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# Changing Student Conceptions of Arid, Urban Watershed Management

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**Abstract:** Despite the central importance of water, few students have the opportunity to study water resources management in secondary education. Even in tertiary education—unless they major in water resources or a closely related field—they are likely to receive only a week or two of instruction about water resources in introductory science courses. Typical instruction in such courses is textbook-based, with the course instructor lecturing on a broad range of topics. Complicating this, little is known about student preconceptions, which may interfere with—or be used to support—learning. We sought to identify preconceptions in an introductory environmental science course at an urban, research (R1) university in the arid Southwest of the United States. We used a pre/post design to assess student preconceptions about their urban campus watershed and designed a brief, experiential learning exercise. While experiential learning is common in water resources management programs, it is less common in introductory courses. We developed a coding scheme to analyze the pre- and post-test responses; results showed students held normative and non-normative preconceptions. There was significant growth in students' conceptual understanding between the pre-test and post-test, ($t(33) = -2.25$, $p < .05$), 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, even in an introductory course. Understanding students' preconceptions of arid, urban watersheds can assist in how to better design curriculum. Such improvements in curricular design can empower students to make better decisions about urban watersheds.

**Keywords:** *experiential learning, water resources education, introductory university courses, Southwestern U.S.*

Water resources management is complex (Loucks 2008), especially in the western U.S. (Willardson 2005; Pease 2010). Adding to the natural water scarcity in the arid Southwest, urban centers continue to see population growth, increasing both water consumption and energy demand; energy production requires water, thus compounding the stressors on water resources (Ortiz et al. 2007; Garfin et al. 2013; Guldan et al. 2013). Another complication of Southwest watersheds is the North American monsoon, during which watersheds receive up to 50% of their total annual rainfall (Sheppard et al. 2002; Garfin et al. 2013). Monsoonal rains can bring about flash flooding events due to the impervious surfaces found in desert landscapes and urban environments (Garfin et al. 2013). Understanding water conservation in the watersheds of the urban Southwest has never been more urgent, given climate change predictions which suggest the Southwest will face increasingly severe droughts and challenges related to reduced water resources for agriculture (Elias et al. 2016).

Many approaches to watershed management include involving stakeholders and educating citizens to make informed choices (e.g., using water wise plants and rain barrels) (Webler and Tuler 2001; Sabatier et al. 2005; Genskow and Born 2006). Such approaches can provide important place-based perspectives and can make barriers to effective management visible, but involving the public can be a complex and fraught process. Having an informed citizenry could aid in water resource management efforts (Gunckel et al. 2012), yet there are limited opportunities for students to learn about water resource management in their schooling if they do not choose to pursue a degree in the discipline. Even introductory university science courses that provide such opportunities, often do so through a few lectures, as their focus is typically to provide students with a broad foundation across environmental or geological science.

Our purpose in this paper was twofold. First, we aimed to identify the preconceptions held by students in an introductory environmental science class about specific watershed management topics. There have been calls for more research in this area (Dickerson et al. 2007; Keinonen et al. 2016), in part because comparatively little research has investigated students' preconceptions about watershed management, especially in urban, Southwest desert environments. While there is research reporting students' level of agreement with factual statements about water safety and access (Mahler and Barber 2015), this is a *drop in the bucket* compared to the depth and breadth of research investigating students' preconceptions about other science topics (e.g., hundreds of studies document students' preconceptions of topics such as climate change, force, and photosynthesis). Because we do not know much about student preconceptions in watershed management, it can be challenging to design effective instruction that can build on their preexisting ideas, as suggested by research on learning (e.g., Bransford et al. 2000).

Second, we sought to understand how a brief experiential learning activity could help these students learn about watershed management topics. Specifically, we focused on aquifer recharge, barriers to water infiltration, and actions that organizations and citizens can take to enhance water infiltration. In response to calls for further research on instructional approaches to teaching about water-related environmental science (Dickerson et al. 2007), we designed an experiential learning activity based upon research about how people learn. In particular, we focused on student preconceptions and how preconceptions can impair or propel learning outcomes. Additionally, we explored experiential learning, including ways it has been used in water resources education and closely related areas, such as sustainability and environmental education.

