Education for Sustainability: A 5E Lesson on the Water Cycle Introduces Elementary Preservice Teachers to Think about Their Impacts on Earth's Fresh Water Supply

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Abstract

The following lesson demonstrates the use of a 5E learning cycle to teach elementary preservice teachers (PSTs) the basic principles of the water cycle and scientific modeling. An Education for Sustainability (EfS) approach was utilized to further engage students in thinking about human impact and the implications we have on this natural process. Through this classroom activity, PSTs were able to explore Earth's water system and the consequential social effects on water availability, cleanliness, and sustainability worldwide.

Background

In our elementary science methods course, we model 5E learning cycles (Bybee, 1997) to highlight instructional strategies during the implementation of a 5E lesson and develop preservice teachers' science content knowledge. This process allowed preservice teachers (PSTs) to realize relationships that exist between concepts, providing them with opportunities to further their understanding on new and prior knowledge (Bybee et al., 2002). In previous semesters we used a 5E modeled lesson to teach PSTs about the water cycle. PSTs engaged in experiences that elicited their thinking about the water cycle, broadened their thinking to Earth's cycling of water and the conservation of matter, and discussed the use of scientific models in elementary classrooms. This 5E plan had been well-received by PSTs in the past; however, we felt we were missing an opportunity for PSTs to think about human impacts on Earth systems and modeling how to incorporate issues of sustainability in the elementary classrooms.

The United Nations Educational, Scientific and Cultural Organization's (UNESCO) vision provided guidelines to promote the Education for Sustainability (EfS) approach and assist in educating young people to create a more sustainable world, through development of appropriately designed curriculum materials (Feldman & Nation, 2015). It is important that preservice elementary teachers be educated in ways to address issues of sustainability in their future classroom instruction. In order to more effectively pursue the goal of educating young people to become citizens of sustainability, UNESCO developed the document *Guidelines and Recommendations for Reorienting Teacher Education to Address Sustainability* (UNESCO, 2005a). An important component of EfS is the adaption and critical reflection of existing educational systems with the inclusion of projects that aim to address

these issues in science classrooms. The following criteria are identified in the document as recommended goals of Education for Sustainable Development (ESD) projects, which is an accommodation of existing curricula about sustainability to address sustainability through environmental stewardship; social equity, justice and tolerance; and quality of life for all peoples in this generation and the next (UNESCO, 2005, p. 15). Listed below are the recommended specific criteria identified in the document for ESD Projects:

- ESD is locally relevant and culturally appropriate … [It] is not imported from another cultural, economic or geographical region.
- ESD is based on local needs, perceptions, and conditions, but recognizes fulfilling local needs often has global effects and consequences … [It] is not "one size fits all," but must be created to account for regional differences.
- ESD addresses content, context, pedagogy, global issues, and local priorities.
- ESD engages formal, non-formal, and informal education.
- ESD is a life-long endeavor.
- ESD accommodates the evolving nature of the concept of sustainability.
- ESD deals with the well-being of all three realms of sustainability – environment, society, and economy. (p. 16)

According to Sterling (2003), EfS is an adaption of existing educational systems, with an incorporation of critical reflection. The result can be sustainability concepts (e.g. population growth; water as a limiting resource; water accessibility; clean water; contamination; etc.) built into preexisting curriculum in a way that reorients the focus toward an ethic of sustainability.

Bentham, Sinnes, and Gjøtterud (2014) outline the following framework, which organizes teaching and learning approaches for integrating EfS in the classroom. The outlined teaching and learning approaches are designed to promote student development of action competence through:

- Participation in decision-making and community-based decision-making (e.g. debates and action plans)
- Active learning approaches regarding sustainability issues
- Learner-centered approaches
- Engagement in community and social development activities
- Participatory and collaborative learning activities.

Bentham et al., (2014) advocate for policies within teacher education that promote alignment with sustainable teaching practices and guide the levels of sustainability competencies that PST should develop as well as the competencies of sustainability that teachers are expected to develop in their students, including the development of "critical and creative thinking that

explores ways of solving locally contextually relevant problems, a sense of respect and responsibility towards others, and critical understanding of community and environmental issues" (p. 356).

The goals of our classroom activity were based on the goals and criteria outlined in the UNESCO document. Preexisting curricula materials were used to model the desired guidelines for preservice elementary teachers specifically addressing the issue of water sustainability. Our modified learning cycle of water sustainability was to use an innovative approach to expose preservice teachers to the goals and methods of EfS instruction through a learning cycle on the water cycle. The result is a learning cycle that allowed teacher educators to model the implementation of a 5E lesson while exposing elementary PSTs to scientific modeling, content knowledge of the water cycle, and issues of water sustainability.

