Teaching Preservice Teachers the Water Cycle With a Conceptual Change Model

By Patricia Morrell and Adele Schepige

The purposes of this study were to examine preservice elementary teachers’ conception of the water cycle; determine if participating in a conceptual change–based role-play alters these conceptions; and ascertain if any conceptual change brought about by the intervention is lasting. We found that most of our students held naive conceptions of the water cycle. Participating in an activity based on a conceptual change model did broaden participants’ notions of the water cycle, and those more sophisticated ideas held for at least 3 months. The students were able to see how a lesson planned using the model could bring about conceptual change for themselves, which hopefully provided the impetus for them to include the model in their own instructional planning. The conceptual change model likely can be applied to any concept to improve understanding.

In our elementary science methods classes, the focus is on pedagogy rather than content. Because preservice elementary teachers might lack confidence in their understanding and in their preparation of science content (Avraamidou, 2013; Gibson & Dembo, 1984), we try to integrate pedagogy and content as often and as seamlessly as we can. One such example is when we cover the topic of conceptual change. To explore the tenacity of misconceptions and how these might be impacted by a teacher, we focus on a topic common to our students: the water cycle.

Water is essential for life and, as such, is one of a few scientific phenomena that every human on the planet has experience with from very early in life until death. Water quality and quantity have been a concern for years (e.g., Denchak, 2018; Hubble, 2021). Having an understanding about water and the water cycle has taken on increasing importance due to water’s connections to international economies and increasing issues with climate change. Glaciers, sea-level changes, droughts, flooding, and severe weather all are at the heart of the science of global climate change and are part of the water cycle.

Water is an important component in primary and secondary school science curricula worldwide. In the United States, the water cycle is recommended as part of fifth-grade foundational science knowledge, although the basics of the water cycle, understanding that water goes through phase changes, begin even earlier, in third grade (National Research Council, 2012).

Water cycle diagrams are found in most elementary through college science textbooks. There are children’s trade books devoted to the topic of the water cycle. A website search for “water cycle” yields animations as well as diagram worksheets and posters teachers can download. The most basic water cycle illustrations commonly include the terms “evaporation,” “condensation,” and “precipitation.” As the target audience becomes older, the diagrams begin to include more features of the water cycle (and the name is sometimes changed to “hydrological cycle”) and introduce terms such as “transpiration,” “evapotranspiration,” “sublimation,” “groundwater,” and “runoff.”

Because water is so familiar, many of us have developed misconceptions or naive conceptions about the water cycle (Osborne & Cosgrove, 1983; Taiwo et al., 1999). Research on student misconceptions in science extends back for more than 40 years (e.g., Driver & Oldham, 1986; Karplus & Stage, 1981). Studies suggest that preservice teachers, especially those at the elementary level, often have the same misconceptions as the students they are about to teach (e.g., Bayraktar, 2009; Schoon, 1995; Schoon & Boone, 1998).

Several studies address student misconceptions about the changes of the state of water through the water
cycle. Bar (1989) and Taiwo and colleagues (1999) conducted studies about children’s perceptions of the water cycle. Their results indicate that younger students’ ideas about the water cycle are often influenced by cultural and pseudoscientific explanations, whereas students in upper-primary grades are more influenced by the correct scientific explanation. Ben-zvi-Assarf and Orion (2005) conducted a study using several different questionnaires, student drawings, and student interviews to examine middle school students’ perceptions of the water cycle. These students had misconceptions and an incomplete understanding of the water cycle, especially concerning how it is part of a system. Similar results were found in studies by Cardak (2009) with university students and Heng and Karpudewan (2017) about primary school students. Brody (1993) completed a literature review about students’ understanding of water and water resources, and Henriques (2002) reviewed the literature for students’ ideas about weather. Both reviews concluded that students of all levels have a poor understanding of the water cycle.

Although there are studies regarding student understanding of the water cycle, there is little research about preservice teachers’ understanding of the water cycle. Considering the importance of water on our planet, the current issues in global climate change, and ongoing concerns over water quality and quantity, this seems to be an important area of scientific conceptual understanding to explore. If preservice teachers have misconceptions about the water cycle, they are likely to reinforce or instill those same misconceptions in their students. Thus, this is appropriate science content on which to focus instruction regarding misconceptions and naive conceptions and conceptual change.