## Misconceptions, alternative conceptions, preconceptions?

Researchers have debated the use of the term *misconception*, which some argue shows a deficit perspective (Hogan and Maglienti 2001; Maskiewicz and Lineback 2013), suggesting that the student is flawed in his/her ability to understand, thus placing blame on the learner (Leonard et al. 2014), rather than critiquing the instructional approach. Researchers like ourselves who take a constructivist stance (Piaget 1966) usually avoid the term misconception (Leonard et al. 2014); according to constructivism, there is no deficit or flawed knowledge. Rather, students' knowledge is constantly being shaped and reshaped by experiences, both in and out of school settings. As an example, consider the layperson's explanation of the cause of the seasons as "distance from the sun." Many people hold the preconception that summer heat is due to closer proximity to the sun. This notion is assembled from everyday experience; when you are closer to a heat source such as a fire or radiator, you feel the heat more strongly. But this notion is also based on formal schooling; commonly, textbooks show perspective drawings of the solar system, depicting it as highly elliptical and contributing to the notion that large changes in distance between the Sun and Earth occur seasonally (Schneps 1989; Atwood and Atwood 1997; Tsai and Chang 2005).

As researchers investigate the experiential and instructional roots of students' ideas, they often employ terms such as *alternative* conceptions, *naive* conceptions, and *pre*conceptions (Maskiewicz and Lineback 2013). We prefer the term preconception because this most accurately describes the experience an instructor faces: students arrive with various ideas prior to our instruction, some of which are normative, meaning they align to current scientific knowledge, and some of which are non-normative, meaning they do not align to current scientific knowledge (Clement 1993).

## Students' preconceptions of water-related environmental science

Researchers have investigated students' preconceptions about various water-related environmental science issues. High school students and college non-science majors tend to hold non-normative preconceptions about the water cycle, including evaporation and condensation (Mills 1983; Ewing and Mills 1994). Students often conceptualize groundwater as being stored in underground lakes or tanks, or traveling through pipes and underground rivers, but seldom envision it as occupying pore space in aquifers (Ben-zvi-Assarf and Orion 2005a, 2005b; Dickerson et al. 2007; Covitt et al. 2009; Unterbruner et al. 2016). They typically have confusion about systems and levels across systems, such as the relationships between water processes at the molecular scale and at the watershed scale (Covitt et al. 2009). Likewise, middle school students in one study held non-normative beliefs that pollution primarily has local and direct impacts, rather than moving through surface and subsurface waters (Rodríguez et al. 2015). Students also tend to hold non-normative preconceptions about how water moves through the environmental system (Ben-zvi-Assarf and Orion 2005a, 2005b). For instance, when drawing the hydrologic cycle, they did not depict groundwater. Adults tend to mirror these findings, as research has shown that they seldom know they live in a watershed or where their water comes from (Thompson et al. 2011).

Frameworks for water-related environmental science include both natural and human-engineered systems (Covitt et al. 2009; Gunckel et al. 2012), such as systems for cleaning and distributing water. Researchers have investigated students' preconceptions of access to safe drinking water. Stringent federal regulations apply to public municipal drinking water, whereas bottled water is under the purview of the FDA, which has enacted lower standards on the bottled water industry (Olson 1999; Fremerey et al. 2014). Yet, Saylor et al. (2011) showed that American undergraduate college students held preconceptions that bottled water is safer than municipal tap water. Likewise, Mahler and Barber (2015) showed that between 1993 and 2014, students enrolled in an introductory environmental science class tended to initially agree that bottled water is safer than tap water.

