centers, will further exacerbate water scarcity and flooding concerns in the urban watersheds of the arid Southwest. In short, the Southwest has earned its place in the most “climate-challenged” region categories of the US (Garfin et al., 2013, p. 2).

One approach for dealing with this is to more carefully manage the watershed. Globally, there has been a long history of human managed urban watersheds; these have evolved over time, in response to changing needs. Some of the oldest evidence of planned urban watershed management is from ~6500 BCE, specifically domestic wastewater conveyance in El-Kown, Syria. Conveyances were dug into the floors of dwellings, constructed of plastered gutters, providing individual rooms with sewerage, as well as holes in walls for pipe conveyance, and piping found under plastered floors. In 4000 BCE instances of planned water drainage for an urban layout were found in the Euphrates delta. Conveyance channels—some constructed as open channels of limestone lined with clay, others as clay fitted piping—were used for discharging wastewater into the countryside on the perimeter of the city. Models of urban watershed management dealing with both

wastewater and flooding exist from 3000-1500 BCE in the Indus valley. In one case, engineered mounds of earth were bricked over to prevent water erosion from flooding events, providing a solid earthen base for building structures (Delleur, 2003).

Historically, urban watershed management focused on conveying wastewater and stormwater. As populations grew, urban watershed management began to include water quality concerns. More recently there has been another concern added, this time involving the need to plan for climate change uncertainties and less water resources for a continually expanding population. This recent change involves managing urban watersheds in the arid Southwest through more intense and longer droughts, less surface water made available from less precipitation, less water available from our already depleted aquifers, and the need to sustain and be resilient under these conditions.

One recent approach to this kind of management is *low impact development* that is tailored to an arid environment, often referred to as ARID LID (aridlid.org). This includes green infrastructure projects aimed at better stormwater management in the Middle Rio Grande basin, with the end goal of conserving water and improving water quality with bioremediation.

A project carried out at Bachechi Open Space Park (established 2011) used permeable pavements, channeling systems to funnel water to water harvesting zones, and above-ground cisterns to collect water from rooftops for supplemental irrigation of landscaping. Less apparent to the untrained eye was the recreation of a riparian forest of cottonwood trees and native plants. This approach slows rainwater flows and encourages infiltration into the aquifer, addressing water quality via the tree canopy and ground vegetation cover (aridlid.org).

A project at UNM proposed to implement innovative ideas (Community & Regional Planning, Advanced Planning Studio, 2007). The goal for this project was to replace the vast

acreage of impervious cement with permeable solutions that would encourage aquifer recharge, as well as providing natural irrigation for landscaping. Some of the more innovative features suggested were turf block and Grasspave. They estimated ~10,000 gallons per year could be diverted from stormwater drains into the aquifer via infiltration through the turf block. Grasspave could put ~4000 gallons back into the aquifer. Unfortunately, this proposal has not been implemented.

As individual citizens, residents of Southwest arid, urban watersheds can also contribute, and are encouraged to do so by state and local programs. For instance, the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) provides generous rebate credits to a resident's water bill, with an approved xeriscape plan to replace turf, and final passing of inspection of completed xeric installation (abcwua.org). Xeriscaping will reduce water use (keeping more in aquifer reserve or surface water supply) simply by installing native, drought tolerant plants, addressing both sustainability and resiliency concepts. And the incentive for the individual homeowner is cost savings in their monthly water bills as well as time savings with no longer needing to water, fertilize and mow a turf lawn.

A second rainwater harvesting program is scheduled to be launched later in 2016 in a collaboration between the New Mexico Water Collaborative (NMWC) and ABCWUA. This collaboration, led by the NMWC, has completed its first phase, having made a final selection of 9 chosen harvesting systems, installed in 2015, out of a pool of 300 applicants located in the ABCWUA service area. The 9 systems were selected to reflect the wide spectrum of how water gets used for both residential and business, diverse socio-economic factors and elevation range dependent biological communities existing in the region. Phase 2 of the rainwater harvesting program will entail releasing a free rainwater harvesting installation information guidebook to the public of the ABCWUA service area. ABCWUA will simultaneously disseminate a new rebate program to incentivize the implementation of

rainwater harvesters (cisterns). Looking to the future of progressively intensified water conservation, this program about to launch this 2016 is only 1 of 6 programs developed by the ABCWUA Water Resources Management Strategy Implementation, 2024 Water Conservation Plan (2013) (abcwua.org). The focus of this greater plan is water conservation progress, new rebate programs for incentivization and finally, youth education of water conservation sustainability issues in our arid region (nmwatercollaborative.org).

This study aims to investigate whether a short instructional, experiential learning intervention can help students develop a more accurate understanding of effective, arid, urban watershed management.

Methods

Participants and Setting

The participants were undergraduate students (n = 79 students consented to participate, with 73 students completing the pre-test and 36 students completing the post-test; the lower response rate on the post-test was because students believed it would not count in their grade) enrolled in an introductory environmental science class at a public university in the US Southwest. Study procedures occurred in two 75 minute class meetings (October 21 and 23, 2014) at the beginning of a unit on water resources.

Instructional Materials and Implementation

The intervention was a two-day Water Wonking workshop designed using experiential learning. “Wonking” is the verb form I coined from the noun, “wonk,” defined by Merriam-Webster online dictionary as a highly learned individual in a specialized field - typically found in policy but applies to any field, e.g., computer wonk, economic policy wonk, water resources policy wonk.

On day one, the students had already been informed by the course instructor that I was the guest speaker. I split the students into groups of three to five (a few students requested to be in bigger or smaller groups, which I allowed). Once in groups, I presented a PowerPoint detailing the instructions for the workshop. The PowerPoint first directed the students to discuss water issues with the question “Why should we care about water in the arid Southwest?” I went on to encourage students to discuss at length more generally about water in the arid Southwest region, but also more specifically within the immediate urban area, narrowing the focus to the students’ campus. I posed questions such as “Are we currently in a drought?” and “Are we wasting water on our campus?” I gave them 10 minutes to discuss within their groups water at both the regional and local level.