**Purpose**

This study sought to examine the impact on preservice teachers when they engage in a teaching activity about the water cycle in a unit on misconceptions and naive conceptions. Specifically, the activity involved students in a constructivist teaching sequence for conceptual change. We sought to:

- examine preservice elementary teachers’ conception of the water cycle;
- determine if participating in a conceptual change–based role play, “The Incredible Journey” activity in Project WET, alters these conceptions;
- ascertain if any change brought about by the intervention is long lived; and
- involve preservice teachers in an activity that applied a constructivist teaching sequence for conceptual change to determine its impact on the preservice teachers’ own thinking.

**Methods**

The sample for this study was 77 preservice elementary teachers enrolled in two different teacher preparation programs in the Pacific Northwest in the United States. In our geographic area, elementary teachers are prepared to teach in self-contained classrooms for kindergarten through eighth grade. This sample was representative of undergraduate preservice elementary teachers in the region, with 21 attending a private, urban university and the remaining 56 enrolled in a public, suburban university. Most students were female and in their early twenties. The sample was one of convenience, as all students were enrolled in an elementary science and mathematics methods course taught by the authors. Each author taught in different universities and sampled her own class. The research design used was a pretest/posttest/delayed posttest design.

The two methods instructors collaborated on the lesson plan and delivery methods to be used in conjunction with this study. Each taught her own class separately. Both methods courses met once a week for 3 hours per session. Classroom field experiences were associated with both courses.

Early in the fall semester during their final-year methods class, the students were introduced to naive conceptions and misconceptions. A misconception is one that is simplistic though not necessarily incorrect and often formed prior to formal instruction. A misconception is an idea that is not commonly accepted as true by scientists. Students were already familiar with constructivist principles from other classes, and we discussed how student conceptions form and why and how they can become deeply rooted and often difficult to change. As an example, we examined the reason for the seasons, with students asked to provide their explanation individually first and then discuss their answers as a class. We showed the well-known Massachusetts classroom from *A Private Universe* from the Annenberg Series (https://beta.learner.org/series/a-private-universe/1-a-private-universe) to anchor and enrich our discussions. We provided students with an abbreviated list of common misconceptions in science and mathematics and explored why and how students might form and believe these ideas (see, e.g., https://newyorkscienceteacher.com/sci/pages/miscon/subject-index.php).

Although there are many models
to help with conceptual change (e.g., Duschl & Gitomer, 1991; Posner et al., 1982), we used the model by Driver and Oldham (1986) to structure the lesson on conceptual change. We like this model because it is simple and effective and focuses on the pupil instead of the teacher. This model is based on a constructivist teaching sequence and consists of the following five phases:

1. **Orientation**: The stage is set and students get interested in the topic.
2. **Elicitation**: Students consider their own ideas and understanding about the topic.
3. **Restructuring**: This multistage phase involves sharing ideas, comparing ideas with others’ viewpoints, and perhaps seeing a different way of looking at things (the teacher can set up a “conflicting” or “disconfirming” situation to get students thinking of inadequacies if needed), leading to the construction of different ways of thinking and the testing of new ideas to make better sense of students’ thinking.
4. **Application**: Students have the chance to “use their developed ideas in ... familiar and novel” situations (Driver & Oldham, 1986, p. 118).
5. **Review**: Students reflect on their original thoughts and how their thinking may have changed through this process.

We applied this model to the lesson by first getting students to explore their own ideas about something common: the water cycle. We did not tell the students about the model or how we were applying it at this point in the lesson. For orientation and elicitation phases, students were given a pre-assessment to determine their conception of the water cycle. This consisted of a blank sheet of white letter-sized paper with the following instructions: “Using words and/or a sketch, please briefly describe/illustrate the water cycle.” The use of drawings to examine conceptual understandings and misconceptions has been advocated by several researchers (e.g., Cardak, 2009; Keong & Karpudewan, 2013; Kose, 2008; Prokop & Fančovičová, 2006; Reiss & Tunnicliffe, 2001). All students drew their response, with some using words to label parts of their sketches.