Preconceptions can be anchored quite firmly in students' minds and can prove difficult to change (Brody 1993; Fremerey et al. 2014). Without knowing students' preconceptions, instructors may waste time reteaching already well-understood topics or neglect weaker areas of comprehension. Understanding the breadth of what those preconceptions are is important for designing instruction that can facilitate conceptual change (Vosniadou et al. 2001; 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. Confronting students with their preconceptions can help students develop more scientifically accurate conceptions (Sellmann and Bogner 2012) and may increase their interest in the topic (Franke and Bogner 2013). In contrast, traditional textbook and lecture approaches to instruction appear to do little to change these conceptions (Abraham et al. 1992; Brody 1993) and such approaches may even contribute additional non-normative conceptions (Brody 1993). 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 (Sinatra 2005).

## Experiential learning supports conceptual change

Experiential learning is an approach to learning by doing (Mayhew and Edwards 1936). It is "the process whereby knowledge is created through the transformation of experience" (Kolb 2014, p. 67). However, experiential learning does not just happen simply by doing; in order for experiential learning to be effective, the experience must be deliberately designed and include a reflection point (Reeves et al. 2014) to allow students to mentally organize ideas gained through activity (Dewey 2007). Experiential learning supports authentic learning by providing value beyond the classroom and opportunities to construct knowledge through disciplinary practices (Newmann and Wehlage 1993; Knobloch 2003).

Experiential learning activities are commonly advocated for and implemented in graduate level water resources programs (McIntosh and Taylor 2013; Kulcsar et al. 2016), as well as in upper division undergraduate coursework (Campana 2010; Dennison and Oliver 2013; Missingham and McIntosh 2013). For instance, a field methods undergraduate capstone course took students to Honduras to design a sanitary water delivery system for a community (Campana 2010). In a campus-wide water resources education project, upper division undergraduate students and graduate students conducted research on the water management system on their campus, which included a wetland, raingardens, and porous asphalt (Welker et al. 2010). Experiential learning has been used in university-level short-courses to prepare future water professionals to accurately identify water resource problems and develop new solutions for global water resource management (Camkin and Neto 2013). During experiential learning projects, students work collaboratively on problems with water management professionals. Having students share their relatively novice personal experiences with water professionals allowed them to see their perspectives as valued and valuable. Likewise, experiential learning activities have been implemented in communities (Camkin and Neto 2013; Oliver and Dennison 2013) and out-of-school settings for high school students, resulting in significant learning gains (Dann and Schroeder 2015).

Experiential learning has also been used to teach elementary and middle school students about water-related environmental science. In one study of a set of units threaded throughout a year of instruction, urban elementary students learned how water moves through their local watershed (Endreny 2010); one insight from this study is that leveraging the local and therefore familiar environment can be particularly beneficial for learners with little prior knowledge of watersheds. Such approaches, especially when well designed within a problem scenario, can help learners connect the science they are learning to actions they can take (Gill et al. 2014). Well-designed experiential learning activities that include both indoor and outdoor activities have been shown to support middle school students to learn challenging, systems thinking aspects of water-related environmental science (Ben-zvi-Assarf and Orion 2005a). While these studies show the potential of experiential learning, there is little evidence to date for its benefit in early undergraduate coursework, especially in broad introductory courses.

## Methods

We sought to investigate student preconceptions and whether a brief experiential learning intervention could help students develop a more accurate understanding of watershed management in an arid, urban environment. We sought to answer two research questions: 1) What preconceptions do students attending a university in an urban setting within an arid, Southwest desert environment hold about specific watershed management topics? 2) How might an experiential learning watershed makeover activity help students understand specific watershed management topics in an arid, urban, Southwest desert environment?

The participants were undergraduate students enrolled in an introductory environmental science class at a public university in the U.S. Southwest. A total of 79 students consented to participate; 73 students completed the pre-test and 36 completed the post-test; the lower response rate on the post-test was because students believed it would not count in their grade. Study procedures occurred in two 75-minute class meetings at the beginning of a unit on water resources.