The PowerPoint then offered detailed instructions for a “Watershed Walk” within the localized watershed of the building in which the class was held (see appendix A). This “Watershed Walk” provided observational opportunities to assess the local subwatershed of the greater Middle Rio Grande Basin. I explained they would do a watershed assessment of the area around the building where their class was held, zooming in on where precipitation falls and what happens to that water. I made available to each student two Google satellite maps of the building outline in which their classroom was housed, and immediate area (local subwatershed). I instructed students to make notes of their initial observations / areas of concern on one map, and to use the other map to design the features of their ‘watershed makeover,’ and that they would submit this ‘watershed makeover’ map in the next class period. I informed them of the final product of this workshop, being a brief, informal presentation, using PowerPoint or some other software, a poster board or even a verbal presentation of their ‘watershed makeover’; I specified that their presentation must include at least 5 new water conservation ideas, with an emphasis on the group’s top 3 choices and an explanation of why these choices are superior. The students were given until the next class period to design and present their informal group presentations.

I instructed the students to further research their initial observations, findings and water waste concerns by locating their own resources, including searching online. In the uploaded PowerPoint to the course website, I offered a slide on additional xeriscaping information not shared during the class. I provided a resource to support their learning: a Word Wall of 33 Water Wonk terms, such as xeriscaping and rain barrels. I suggested that each student snap a picture of these Water Wonk terms with their smartphones as they left en route to their Watershed Walk for the remainder of the class period. The intention was for students to make water resources vocabulary connections independently.

Many students had questions about the assignment and about whether they would be graded. After answering questions, I sent groups outside to assess the watershed surrounding the building.

On day two, student groups gave their 5-10 minute informal presentations of their watershed assessment. This assessment included their concerns and how they would improve the watershed with a 'watershed makeover.'

Table 3.1. T-chart detailing sequencing of events for learning activity: "Water Wonking" workshop

Time	Facilitator activity	Student activity	rationale
Several days before class	Made pre-test available online	Completed pre-test	Prompted students to start thinking about water resources issues; enabled facilitator to learn of students' preconceptions
1 st class period			
Directly before class commenced	Made a "Word Wall of Water Wonk" available on chalkboard in front of room	Could view anytime throughout entire duration of class	Exposure to new water resources vocabulary
NA	Launched PowerPoint presentation (also posted on course website) with initial Water Wonking workshop instructions	Listened and viewed	Oriented students
3 minutes (min)	2nd slide instructed students to form groups of 3-5 (making sure at least one student's smartphone available for entire group use) – Advised that each group would produce a final product together, due next class period	Formed groups of 3-5	Organized group work for peer-to-peer learning opportunities; encouraged technology use

Time	Facilitator activity	Student activity	rationale
5-10 min	3 rd slide provided group discussion prompt: "Why should we care about water in the Southwest?" Canvassed classroom, prompting further group discussion when necessary	Group and whole class discussion	Encouraged group learning; elicited and generated ideas
10 min	4 th -5 th slides introduced and gave explicit instructions for watershed walk, including observation methods	Listened and viewed; asked questions about instructions	Form of direct instruction; could be accessed for clarification anytime on course website (including additional slide with xeriscaping information)
10 min	6 th -7 th slide presented detailed instructions for final products	Listened and viewed; asked questions about instructions	Created a need to know
10 min (+ or -, depending on number of questions)	8 th slide showed Word Wall of Water Wonk, suggesting students revisit this list of vocabulary with a smartphone picture for reference during watershed walk; Prompted students to depart classroom in groups with observation tools, maps of local watershed and begin their watershed walks for remainder of scheduled class time; Fielded clarification questions	Listened and viewed; asked questions about instructions; began watershed walk in groups	Form of direct instruction; exploratory and discovery learning; self-directed learning; learning by doing

Time	Facilitator activity	Student activity	rationale
Out of class work time			
Unknown amount of time	NA	Completed watershed walk, performed group and / or individual online research, continued to work on watershed makeover maps and prepared presentation	Experiential component; student choice and voice; exploratory and discovery learning; self-directed learning; learning by doing building knowledge with constructionist learning theory, producing something tangible and shareable
2nd class period			
5 min	Launched PowerPoint presentation— reminder for final products to be uploaded and complete post-test:	Listened and viewed asked last minute questions	Instructions available
65 min	Listened to student presentations; Asked questions	presented final products of watershed makeovers	Student direct instruction; peer-to-peer learning
Out of class			
NA	Provided access to online post-test	Completed post-test	Built-in reflection point

Data Collection

Data collection began following IRB approval. Consent was collected in class using university IRB-approved consent forms prior to data collection. In order to assess prior knowledge and learning, a pre-test was completed via Google Forms directly before the

Water Working workshop commenced. Several days were given to complete the pre-test voluntarily. The pretest and post-test comprised 3 questions:

- 1) What kinds of things prevent rainwater from being absorbed into the ground?
- 2) What could [our university] do to waste less rainwater?
- 3) Why would this be a good solution?

Data Analysis

Data were downloaded from a Google Form as an Excel spreadsheet. Non-consented students were removed from the sample. Three students completed the pre-test twice. Their answers differed but their submissions were close in time, based on the timestamp, suggesting they had hit submit prior to finishing. Thus, I copied their second response into their first to ensure each row represented a unique individual.

One way to analyze qualitative data is to review data for common “codes.” Once developed, this coding process is similar to applying a rubric to grade student work. I developed a coding scheme using a grounded approach (Charmaz, 2001; Corbin & Strauss, 1990, 2007), meaning I grounded codes in data and compared these to an expert answer to the three interrelated questions posed in the pre and post-test:

1. Things that prevent rainwater from being absorbed into the ground include: impermeable surfaces (e.g. impervious cement, pavement, plastic landscaping rock liners, drought-stricken, hard packed soils, etc) and stormwater drainage systems that transport water away from both permeable and impermeable ground surfaces.
2. The college campus could do the following to waste less rainwater: An umbrella term offered and defined, taken directly the Environmental Protection Agency (EPA) (2014) webpage, is "green infrastructure." Green infrastructure comprises many elements, such as xeriscaping, rain barrels,

rainwater harvesting, rain gardens, urban planter boxes, permeable pavement, bioswales, green roofs and parking, urban tree canopy, land conservation, and wetland features (epa.gov).

3. These would be good solutions because these solutions allow water to be absorbed into the ground ultimately, whether immediately or eventually, according to the mechanism of the solution's system. The primary intent of allowing water to be infiltrated into ground surfaces, specifically on a college campus in the arid Southwest, and within the Southwest region in general is so that the dwindling aquifer supply may be recharged.