According to the Next Generation Science Standards (NGSS), models represent "diagrams, physical replicas, mathematical representations, analogies, and computer simulations" (NGSS Lead States, 2013b, p. 52). Cartier, Rudolph, & Stewart (2001) explain scientific models as consisting of "a set of ideas that describe a natural process" (p. 2) and further suggest scientific models can be used to explain and predict natural phenomena. The PSTs that participated in the activity were able to use their expanded scientific content knowledge of water sustainability through the lesson's activities to critique water cycle models that failed to realize the full social, economic, and political implications of the water cycle diagrams. This lesson also allowed PSTs to consider the application of science in society and develop science knowledge and skills beyond the standards (NSTA, 2004). The lesson integrated the Next Generation Science Standards for educating elementary science students on human impacts on Earth systems (ESS3.C) and natural resources (ESS3.A), (NGSS Lead States, 2013).

Provided below is a detailed narrative of the 5E learning cycle modeled for PSTs during an elementary science methods course. During the 5E lesson, PSTs were asked to take on the role as "learner," so PSTs are referred to as students throughout.

5E Learning Phases

Engage

The goal of the engage phase was to elicit students' ideas about the water cycle and provide teachers with an opportunity to identify students' misconceptions or misunderstanding (Lorsbach, 2008). We began by asking students, "What is a cycle?" Responses such as, "a circle" and "never-ending" were recorded on the board. We invited students to name some cycles they were familiar with. Students shared their daily routines as a cycle, the cycle of seasons, and the water cycle. When asked who had heard of the water cycle, all students reported they had, so students were asked to draw a picture of the water cycle from memory. We told students the water cycle is a model for thinking about the journey that water takes

and that we would read aloud a book that will describe more about *The Water's Journey* (Schmid, 1989). In the book, detailed images accompanied the text diagraming and describing the process of water's movement from mountains to the ocean. Following the reading, students were asked to discuss their drawings and ideas, and how those compared to the ideas shared by the author. As a whole group we discussed elements of the water cycle included in the author's description of the water's journey that were omitted from our drawings, and vice versa. Finally, students were asked to participate in critical discussions regarding the shortcomings of their models. Upon sharing their water cycle models with each other they suggested modifications to make to the diagrams based on the read aloud. For example, because of our geographic location in Florida, mountains are not a part of students' daily lives; therefore, were not represented in their original drawing. However, after listening to the story, students wanted to include mountains in their drawing modifications, as well as humans, plants, and animals. Additional modifications made to individual water cycles were the inclusion of aquifers, and other fresh water reservoirs beyond simply rivers or streams. Some students removed glaciers as a source of water due to the limited access that living organisms have to that particular source. However, for the majority of the students, additional detail was added to their drawings, rather than removing components.

Explore

The purpose of this phase was to involve students in a student-centered activity to work collaboratively to discover new ideas (Lorsbach, 2008) about the water cycle. Approximately sixty students were asked to participate in the whole group activity, *Go to the Head of the Cloud* (Supplemental File, Activity #44 in Project Learning Tree Curriculum Guide, 1995), an interactive game of chance in which students act as droplets of water and follow written instructions on cards directing them to stations. Each station was a reservoir of water that exists naturally in the water cycle (e.g. groundwater, glaciers, ocean, clouds, animals, plants, streams). Students removed a scenario card from the envelope at their station. They read the scenario and recorded the step in their journey, followed by the name of the station they were to "visit" next. For example, "you fall as rain onto an ocean. Go to Ocean." The students completed this process five times before they returned to their seats to write a brief story from a water droplet's point of view describing the journey they took. The desired outcome of the explore component of the activity was for the students to reflect on their experiences as a water droplet in the activity. They were asked to write about this experience in narrative form to portray a first-hand account of where water tends to reside during much of the water cycle. The goal of the activity was for students to be able to recognize that water is constantly moving; yet there are common reservoirs for the majority of Earth's water.

Explain

Students were asked to pair up and share their stories. The teachers prompted students to discuss how their journeys were alike and how their journeys differed. To capture the nuances of each student's journey, the teacher listed all seven water stations from the

activity on the board for students to create a whole-class tally chart (Table 1). Every student reported the total number of times they visited each station.

Table 1.

Student Whole-Class Tally Chart for Water Journey

Variables	Total
Ocean	80
Cloud	58
Stream	48
Groundwater	36
Animals	19
Glacier	18
Plant	16

Once the tallies were totaled, students were asked a few questions to infer meaning from the data:

- In the game, which “bodies of water” seem to be visited most? What can we infer from this?
- In what way(s) was this game of chance similar to your understanding of the water cycle?
- In what way(s) was this game of chance different from your understanding of the water cycle?

PSTs listened critically to others and used their own experiences as a droplet of water during the game to develop explanations to “explain” (Lorsbach, 2008) what this meant about movement of water and water reservoirs. The students were asked to think critically about the amount of water on Earth, and where the vast majority of it is located. Students were asked the question “Why do you think many of us spent a majority of time in the ocean?” Further, the teacher introduced some figures concerning the amount of water on Earth, indicating that while 70% of Earth’s surface is water, roughly 97% of that water is salinated, leaving only 3% of Earth’s water as usable drinking water for humans. Students were also asked to think about what this meant for drinking water, and the term “water insecurity” was

introduced as defined by Wutich and Ragsdale's (2008) three dimensions: (1) inadequate supply; (2) insufficient access to water distribution systems; and (3) seasonal variability of water sources impacted by climate and drought.