The intervention was a two-day experiential learning activity. On day one, we directed the students to discuss local and regional water issues, posing questions such as: "Why should we care about water in the arid Southwest?"; "Are we currently in a drought?"; and "Are we wasting water on our campus?". We then instructed students to take a watershed walk to assess the area around the lecture hall. We provided satellite maps of the building and instructed students to make notes of their observations on one map, and to use the other map to design a watershed makeover. We provided a list of relevant terms and encouraged students to use their smartphones to search for information while on the watershed walk. On day two, student groups gave five-minute presentations of their watershed assessment. This assessment included their concerns and how they would improve the watershed.

Students completed a pre-test and post-test that comprised three 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? We chose to use open-ended questions because previous research has demonstrated that students can sometimes select accurate answers on multiple choice tests, yet cannot explain or depict fundamental water-related environmental science concepts (K.L. Schwartz et al. 2011).

We used a common qualitative analysis technique to analyze student responses on the pre/post-test. We developed a coding scheme inductively (Strauss and Corbin 1998), then added codes based on an expert answer. We used an open coding process that established the credibility of our coding scheme using referential adequacy (Lincoln and Guba 1985), meaning we iteratively developed it with a subset of data, then applied it to the remainder. As we developed the coding scheme, we created an audit trail to track our decisions and versions in research memos and notes. We iteratively reviewed the coding scheme, combining codes that were conceptually similar, dividing complex codes to make them more reliable, and refining definitions to ensure the codes required little inference. We reviewed the scheme with our lab (which included multiple members not part of this project), triangulating across members, discussing any disagreements (Hammer and Berland 2014) and refined the coding scheme until two coders could reliably apply it. To enhance credibility, we held frequent debriefing sessions and opened our process to scrutiny by members of our research lab on multiple occasions throughout our research process (Shenton 2004). We conducted a dependability audit to ensure the data were accurate (checking for duplicate responses; checking timestamps to ensure data were from the expected timeframes; maintaining a raw data file and confirming that analyzed data conformed to raw data). With our research lab, we conducted a confirmability audit, in which we reviewed our research memos and notes where we documented our decisions, interpretations, and choices, finding that our process was understandable and logical to those outside the project.

We used a numeral 1 to indicate the code was present and a numeral 0 to indicate its absence (Table 1). To reduce bias, we coded student responses blind to timing (pre or post). We calculated a total score for each student by summing all normative codes. We omitted any students who did not have both a pre- and post-test response, resulting in a sample size of 33. We calculated the mean and standard deviation for both the pre and post-test. We also calculated descriptive statistics for each code. We used SPSS (version 23) to conduct a paired samples t-test. We hypothesized that the post-test scores would be higher than the pre-test scores.

## Results

### Student preconceptions

We investigated students' preconceptions about watershed management topics. Based on analysis of the pre-test, students held irrelevant, non-normative, and normative preconceptions (Table 2). Most students included multiple normative ideas. Slightly more than half of the students mentioned impervious surfaces as a barrier to aquifer recharge. Over 75% 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 to this learning experience. However, few students mentioned that drought, growing non-waterwise plants, and slanted surfaces contribute to the problem.

Many students also held non-normative preconceptions, some of which had 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. Seventeen percent 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. Some students described plants absorbing all the water, preventing infiltration.