I created an initial set of codes based on this expert answer. For instance, I created the code `Acc_Impervious` surfaces to reflect an accurate understanding that impervious surfaces prevent absorption. I began coding in the Excel file, placing a 1 where I recognized the concept in the answer, and noting with 999 any instances that were ambiguous. I used an open coding process, meaning I identified other codes, many of which I categorized as irrelevant or inaccurate. Irrelevant codes may contain accurate information, but do not address the questions in a way that is accurate. For instance, `Irr_Evaporation` accurately described that evaporation can happen to standing water on an impervious surface, but it is the impervious surface that is the issue.

Table 3.2. *Initial codes grounded in data*

Code	Description	Example
Acc_Impervious surfaces	Accurately describes / refers to impervious / impermeable surfaces	cement sidewalks prevent the absorption of water into the ground
Acc_Stormwater_Drainage	Accurately describes / refers to a stormwater drainage system	drains in the parking lot by Northrop Hall funnel water instead of allowing it to absorb into the ground
Acc_Eroded_Surfaces	Accurately describes erosion or the results of an erosive process that results in runoff	water does not soak in because it runs off where there are no plants or grass, and the soil is hard like cement
Irr_Evaporation	Irrelevant discussion / reference to evaporation or an aspect of the evaporative process	the water can sometimes disappear with the heat of the sun
Acc_Phreatophytes/Non-native_Plants	Accurate mention of a phreatophyte or non-native species or exotic plants to the arid Southwest	non native invasive plant species which absorb all the water in the ground (row 40 in POST)
Acc_Control	Accurate mention of solution as a way to control water usage	This is a good solution because it would give us greater control over when we want to utilize rainwater instead of relying on the time of the actual rain.
Inacc_Too_Many_Plants	Student says adding plants will decrease absorption	You could prevent rain water being observed into the ground by adding more plants.
Irr_Rerouting_Drainage_Vague	Student suggests rerouting water but does not mention permeable location	campus could focus on structuring all their buildings into having an outlet for all the rainwater to escape into the ground for the water to be absorbed.
Inacc_Dirt_Field	Student suggests dirt scape as way to get water absorbed	make a big field with nothing but soil so the rain can absorb into the ground to produce more groundwater.
Irr_Plants absorb water	Student understands plants absorb water but does not connect this to any other relevant idea	Plant more trees and plants around Albuquerque. This would be a good solution because more plants and trees would absorb more water.
Irr_Less_water	Student suggests watering less / using less water	campus could limit the use of water by watering plants less and using water only when absolutely needed. This would be a good solution because it would prevent the misuse of water.

Code	Description	Example
Innacc_Manmade_bad	Student describes man-made as bad or as impervious and / or natural as good or pervious	Things that prevent rainwater from being absorbed into the ground would be any type of man-made "blocker"
Inacc_Dry_Ground	The ground being dry prevents water from being absorbed	if the ground is too dry it will not absorb water
Inacc_Recharge_is_bad	Student sees water being absorbed as a waste of water	Arroyos, drains, and barriers could prevent rainwater from being absorbed into the ground. These lead into the rainwater into filters that could clean the rainwater for Albuquerque. campus could build a filter or some sort of device that contains the rain as it falls. These filters could be placed around campus. This would be a good solution because rainwater would not being wasted.
Innacc_Oversaturated	Student talks about the soil being too wet or too saturated to absorb water	I think things such as oversaturation of the soil can lead to water not being absorbed into the ground.

The coding scheme expanded as I worked with data. This supported my ability to identify the scope of ideas students brought into their pre-test responses. However, to develop a pre / post comparison, I separated the coding scheme into two parts. I aimed to compare the frequencies of accurate answers before and after the activity, so I focused on codes that were part of an accurate answer. I combined codes that were conceptually similar, such as a code for rain barrel and a code for storage of rain. I also broke complex codes into two codes and refined definitions to ensure the codes required little inference; for instance, I broke a code about water catchment into two codes, one about catching or storing water, and another about reuse of water.

I brought this refined coding scheme to a research lab meeting, along with randomly selected, pre and post responses mixed together. Three lab members coded 10% of the data. We compared agreement rates for each code, and discussed the nature of disagreements. This led to refinements of code definitions for several codes.

Table 3.3. *Refined coding scheme for research question one.* Coding scheme is used as follows: A score of 1 indicates the code is present; score of 0 = code is not present; score of 999 = ambiguous.

<i>Code</i>	<i>Description</i>
Irr_Evaporation	irrelevant discussion / reference to evaporation or an aspect of the evaporative process, heat, or to strong sun
Irr_Plants absorb water	understands plants absorb water but does not differentiate xeric / water-wise plants, or statement is vague in terms of whether absorbing water is good or bad – Don't count if reusing water to water plants, as part of the solution.
Innacc_Manmade_bad	Inaccurately claims manmade = impervious and / or natural = pervious. Only code for this when very clear.
Inacc_Pollution	any mention of pollution preventing rainwater from being absorbed - inaccurate concept
Inacc_Recharge_is_bad	inaccurately perceives water being absorbed as a waste of water
Inacc_Too_Many_Plants	inaccurately perceives adding plants will decrease absorption
Inacc_Dry_Ground	inaccurately claims that the ground simply being just dry prevents water from being absorbed
Inacc_Dirt_Field	inaccurately suggests dirt scape to enable water absorption

Table 3.4. *Refined coding scheme for research question two.* Coding scheme is used as follows: A score of 1 indicates the code is present; score of 0 = code is not present; score of 999 = ambiguous.

Code	Description
Acc_Impervious surfaces	Accurately describes / refers to impervious / impermeable / hard packed / solid rocky surfaces that prevent water from recharging the aquifer. Can mention a surface like a road, cement, sidewalk or similar. Can also include reference to buildings that would be impervious.
Acc_Recharge_problem	Student talks about the problem of an impervious barrier preventing water sinking in / absorbing / soaking in / recharging the aquifer; the word "aquifer" need not be mentioned. Does not need to be an accurate statement as long as response includes idea / process of water sinking into ground. Must be connected to the idea of what prevents water from being absorbed into the ground.
Acc_Slanted_problem	Slanted or steep surfaces, including hills, roofs, sidewalks. Not as a solution.
Acc_Non_Water-Wise_Plants	Accurate description / mention of plants that are not drought tolerant or use too much water for the arid Southwest.
Acc_Use_less_water	Response suggests watering less / using less water as a solution. Do NOT count if less water use is an outcome or justification. This is about lowering water usage to solve the problem.
Acc_Xeriscaping	Accurately describes / mentions the terms: xeriscape, drought resistant plants, low water use plants.
Acc_Catchment	Describes some way to catch water or store water.
Acc_Rerouting	Accurately describes methods / ideas to (re)route water.
Acc_Reuse	Describes later (re)use or having control over when it is used. They may or may not describe cleaning or filtering water. Can include using water for humans or for plants, but does not include recharging the aquifer.
Acc_Recharge_solution	Offered as (part of) a solution. Accurately describes / mentions some version of a permeable surface, i.e. paver stones / or pebbly / crushed rocky surfaces to allow water absorption. Okay if it is a grassy field, or other non-ideal solution, as long as it is connected to the idea of recharging / soaking in / returning to the aquifer.