After the students completed this individual assessment, we moved into the restructuring of ideas phase, with students sharing their responses in small groups and then discussing them in a whole-class setting. This helps students really “own” their thinking and compare their thoughts with those of their peers.

The students next participated in a modified version of “The Incredible Journey” activity from Project WET, which served as the bulk of the restructuring phase by providing a context for students to consider when thinking about water molecule movements. This activity, geared to upper-elementary and middle school students, is designed to have students “describe the movement of water within the water cycle and identify the states of water as it moves through the cycle” (Project WET International Foundation and CEE, 2005, p. 161). It is similar to activities such as “Water Wonders” in Project Learning Tree, “What a Cycle” by the National Oceanic and Atmospheric Administration, and others available online (e.g., http://arcticclimatemodeling.org/lessons/acmp/acmp_k4_WaterCycle_WaterCycleGame.pdf). Stated simply, nine stations are set up around the room representing clouds, plants, animals, rivers, oceans, lakes, groundwater, soil, and glaciers. An even number of students is assigned to each station to start the simulation. The students work individually. Each student pretends they are a water molecule and moves through the water cycle “stations” by rolling the special die placed at each station. The faces of the die indicate which station the student should move to or if the student should stay at the same station. Students keep written track of their movements. Prior to the role-play, each station is discussed, with the students prompted to suggest how each station fits into the water cycle (e.g., the water in a plant enters an animal when it is consumed or water leaves the plant and enters the atmosphere through transpiration). The role-play continues until most students have been through about a dozen roles.

To wrap up the restructuring phase, the students discussed with their table groups the path their water molecules took, connected the pathways to phase changes, and compared the different paths of the water molecules with their classmates. The whole class then shared these differences and similarities and discussed why it was harder to move from some stations (e.g., clouds, ocean) than others.

To conclude the conceptual change model steps, the students were then post-assessed by being asked to again describe or illustrate the water cycle on the reverse side of their pre-assessment papers. It was important to stress that they did not need to provide a picture of their particular water molecule journey but of the water cycle in general. Students reflected on the comparison of their original ideas with new ideas about the water cycle components. The class then discussed any changes between the pre- and postactivity sketches and the reasons for any differences. The assessment sheets were collected to be returned.
at the end of the semester.

After this initial engagement in “The Incredible Journey” activity and the discussion of the changes in the students’ pre- and post-activity drawings, the idea of conceptual change was introduced to the students. The model put forth by Driver and Oldham (1986) was examined, and the students (with guidance) tied the lesson they just experienced with the different steps of the sequence as outlined earlier.

Three months after the activity, at the end of the semester, the students were again asked to complete the task of describing or illustrating the water cycle. This was done as an opening activity to a class session. The original set of sketches was returned to the students to use for comparing the three assessments. The differences were noted, shared, and discussed. We revisited the constructivist teaching sequence model of Driver and Oldham (1986) and again compared it with the lesson the class did with “The Incredible Journey.” A rich discussion of conceptual change again ensued. The preservice teachers were impressed with the changes and retention of complexities in the water cycle over time in students’ drawings and attributed these changes to the use of the model in instruction.

For a quantitative look at the impact of this teaching episode, the students returned their three sets of sketches to the instructors. Similar to the drawing analyses done by Rennie and Jarvis (1995) and Ben-avi-Assaraf and Orion (2005), the student drawings were examined by the researchers and the following coding scheme was designed. The authors looked through their students’ drawings separately and then together and compiled a list of elements that would capture most students’ drawings. No differences were found between the two university groups, so the pictures were combined to form one data set.

A total of 18 specific components were identified: the nine “Incredible Journey” stations mentioned earlier; arrows; the Sun; a drawing of some type of precipitation; and the words “condensation,” “precipitation,” “evaporation,” “transpiration,” “sublimation,” and “runoff.” In sketches containing snow-capped mountains, some were specifically labeled as glaciers. Speaking with a sample of students who did not label the mountains, we learned that their intent was that the snow-capped mountains represented glaciers. By using these 18 categories, all salient pieces of the students’ drawings were captured for coding. If the item was present, it was noted with a 1; the absence was noted with a 0. The tallies for each student’s drawings were totaled. We acknowledge that just counting items in a drawing does not in itself reflect conceptual change. It is a simple measure, however, of what students retained from the activity.