### Conceptual change

We also investigated whether a brief experiential learning activity could change students'

**Table 1.** Coding scheme included irrelevant, non-normative, and normative ideas.

| ***Codes tied to irrelevant ideas*** | ***Description of student response*** |
|---|---|
| Evaporation | Evaporation or an aspect of the evaporative process, heat, or too strong sun. |
| Plants absorb water | Plants absorb water but response 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 to water plants as a proposed solution. |
| ***Codes tied to non-normative ideas*** | ***Description of student response*** |
| Manmade is bad | Claims that manmade things are impervious and/or that natural surfaces are pervious. |
| Pollution | Pollution prevents rainwater from being absorbed. |
| Recharge is bad | Perception that any water being absorbed is a waste of water. |
| Too many plants | Adding plants will decrease absorption. |
| Dry ground | Dry ground prevents water from being absorbed. |
| Dirt field | A dirt scape will enable water absorption. |
| ***Codes tied to normative ideas*** | ***Description of student response*** |
| Impervious surfaces | Description of impervious, impermeable, hard packed, or rocky surfaces that prevent water from recharging the aquifer. Can mention specific surface (e.g., road, cement, sidewalk, buildings). |
| Recharge problem | An impervious barrier prevents water from sinking in, absorbing, soaking in, or recharging the aquifer; the word "aquifer" need not be mentioned. Does not need to be an accurate overall statement as long as response includes idea, process of water sinking into ground. Must include something that prevents water from being absorbed into the ground. |
| Slanted problem | Slanted or steep surfaces, including hills, roofs, sidewalks. Not proposed as a solution. |
| Non water-wise plants | Plants that are not drought tolerant or use too much water for the arid Southwest. |
| Use less water | Suggests watering less or using less water as a solution. Do NOT count if less water use is an outcome or justification. |
| Xeriscaping | Xeriscape, drought resistant plants, low water use plants. |
| Catchment | Some way to catch water or store water. |
| Rerouting | Methods to (re)route water. |
| Reuse | Later (re)use or having control over when water is used, possibly after cleaning or filtering the water. Can include using water for humans or for plants. |
| Recharge solution | Permeable surface as (part of) a solution (e.g., paver stones, or pebbly/crushed rocky surfaces, grassy field) to allow water absorption. Count as long as it is connected to the idea of recharging, soaking in, returning to the aquifer. |
| Runoff | Includes word run-off or runoff. |
| Drought | Includes word drought. |

**Table 2.** Irrelevant, non-normative, and normative preconceptions identified in the pre-test.

| ***Codes tied to irrelevant ideas (% of responses coded)*** | ***Sample response*** |
|---|---|
| Evaporation (17%) | Evaporation prevents rain water from being absorbed into the ground. |
| Plants absorb water (14%) | 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. |
| ***Codes tied to non-normative ideas (% of responses coded)*** | ***Sample response*** |
| Manmade is bad (12%) | Things that prevent rainwater from being absorbed could be pesticides and manmade objects covering the ground. |
| Pollution (18%) | Contaminants and other debris lay over the ground and do not allow full absorption of the water. |
| Recharge is bad (8%) | 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. 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. |
| Too many plants (5%) | Because plants suck up water, so with less plants there is more water. |
| Dry ground (5%) | If the ground is too dry it will not absorb water. |
| Dirt field (3%) | Make a big field with nothing but soil so the rain can absorb into the ground to produce more groundwater. |
| ***Codes tied to normative ideas (% of responses coded)*** | ***Sample response*** |
| Impervious surfaces (58%) | Water can't be absorbed through asphalt and I think it is hard in big cities for water to be absorbed into the ground. |
| Recharge problem (77%) | Water can't be absorbed through asphalt and I think it is hard in big cities for water to be absorbed into the ground. |
| Slanted problem (0%) | None on pretest. |
| Non water-wise plants (3%) | Also, plants that are not suitable for certain environments may use up water before it can be absorbed. |
| Use less water (9%) | Not water when it rains frequently so the rain water is used more effectively. |
| Xeriscaping (3%) | One being green planting of native plant species. |
| Catchment (67%) | 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. |
| Rerouting (32%) | 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. |
| Reuse (45%) | 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. |
| Recharge solution (15%) | 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. |
| Runoff (11%) | We could use large barrels to collect water from rain gutters and other water runoffs. |
| Drought (5%) | We save the collected water for times of drought. |

conceptions about watershed management. We found minor growth in students' conceptual understanding between the pre-test (*M* = 3.12; *SE* = 0.25, maximum possible score of 12) and post-test (*M* = 3.82; *SE* = 0.28), 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 see that growth occurred in specific areas (Figure 1). 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 3% of students mentioned xeriscaping as a solution on the pre-test, whereas 21% did so 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, both during small group activities and in listening to their peers present their ideas. Students had opportunities to choose specific topics to investigate, and this is reflected in the learning growth regarding specific ideas, such as xeriscaping and using less water.