<i>Code</i>	<i>Description</i>
Acc_Runoff	Includes word run-off or runoff.
Acc_Drought	Includes word drought.

I then applied this refined coding scheme. Two approaches support the validity and reliability of the coding. First, I followed guidelines set by Hammer and Berland (2014) that state that disagreements between coders should be discussed. I brought ambiguously-coded items to my research group, and we discussed these items to develop a consensus about them. I coded using a numeral 1 to indicate the code was present and a numeral 0 to indicate its absence.

I calculated a total score for each test by summing all normative codes. I omitted any students who did not have both a pre-test and post-test response, resulting in a sample size of 33. I calculated the mean and standard deviation for both the pre and post-test. I also calculated descriptive statistics for each code. I used SPSS (version 23) to conduct a paired samples t-test. I hypothesized that the post-test scores would be higher than the pre-test scores.

Limitations

Because many students believed they would not receive course credit, it is possible that they did not engage with the assessments seriously. Thus, the post-test may not have accurately measured the learning that occurred.

Results

Results Related to Research Question 1

Research question one investigated students' preconceptions about specific watershed management topics in an arid, urban Southwest desert environment. Based on analysis of the pre-test, students held both normative and non-normative preconceptions. I present my findings about these preconceptions below.

I coded non-normative ideas in the pre-test answers (Table 4.1). The most unexpected non-normative preconception that I found in the pre-test answers was the belief that pollution prevented water from recharging our aquifer. Other preconceptions included ideas that were irrelevant, such as evaporation. Students described plants absorbing all the water, preventing infiltration. Some students did not distinguish between non-native species and xeric plants.

Table 4.1. *Non-normative preconceptions identified*

<i>Code</i>	<i>Description</i>	<i>Sample responses</i>
Irr_Plants absorb water	understands plants absorb water but does not differentiate xeric / waterwise plants, or statement is vague in terms of whether absorbing water is good or bad	There are many things that prevent rainwater from being absorbed into the ground, but the major factors are for example: excess of paved areas and areas without vegetation to absorb the water.
Innacc_Manmade_bad	Inaccurately claims man-made = impervious and/or natural = pervious	Man-made materials can prevent rainwater from being absorbed.
Inacc_Pollution	any mention of pollution preventing rainwater from being absorbed - inaccurate concept	Contaminants and other debris lay over the ground and do not allow full absorption of the water
Inacc_Recharge_is_bad	inaccurately perceives water being absorbed as a waste of water	Arroyos, drains, and barriers could prevent rainwater from being

<i>Code</i>	<i>Description</i>	<i>Sample responses</i>
		absorbed into the ground. These lead into the rainwater into filters that could clean the rainwater for Albuquerque. UNM could build a filter or some sort of device that contains the rain as it falls. These filters could be placed around campus. This would be a good solution because rainwater would not being wasted.
Inacc_Too_Many_Plants	inaccurately perceives adding plants will decrease absorption	because plants suck up water, so with less plates there is more water.
Inacc_Dry_Ground	inaccurately claims that the ground simply being just dry prevents water from being absorbed	if the ground is too dry it will not absorb water
Inacc_Dirt_Field	inaccurately suggests dirt scape to enable water absorption	make a big field with nothing but soil so the rain can absorb into the ground to produce more groundwater.

In Figure 4.1, the percentages of the non-normative codes are shown for the pre-test. Eighteen percent of the students included the idea that pollution prevented water from recharging our aquifer. Seventeen percent of students included the idea that evaporation prevented water from recharging the aquifer. Fourteen percent of students described plants absorbing all the water, preventing infiltration.

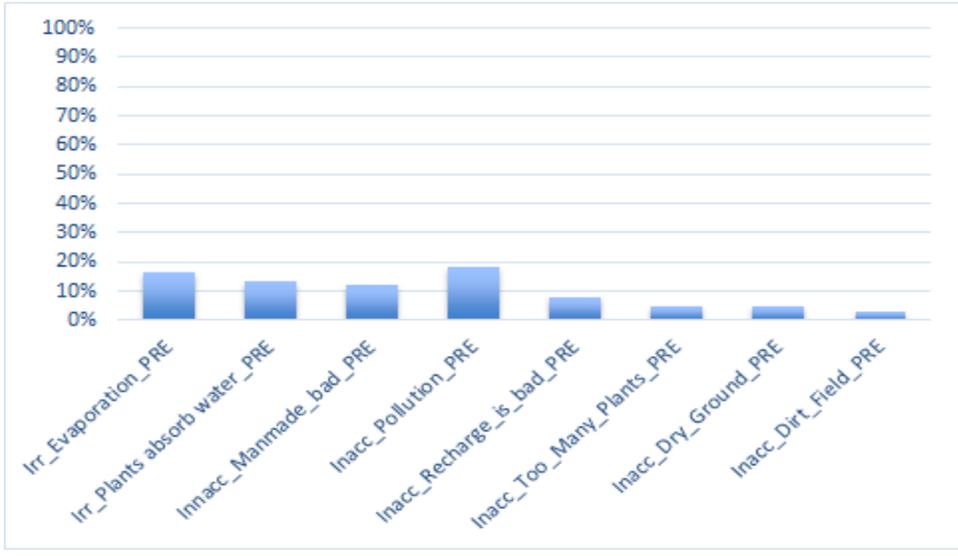


Figure 4.1. Percent of students' responses coded as containing each non-normative idea

The coding scheme used to identify normative ideas present in students' pre-test answers is displayed in Table 4.2. The table includes samples of students' responses. Figure 4.2 shows the percentages responses coded as containing normative codes. Most students included the idea that recharging the aquifer is needed and that catchment systems could be a solution. Slightly more than half of the students mentioned impervious surfaces as a barrier to aquifer recharge. Few (less than 5%) students mentioned xeriscaping as a solution, slanted surfaces increasing runoff, non-water-wise plants, or that drought is a problem.