**Results and discussion**

Of the 18 possible codings, a mean of 9.41 (SD = 2.29) was found in the pre-assessment (n = 76), whereas a mean of 13.58 (SD = 2.45) was found in the post-assessment (n = 77). For the delayed postactivity (n = 66), the average number of codings was 11.64 (SD = 2.17). In comparing the items noted in the three phases of assessments for all students, there was a gain between pre- and postactivity (+5), a loss between post- and delayed postactivity (–2), and a gain between pre- and delayed postactivity (+3).

Initially, many students drew a water cycle that looked like a typical elementary textbook picture (see Figure 1). In more than 90% of the drawings, there was at least one large body of water and a cloud, with curved arrows going in both directions between the two, with precipitation coming from the cloud. As with research done with school-age children (e.g., Ben-zvi-Assaraf & Orion, 1995), the atmospheric component of the water cycle was most prevalent in these preservice teachers’ conceptions. When contrasting the findings with those from Cardak’s (2009) university students, they were found to be similar; in Cardak’s sample, 91% of drawings had surface water and 75% included the atmosphere.

The three phase-change terms that appear on nearly every water cycle diagram in books and websites are “precipitation,” “condensation,” and “evaporation.” This may have influenced our own students. On the pre-assessment, most students (87%) labeled “evaporation,” and more than half included the words “condensation” (57%) and “precipitation” (78%). Elements that occurred the least included plants (29%), groundwater (22%), animals (11%), and soil (7%).

After participating in the activity, the drawings became more elaborate (see Figure 2). The majority of the students included most of the stations from “The Incredible Journey” activity. Although not all students included all nine possible stations from the activity, seven of the stations (clouds, animals, river, lake, plants, ocean, glacier) were included more than 90% of the time; groundwater occurred in 89% of the drawings; and soil was represented almost 60% of the time.

Arrows depicting the path of water became more complex in the postactivity assessment. The arrow pattern often changed from the initial circular atmospheric pattern to include multiple arrows pointing up...
and down between all bodies of water and the atmosphere. Some drew arrows underground pointed sideways and curving up to show groundwater movement. There was also a change in the number of arrows representing phase changes. Most drawings in the pre-activity assessment had one arrow each for evaporation, condensation, and precipitation. In the post-activity assessment, multiple arrows were drawn to represent each of those terms. It was also common to see an arrow going up for evaporation and a parallel one alongside it pointing down for precipitation.

There were several aspects of the water cycle drawings that proved to
be especially interesting. There was a lack of humans and continental glaciers in the drawings. Although we did not include humans in our checklist, as only three of the 78 students included humans (either as stick figures or via houses) in the pre-activity assessment, it should be noted that none of the students included humans in the postactivity assessment. Was this because humans are not specifically included in “The Incredible Journey” activity (technically they are animals but they are not “called out”)? Also, from their drawings, it would appear that students did not fully understand glaciers. All the glaciers drawn looked like snow atop mountains. No students indicated the presence of continental glaciers on the pre-activity assessment. In the postactivity assessment, only two students drew and labeled what appeared to be a continental glacier or at least a glacier that was not part of a snow-capped mountain. Attending a school in the Pacific Northwest, where glaciers are not common but volcanic mountains are, students’ lack of personal experience with glaciers might be a source of this confusion.

One of the most dramatic changes in the pre- and postactivity drawings was the inclusion of plants and nonhuman animals in the postactivity assessment. As noted earlier, few students included either of these in their first drawings. In the postactivity drawing, 92% of students included plants and 96% included animals. Not only did most drawings have both, but many students added water cycle terms to align with the concepts. The word “transpiration” was placed by drawings of plants; “respiration,” “evaporation,” “feces,” and “urine” were the terms found near animals. The addition of animals is unique when one considers the majority of water cycle diagrams typically found in printed texts do not contain animals. “The Incredible Journey” activity does, however, include animals as a station.