## Discussion and Conclusions

Prior research on student preconceptions about water-related environmental science issues focused on the water cycle (Mills 1983; Ewing and Mills 1994), how water is stored and moves underground (Ben-zvi-Assarf and Orion 2005a, 2005b; Dickerson et al. 2007; Covitt et al. 2009; Unterbruner et al. 2016), and about systems thinking aspects of water (Ben-zvi-Assarf and Orion 2005a, 2005b; Covitt et al. 2009; Rodríguez et al. 2015). Likewise, preconceptions about the safety of tap water (Saylor et al. 2011; Mahler and Barber 2015) and its treatment (Fremerey et al. 2014) have been investigated. Past research has shown that instruction can increase students' level of agreement with factual statements about the amount of pollution in water resources and the safety of tap water (Mahler and Barber 2015). We extend this body of knowledge by investigating preconceptions about watershed management in an arid, urban, Southwest desert environment.

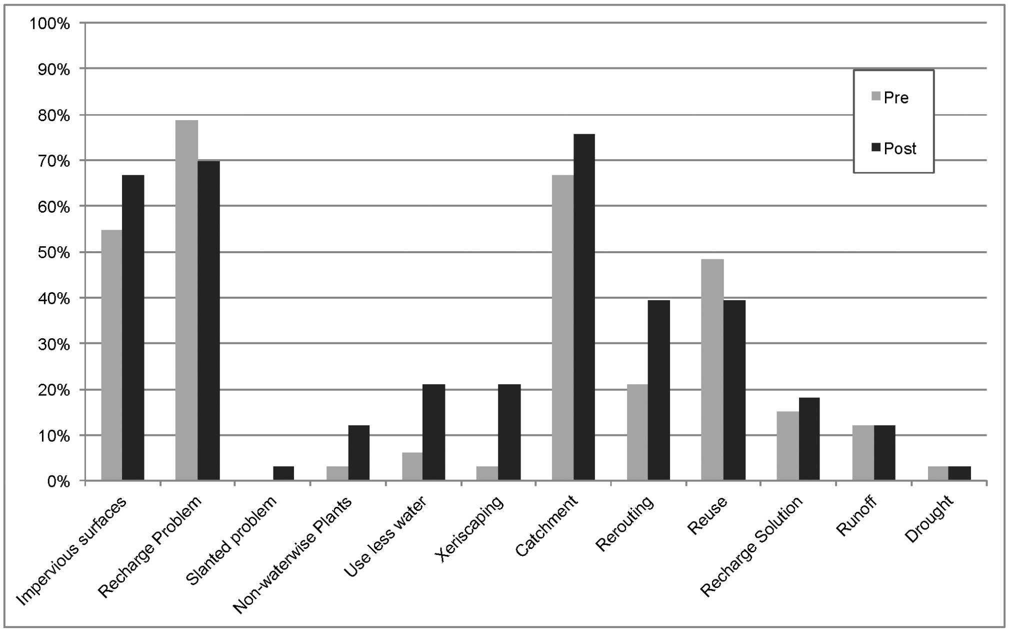

**Figure 1.** Percent of student responses containing normative ides on the pre-test and post-test.

We found most students described normative ideas, but many also included unexpected non-normative ideas; for instance, students explained that plants, pollution and trash, and man-made surfaces prevent water from recharging the aquifer. Based on the non-normative preconceptions we identified in our population of university students in an introductory course, we see a need for increased water resources education at the high school level. Such instruction could target the non-normative preconceptions we identified. The idea that pollution prevents water infiltration could be addressed by providing instruction about the actual effects of pollution. The idea that manmade surfaces are always impervious to water could be addressed to clarify that some human-designed objects can be very effective watershed management tools.