Table 4.2. Normative preconceptions identified

Code	Description	Sample responses
Acc_Impervious surfaces	Accurately describes / refers to impervious / impermeable / hard packed / solid rocky surfaces that prevent water from recharging the aquifer. Can mention a surface like a road, cement, sidewalk or similar. Can also include reference to buildings that would be impervious.	Also water can't be absorbed through asphalt and I think it is hard in big cities for water to be absorbed into the ground.
Acc_Recharge_problem	Student talks about the problem of an impervious barrier preventing water sinking in / absorbing / soaking in / recharging the aquifer; the word "aquifer" need not be mentioned. Does not need to be an accurate statement as long as response includes idea / process of water sinking into ground. Must be connected to the idea of what prevents water from being absorbed into the ground.	There are many things that prevent rainwater from being absorbed into the ground, but the major factors are for example: excess of paved areas
Acc_Slanted_problem	Slanted or steep surfaces, including hills, roofs, sidewalks. Not as a solution.	When I think of reasons why rainwater doesn't absorbed directly into the ground, I think of how water right away runs to the lowest part of the city.
Acc_Non_Water-Wise_Plants	Accurate description / mention of plants that are not drought tolerant or use too much water for the arid Southwest.	Also, plants that are not suitable for certain environments may use up water before it can be absorbed.
Acc_Use_less_water	Response suggests watering less / using less water as a solution. Do NOT count if less water use is an outcome or justification. This is about lowering water usage to solve the problem.	not water when it rains frequently so the rainwater is used more effectively.

<i>Code</i>	<i>Description</i>	<i>Sample responses</i>
Acc_Xeriscaping	Accurately describes / mentions the terms: xeriscape, drought resistant plants, low water use plants.	One being green planting of native plant species.
Acc_Catchment	Describes some way to catch water or store water.	The storage system is used to hold the rainwater for future use; a barrel, a cistern or a tank is the items that hold the rainwater.
Acc_Rerouting	Accurately describes methods / ideas to (re)route water.	I think that this will be a good solution in wasting less rainwater cause the drainage system can lead to places that are good for absorbing rainwater into the groundwater.
Acc_Reuse	Describes later (re)use or having control over when it is used. They may or may not describe cleaning or filtering water. Can include using water for humans or for plants, but does not include recharging the aquifer.	could set up rainwater barrels or a pipe system that would use the rain water to water the plants and grass at night when less of the water will evaporate.
Acc_Recharge_solution	Offered as (part of) a solution. Accurately describes / mentions some version of a permeable surface, i.e. paver stones / or pebbly / crushed rocky surfaces to allow water absorption. It is okay if it is a grassy field, or other non-ideal solution, as long as it is connected to the idea of recharging / soaking in / returning to the aquifer.	If less of the campus is covered in concrete and instead covered with bricks or something like that then more water should make it down into the ground.
Acc_Runoff	Includes word run-off or runoff	we could use large barrels to collect water from rain gutters and other water runoffs
Acc_Drought	Includes word drought	We save the collected water for times of drought

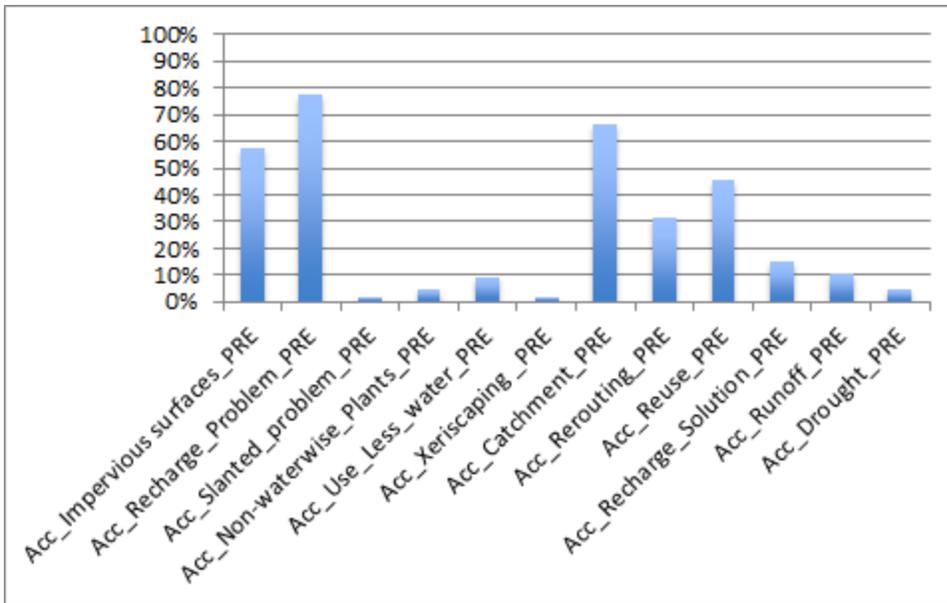


Figure 4.2. Percent of students' responses coded as containing each normative idea

On the pre-test, over 50% of students mentioned one of the fundamental challenges of urban aquifer recharge: impermeable barriers such as roads and sidewalks. Over 75 percent of students mentioned recharge in some manner. Over 60% of students mentioned some form of water catchment as a solution. Thus, over half of the students brought some important normative preconceptions coming to this learning experience.

However, many students also held non-normative preconceptions, some of which have not been noted in the research literature previously. For example, 18% of the students described pollution as a barrier to recharge. These students explained that some form of pollution, trash debris, oil residues or chemical contaminants prevented water from infiltrating the ground and recharging our aquifer. 17% of the students mentioned evaporation, an idea that is irrelevant because evaporation cannot be managed out of a water budget within a watershed management plan. High rates of evaporation are a natural process in an arid climate. However, effective watershed management techniques in arid, urban environments can help reduce evaporative losses.

Results Related to Research Question 2

The second research question investigated how and if an experiential learning watershed makeover activity might help students understand specific watershed management topics in an arid, urban, Southwest desert environment. There was minor growth in students' conceptual understanding between the pre-test ($M = 3.12$; $SE = .25$) and post-test ($M = 3.82$; $SE = .28$), and though minor, this growth was significant, ($t(33) = -2.25$, $p < .05$), with a small to medium effect size, $d: -0.393$.

By looking at the frequencies of specific codes, we can see that growth occurred in certain ideas from the pre-test to post-test (Figure 4.3).