The Sun is the driving force behind the water cycle. Most, but not all, published water cycle diagrams include the Sun. More often, when the Sun is represented, there are no words indicating why it is an important factor in the water cycle. Fifty-one percent of the students drew the Sun in the pre-activity drawings, but only 43% did in the postactivity drawing. Sixteen students changed from including the Sun to not including it, and nine that did not have it at first added it. This may be connected to the lack of a direct mention of the Sun in the activity, requiring the inference that the Sun is responsible for many aspects of the water cycle.

An analysis of variance (ANOVA; EZAnalyze) was used to compare the pre-, post-, and delayed postactivity drawings for students participating in all three assessments (n = 65). Significance level was set at 0.05. There was a significant difference (p < 0.05) among all three assessments: a gain between pre- and postactivity, a loss between postactivity and delayed postactivity, and a gain between pre- and delayed postactivity (see Table 1). On average, prior to the intervention, the students included 10 components in their drawings. After participating in “The Incredible Journey” activity, the average increased to 14. A drawing done 3 months later showed a dip to an average of 12 categories represented. Although the analysis of the drawings was simplistic, it suggests that although students did not retain all the components measured, participating in the Project WET role-play lesson did have a positive, lasting impact on helping the students realize the complexity of the water cycle.

Conclusions

An analysis of the students’ initial drawings suggested that these preservice teachers tended to have the same naive conceptions of the water cycle as elementary and middle school students. They were well versed in the atmospheric side of the cycle but did not tend to include the systemic components of the water cycle from the geosphere and biosphere. The Project WET activity did impact the students’ drawings in terms of the complexity of the water cycle. Furthermore, for the students in this study, participating in “The Incredible Journey” activity presented using the conceptual change format produced a strong enough change that 3 months later they had retained a more complex rendering of the water cycle.

<table>
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<tr>
<th>Drawing</th>
<th>Number</th>
<th>Mean</th>
<th>SD</th>
<th>Pre</th>
<th>Post</th>
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<td>Pre-activity drawing</td>
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<td>2.26</td>
<td></td>
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<tr>
<td>Postactivity drawing</td>
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<td>13.65</td>
<td>2.42</td>
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<td>11.63</td>
<td>2.18</td>
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*ANOVA significance p = 0.000
*Post-hoc comparisons computed using Tukey’s HSD
Thus, engaging in this conceptual change–focused activity served several purposes for preservice teachers. It had the students reflect on their own ideas about the water cycle and enrich these; provided the students with a model lesson they could use in their field classes; and provided a participatory and concrete application of a model for pedagogical development on conceptual change.

The limitations of this study include examining only two groups of students, focusing on one concept with the conceptual change model, and testing over the course of a single semester. Additionally, the use of coding with the drawings is a simplistic measure of conceptual understanding.

**Implications**

Several changes are suggested to increase the impact of this activity on student thinking. It is important to specifically address phase changes and the role of the Sun in the water cycle. Students, at least in areas that do not have glaciers locally, may also need to be educated about glaciers and how they differ from snow-capped mountains. The roles of human beings in the water cycle should also be noted.

Teaching about global climate change is becoming more important, and the water cycle is a foundational piece to understanding global climate change. The literature review revealed there are only a few studies related to understanding what the water cycle is and how it works, and most of the studies are from the K–12 student perspective. Little is known about preservice teachers’ understandings of the water cycle. This study helped add to that knowledge base by examining preservice teachers’ depictions of the water cycle and providing evidence that, with the use of an appropriate teaching activity, it is possible to bring about lasting change. Because the preservice teachers have strengthened their conception of the water cycle, they should be able to teach a richer version of the water cycle to their students. Additionally, because they personally experienced a change in their thinking and were able to connect that to a specific way of being taught, preservice teachers will hopefully be more intentional in planning and selecting activities they use with their own students to move their students’ prior knowledge to more scientifically acceptable knowledge. Although we did not test the model with other naive conceptions and misconceptions, it is possible that using this model of conceptual change will help correct other naive conceptions and misconceptions in science as well.

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