Preconceptions can be held quite firmly, preventing new learning from taking place. Understanding students' preconceptions can serve as a starting point to initiate conceptual change (Fremerey et al. 2014). One of the most promising approaches to conceptual change is experiential learning. Such approaches are deliberately designed experiences that begin with student ideas, followed by opportunities for experience, and finally ending with reflection (Mayhew and Edwards 1936; Dewey 2007; Reeves et al. 2014). The experience we designed included a carefully planned sequence backed by past research on learning. First, many studies underscore the importance of beginning instruction by first eliciting students' ideas (Linn et al. 2004; Linn 2006; Martin et al. 2007; Fremerey et al. 2014). In our design, the pre-test and small group discussion elicited students' preconceptions. Students then had opportunities for experiential learning in the field and time to conduct independent research (Mayhew and Edwards 1936; Dewey 2007; Reeves et al. 2014). Following this, students presented to one another as a form of direct instruction. This sequencing of direct instruction *following* an activity is also supported by research (D.L. Schwartz and Bransford 1998). Lastly, the post-test provided a specific reflection point, allowing students to further process newly acquired knowledge, as recommended by research on learning (Mayhew and Edwards 1936; Dewey 2007; Reeves et al. 2014).

Educators have advocated for experiential learning in upper-level water resources within undergraduate and graduate programs (Ballantyne and Packer 2009; Campana 2010; Camkin and Neto 2013; Missingham 2013). Our study builds on prior work by showing that this approach can extend to an introductory course. Our two-day activity is realistic and could easily be included in a broad introductory level course to teach about watershed management. Based on our findings, experiential learning is a promising approach, even for students with little prior knowledge of the specific subject area being introduced (Welker et al. 2010). Having multiple experiential learning experiences across subjects supports students to develop stronger teamwork skills (Coker et al. 2017). Our findings demonstrate the feasibility of incorporating brief experiential learning activities into an introductory level course, which could then encourage the development of teamwork skills among students in these early courses.

Few previous studies of experiential learning in water-related environmental science have assessed the impacts on learning (e.g., Thompson et al. 2011), though some have assessed participants' perceptions (Cockerill 2010). An exception is an evaluation of learning gains related to three Project WET lessons on the water cycle, which showed similar amounts of growth to our intervention (D'Agostino et al. 2007). However, no detail is provided on the type of activities included in the lessons and all questions in their assessment were multiple choice. Given concerns raised over this format (K.L. Schwartz et al. 2011), it is unclear if such gains represent increases in conceptual understanding. Our study assessed students' conceptual change related to water resources. Even though only minor growth was detected overall, we found larger increases for specific ideas, such as using xeriscaping, using less water, rerouting water, and using catchment systems as solutions. We encouraged students to engage with ideas tied to water resource management outside of class, and given the limited duration of the learning experience, we see that this growth can likely be attributed to the experiential learning approach. Overall, our findings suggest that implementing a brief experiential learning intervention on water resources can change students' preconceptions.

## Limitations and Future Directions

Although our brief experiential learning activity appeared successful, we discuss methodological limitations to our interpretation and outline future directions. We lacked a control group and relied on students' pre-test scores to provide a covariate. This limits the degree to which we can attribute the observed changes to our intervention.

In future, we also plan to investigate refinements to our curricular design. One refinement would be providing feedback to students and asking them to revise their work based on that feedback. A second refinement would be to have students reflect on how their ideas had changed, supporting metacognitive processing. Future work could compare results from studies carried out in varied geographical regions, and in urban and rural areas, to better understand the breadth of students' preconceptions and ways these may be influenced by everyday experiences.

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