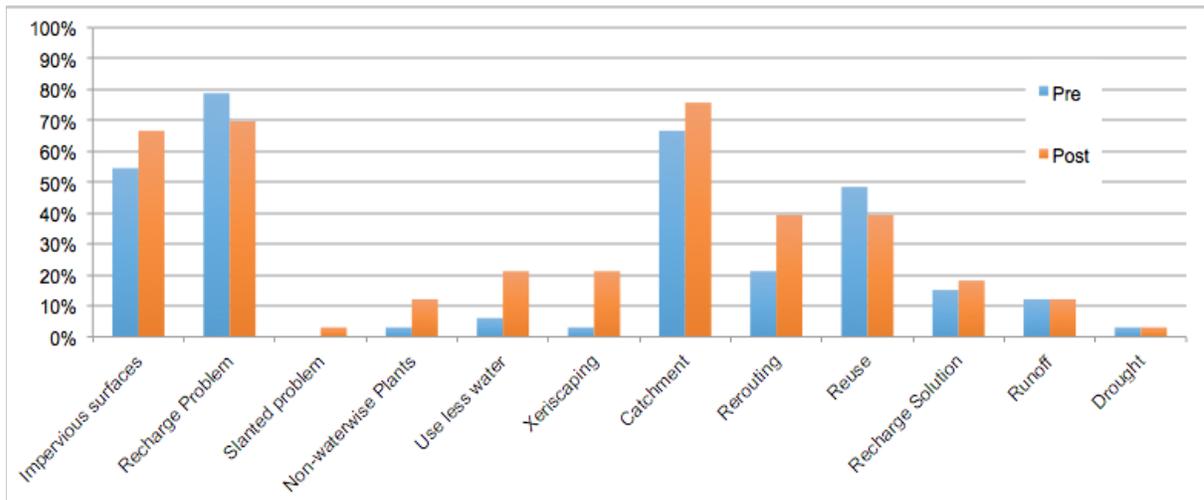


Figure 4.3. Percent of student responses containing normative ideas on the pre-test and post-test

For instance, 21% of students mentioned that rerouting water can provide a solution on the pre-test, whereas 39% mentioned it on the post-test. Fifty-five percent of students mentioned impervious surfaces as a problem on the pre-test, whereas 67% did so on the post-test. Six percent of students suggested using less water overall on the pretest, whereas 21% did so on the post-test. Sixty-seven percent of students mentioned catchment systems as a solution on the pre-test, whereas 76% did so on the post-test. Only three percent of

students mentioned xeriscaping as a solution on the pre-test, whereas 21% did so on the post test. There was no change in the percent of students bringing up drought or runoff. Fewer students mentioned recharging the aquifer as a problem on the post-test.

Many students brought the ideas of impervious surfaces and catchment systems with them to this experiential learning activity. There were opportunities for students who did not know about these ideas to learn about them from their peers. Students had opportunities to choose specific topics to investigate, and this is reflected in the growth in specific ideas, such as xeriscaping and using less water.

Discussion

I choose to use the term preconception to describe students' ideas as it avoids implying a cognitive deficit in the learner. Preconception refers to students' previously held understandings (Clement, 1993). Other terms like misconception (Helm, 1980) and naive conception (Maskiewicz and Lineback, 2013) suggest a cognitive deficit.

There is little prior research on students' preconceptions about water resources. One study investigated students' preconceptions of the safety of tap water, finding students believed that bottled water is safer than tap water (Saylor, Prokopy and Amberg, 2011). Another study found that students believed that drinking water was treated for safe human consumption at wastewater treatment facilities (rather than at water utility treatment facilities, Fremerey et al., 2014). More is known about student preconceptions in the environmental sciences, especially in the areas of pollution and contamination. For instance, one study found that students held non-normative preconceptions about how pollutants interact chemically within environments (Rodriguez, Kohen and Delval, 2015). Another study surveying Taiwanese students focused on human-nature relationships, finding that students' beliefs spanned a spectrum of worldviews from humans are a part of nature, humans are the dominator in nature, to humans must steward natural resources to nurture sustainability (Liu & Lin, 2014). But because so little has been researched in the scope of student preconceptions in water resources, my study contributes new information about student preconceptions regarding water resources. My analysis showed that around 20% of students in the study possessed the preconception that pollution prevents water from recharging the aquifer. Another unexpected preconception that appeared in the data, in 12% of pre-test answers, was the notion that anything "man-made" is impenetrable by water, or that all "man-made" surfaces are impervious.

According to past research on student preconceptions, these beliefs can be held quite firmly and can prevent new learning from occurring. Having a detailed understanding of what those preconceptions are can serve as a starting point to initiate conceptual change (Fremerey et al., 2014), in part because this approach can increase students' interest in the topic (Franke & Bogner, 2013). One of the most promising approaches to conceptual change is experiential learning, or learning by doing. Such approaches are deliberately designed experiences that begin with student ideas and include reflection (Dewey, 1938; Mayhew and Edwards, 1936; Reeves, T., Reeves, P., & McKenney, 2014).

The experience I designed included a carefully planned experience involving a sequence of small group discussion to elicit students' ideas, hands-on discovery learning in the field, further group research, direct instruction, and a reflection point in the form of a post-test. This sequence is backed by past research on learning. Many studies underscore the importance of beginning instruction by first eliciting students' ideas (Fremerey et al., 2014; Linn, 2006; Linn, Bell & Davis, 2004; Martin, Pierson, Rivale, Vye, Bransford & Diller, 2007). I encouraged students to take pictures of the Word Wall of Water Wonk vocabulary so they could easily refer to it on their watershed walk. I also encouraged students to use their smartphones to document observations with phone cameras and to access the internet with questions in the field.

Following the experiential portion of the learning experience, students presented to one another, a form of direct instruction. Instead of the facilitator lecturing, the students lectured each other on their newly acquired learning, again allowing for peer-to-peer learning. This sequencing of direct instruction *following* an activity is also supported by research (Schwartz & Bransford, 1998). Lastly, the post-test provided a specific reflection point, allowing the student to further process newly acquired knowledge.

Educators have advocated for experiential learning in water resources to support learning (Campana, 2010; Missingham, 2013, Camkin and Neto, 2013; Ballantyne and Packer, 2009). For example, in the capstone Field Methods course in the UNM Water Resources Program, students took part in engineering and constructing a sanitary water delivery system for an economically-challenged village in Honduras (Campana, 2010). My study builds on this example by offering another alternative to traditional teaching methods—an introductory water resources experiential learning experience of brief duration, making it a feasible activity to include in many contexts.

Like Camkin and Neto (2013), my study shows that through participation and co-learning, in which the instructor promotes student sharing of experiences about their classroom's subwatershed, students can learn about watershed health. My study builds on Welker et al.'s (2010) research on how students on a college campus, who may have little prior knowledge about watershed management in an arid environment, learn about their immediate campus watershed. Previous work showed that learners can make water-landscape connections about their local subwatershed and local stormwater management (Giacalone et al, 2010). My study builds on this by measuring learners' preconceptions about the local subwatershed within their immediate school campus, and how a learning experience might change that understanding. By designing an investigation at the local level, I believed greater understanding could be fostered because it connected to their everyday experience. This could later be scaled up to the regional scale, the Middle Rio Grande Basin.

Based on my findings, experiential learning is a promising approach to learning. Few previous studies of experiential learning in water resources have assessed the impacts on learning. My study assessed students' conceptual change related to water resources. Even though only minor growth was detected overall, I did find larger increases for specific ideas,

such as impervious surfaces as a problem, and xeriscaping, using less water, rerouting water, and using catchment systems as solutions. Given the limited duration of the learning experience (less than a week) this growth can be attributed to the experiential learning approach.

Conclusions

In research question one, I investigated students' preconceptions about specific topics related to watershed management in an arid, urban, Southwest desert environment. I found students held both normative and non-normative preconceptions. In particular, I found most students described normative ideas, but many also included unexpected non-normative ideas, such as that plants prevent water from recharging the aquifer, that pollution and trash prevent water from recharging the aquifer, and that man-made surfaces prevent water from recharging the aquifer.

In research question two, I investigated how and if an experiential learning watershed makeover activity might help students understand watershed management in an arid, urban, Southwest desert environment. I found there was minor growth in students' conceptual understanding between the pre-test and post-test, and this change was significant ($t(33) = -2.25, p < .05$), with a small to medium effect size, $d: -0.393$. I also found larger growth of specific ideas: impervious surfaces as a problem, and xeriscaping, using less water, rerouting water, and using catchment systems as solutions. The growth can be attributed to my experiential learning activity, suggesting that there is promise in using experiential learning in water resources education.

Limitations

There are several reasons why my experiential learning activity did not produce significant growth. My sample size was small, with 73 pre-test responses but only 36 post-test responses, and only 33 responses to both pre-test and post-test. This smaller number of post-test returns limits our understanding of actual growth achieved by the entire sample size. This was my first attempt at designing such a brief, experiential learning intervention. Although I employed research-supported methods for successful experiential learning, there

may have been issues with the sequencing of learning events. It is possible instructions were not coherent enough to be universally understood.

Additionally the study site chosen within the arid Southwest has a highly unique climate. In addition to the specific climate of this region, it has high altitude geography. These unique climate and geography factors, which affect watershed management approaches, may be foreign to some student participants.

Also, there was no control group, to compare results against. Comparing results against a direct instruction group of student participants could elicit more telling conclusions.

Implications

For Instruction and Curricular Design

The findings of my study suggest that implementing a brief experiential learning intervention on water resources can change students' preconceptions. My learning intervention produced minor growth. This would imply that refining of the overall learning design could result in greater growth. This refinement could include improving the clarity of the instructions and asking questions that better prompt students to explore narrower topics related to their preconceptions.

One way to improve the design would have been to have provided written instructions about how to conduct the watershed walk and to have shortened the time prior to beginning the watershed walk. I could have then used the last 15 minutes of class to discuss their observations and then to provide specific directions on their presentations.

This study was conducted with undergraduate students in an introductory environmental science class. Based on the findings related to the non-normative preconceptions they held, there is a need for increased water resources education at the high school level. Such instruction could target the non-normative preconceptions I identified. The idea that pollution prevents water infiltration could be addressed by providing instruction about the actual effects of pollution. The idea that "man-made is bad" in general and that man-made surfaces are always impervious to water could be addressed to clarify that some human-designed objects can be very effective watershed management tools.

Another way to improve the experiential learning intervention would be to increase the amount of instructional time. With more time, students could have conducted more research regarding watershed management approaches. I could have provided feedback to students, and they could have revised their work based on that feedback. I could have requested written reflections about how their ideas had changed, supporting metacognitive

processing. With more time, additional activities could be added to target areas that showed no growth.

For instance, I found that there was no change in the percent of students bringing up drought from pre- to post-test. This finding is not surprising because the activity did not focus students on causes of water scarcity. To better focus students on drought, adding a focus on climate change might help. For instance, Internet searches about climate change and the southwest turn up results related to drought predictions. Also, students could have worked with an online drought monitor, such as NOAA Palmer Drought Severity Index, or the National Drought Mitigation Center. They could have been guided to include such data on their posters with the prompt, “How does drought play a role in our local watershed?” and by giving them access to a few online tools to choose from.

I found that there was no change in the percent of students bringing up runoff from pre- to post-test. Similar to the idea for incorporating drought, students could have been directed to online resources that provide stream gauge data for the Rio Grande. However, students would have needed a tutorial to help them understand how to read hydrographs; thus, adding this would take more time. A tutorial would include what a hydrograph peak is, and students could look at the past year of data. This would allow them to see the monsoon season impacts and this could help them understand runoff.

Fewer students mentioned barriers to recharging the aquifer as a problem on the post-test. This might simply be due to their perception that the post-test was not worth class credit. However, it might also be due to students taking up the idea that water catchment is important, leading them to think that water should not enter the ground. Students could investigate where water comes from and where it goes, and make a poster with this information to post at campus drinking fountains. A simple activity could be added to have

students investigate how much water was once thought to be in our aquifer, and how much less is in the aquifer now.

However, the limited time is realistic in the climate of teaching today. And there was still significant growth, although minor, shown by students. A brief intervention like mine can easily be included in a broad introductory level course to introduce ideas about watershed management. Finally, the intervention was inspired by project based learning. As such, the activity I designed could also be used to introduce a project on water resources.

For Research

Future research is needed to study experiential learning failures and successes when utilized in water resources education efforts. Future studies should involve comparing the results of an experiential learning intervention against a direct instructional strategy. Future work could look at the differences produced with variations in sequencing of learning events within a brief experiential learning intervention. It would be helpful to compare results from studies carried out in highly dissimilar climatic and geographical regions, in both urban and rural areas.

Appendix A

The instructions articulated in the PowerPoint presentation are as follows:

Work in your groups

You will need in your group:

- Everyone: pen & paper data taking – which you'll do on 1 of your hard copy maps
- 1 person: voice recorder (using ph option for a voice memo) - optional
- 1 person: picture documenter of observations / evidence – highly recommended for your eventual PowerPoint

I WILL HAND OUT 2 MAPS FOR EACH PERSON (1 on which to indicate initial areas of water waste, the 2nd will be your water conservation 'makeover' map)

- make voice recordings of what you see – optional
- take pictures of key observations / areas of concern

Graphically depict features representing how you can conserve water / prevent runoff on hard copy (b&w paper map)

- Provide at least 5 new water conservation ideas that are realistic / feasible designs
- Provide a map key for your features – using color and/or symbol coding
- Provide directional arrow for North orientation

You will turn in first hard copy map with your initial observations

You will turn in second hard copy map with your 5 new water conservation ideas graphically depicted

See full PowerPoint slides in Appendix B

Word Wall of Water Wonk:

- watershed / basin
- storm water drainage features: storm drains, ditches, arroyos, canals, conveyance channels, acequias
- surface permeability
- infiltration, percolate
- runoff, slope, topography, erosion
- berms, swales
- aquifer / groundwater
- drought tolerant plants, native species (i.e. apache plume, chamisa), low water use plants / trees (i.e. western catalpa tree, black pine tree) non-native species, invasive species, exotic species
- drip irrigation, spray irrigation
- rooftop rainwater harvesting, rain barrels, rain chains, French drains
- green infrastructure

Other resources provided:

- Added final slide of specific xeriscaping information (epa.gov) in PowerPoint made available on course website directly after 1st class period, accessible through duration of Water Working workshop - so that students who took time to revisit PowerPoint would be rewarded with this additional information provided them

Water Wonking

For today:

- ▶ Get into groups of 3-5
- ▶ Make sure one person in your group has a smart phone with a camera
- ▶ You will work with this group for a Water Wonk project due Th, 10.23.14

Why should we care about water in the arid Southwest?

► Discuss

Watershed walk - assessing areas of water waste on your campus

- As soon as I've given you instructions and provided you with necessary material, you can proceed on your watershed walk & assessment

Watershed Walk within proximity to our classroom building :

- ▶ Work in your groups
- ▶ You will need in your group:
- ▶ Everyone: pen & paper data taking - which you'll do on 1 of your hard copy maps
- ▶ 1 person: voice recorder (using ph option for a voice memo) - optional
- ▶ 1 person: picture documenter of observations/evidence - highly recommended for your eventual Powerpoint

- ▶ I WILL HAND OUT 2 MAPS FOR EACH PERSON (1 on which to indicate initial areas of water waste, the 2nd will be your water conservation 'make-over' map)
- ▶ make voice recordings of what you see - optional
- ▶ take pictures of key observations/areas of concern

Instructions for Th, 10.23.14

- ▶ Graphically depict features representing how you can conserve water/prevent run-off on hard copy (paper, b&w map)
- ▶ Provide at least **5 new water conservation ideas** that are realistic/feasible designs
- ▶ Provide a map key for your features - using color and/or symbol coding
- ▶ Provide directional arrow for North orientation

- ▶ You will turn in first hard copy map with your initial observations
- ▶ You will turn in second hard copy map with your **5 new water conservation ideas** graphically depicted

Instructions for Th, 10.23.14

5-10 min max mini-presentations

- ▶ Graphically depict features representing how you can conserve water/prevent run-off (Powerpoint is preferred mode of presenting)
- ▶ Provide at least 5 new water conservation ideas that are realistic/feasible designs
- ▶ Provide a map key for your features - using color and/or symbol coding
- ▶ Provide directional arrow for North orientation
- ▶ Provide group member names (for credit)
- ▶ ** Choose 3 TOP recommendations that you think will allow for the most effective water conservation on our campus nearby our classroom Hall watershed AND TELL US WHY THEY ARE YOUR TOP 3 PICKS
- ▶ Choose 1 (or more) spokesperson(s) in your group to present (5-10 min maximum time allowed) your TOP recommendation

Before you head out to your watershed walk...

- ▶ Grab a picture of the Wall of Water Wonk (some water wonk terminology)
 - ▶ Think about what you might know about these words on your walk
 - ▶ Discuss water wonk words with your group members
 - ▶ Ask each other questions about these water wonk terms if you're completely unfamiliar with them
 - ▶ It's ok if you are clueless about these terms - you can google them later for the mini-presentations

For today:

- ▶ **Each student** should be handing in BOTH your maps on front table
- ▶ **As a group**, 5-10 min, NOT fancy, PowerPoint - just a basic offering of your TOP 3 WATER WISE RECOMMENDATIONS
- ▶ We will start with volunteers - If I don't get volunteers, I'll volunteer you and your group

Finally, by Sun, midnight, 10.26.14...

- ▶ **Take survey again, link given on course website**
 - ▶ It will look identical to the first survey you took, but now you may have some new ideas to add
- ▶ **Upload your PowerPoint to course website** (assign created by your instructor for uploading)

- ▶ **Xeriscaping**
- ▶ Xeriscaping is a systematic method of promoting water conservation in landscaped areas. Although xeriscaping is mostly used in arid regions, its principles can be used in any region to help conserve water. Here are seven basic xeriscaping principles:
- ▶ **Planning and design.** Provides direction and guidance, mapping your water and energy conservation strategies, both of which will be dependent upon your regional climate and microclimate.
- ▶ **Selecting and zoning plants appropriately.** Bases your plant selections and locations on those that will flourish in your regional climate and microclimate. Always group plants with similar water needs together.
- ▶ **Limiting turf areas.** Reduces the use of bluegrass turf, which usually requires a lot of supplemental watering. Consider substituting a turf grass that uses less water than bluegrass.
- ▶ **Improving the soil.** Enables soil to better absorb water and to encourage deeper roots.
- ▶ **Irrigating efficiently.** Encourages using the irrigation method that waters plants in each area most efficiently.
- ▶ **Using mulches.** Keeps plant roots cool, minimizes evaporation, prevents soil from crusting, and reduces weed growth.
- ▶ **Maintaining the landscape.** Keeps plants healthy through weeding, pruning, fertilizing, and controlling pests.

Before you head out to your watershed walk...

- ▶ Grab a picture of the Wall of Water Wonk (some water wonk terminology)
 - ▶ Think about what you might know about these words on your walk
 - ▶ Discuss water wonk words with your group members
 - ▶ Ask each other questions about these water wonk terms if you're completely unfamiliar with them
 - ▶ It's ok if you are clueless about these terms - you can google them later for the mini-presentations

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