The purpose of this explain-phase activity was to probe students to think about accessibility of water on Earth. Students began to make connections during this phase between the largest reservoirs of water on Earth and the impact that has on access for drinking water. Students also began to recognize limitations of their original representation of the water cycle in their drawings, as some students noticed they lacked certain prominent water reservoirs in their own water cycles, which was evident based on student feedback during the lesson and examples of student work samples.

Extend

During the extension phase, students were asked to apply their new ideas from the engage, explore, and explain phases (Lorsbach, 2008) as the teachers introduced EfS. Predetermined sets of articles that were current, represented by popular media outlets, and related to issues of sustainability—specifically water from around the globe—were distributed to the students in small groups. Each group just received one article. The articles were taken from a popular media outlet, *The New York Times*, which focused on issues related to barriers of water accessibility (e.g. water contamination and cleanliness as well as barriers of water access due to lack of water availability in certain desert regions or due to drought). Below is a selection of the articles provided to students for the activity:

1. Parker, R. (2015, March 13). The southwestern water wars, how drought is producing tensions in Texas. *The New York Times,* p. A29

The article discusses the historical nature of drought in the Southwest United States, an issue that is plaguing the area currently. Many issues of sustainability impacts are discussed in the article, including population growth of the area, the technology needed to solve the scarcity, and the political and economic struggles of those in smaller and more rural areas as they compete for the same water as larger metropolitan areas.

2. Roy, N.S. (2013, May 21). Leading the push for clean water. *The New York Times,* Retrieved from http://www.nytimes.com/2013/05/22/world/asia/22iht-letter22.html

The article sheds light upon the impacts of water insecurity specifically on women throughout the nation of India. It further explores the lack of infrastructure and availability of clean water to its citizens, which contributes to reliance on women to forgo their education and use time-consuming methods of obtaining water for their families.

3. Bornstien, D. (2013, August 21). The real future of clean water. *The New York Times,* p.1. Retrieved from http://opinionator.blogs.nytimes.com/2013/08/21/the-real-future-of-clean-water/

The article examines past failures as a way to solve the world's water crisis. The article focuses on widespread grassroots contributions to local water crisis. The lead engineer in the study advocates for individual installation of existing technology, and away from the idea of fundraising and widespread top down approach from large organizations.

4. Beckman, D. (2014, August 7). The threats to our drinking water. *The New York Times,* p. A7.

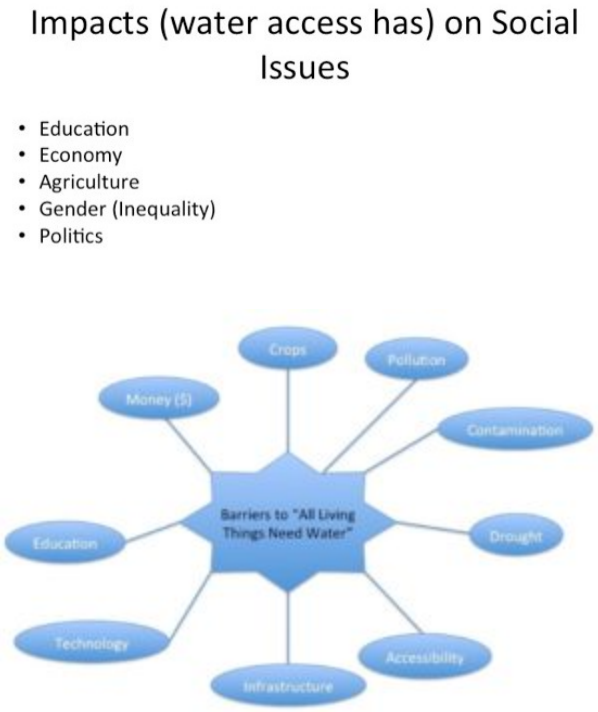
The article examines threats to clean water access in the United States, discrediting the common misconception that U.S. citizens are removed from this global matter. Other issues of water insecurity and sustainability are addressed in the article as contributing factors to this problem, including drought, pollution, and agriculture. The article then focuses on future steps needed to prevent these types of crisis in the future.

Using a jigsaw reading exercise approach, students read and discussed the major ideas of the shared article within small groups. After small-group discussions, the students regrouped into four member-groups, each member having read a different article. The groups shared major ideas from their articles, while discussing similarities and differences among them. Some of the major ideas discussed were the similarities and differences related to water access in the United States compared to that of underdeveloped nations. Students also discussed impacts that water access can have on individuals and families, specifically focusing on education, poverty, and health factors. Lastly, students discussed possible solutions to the issues represented in the articles, focusing on political, economic, and technological factors.

During this activity, students were also asked to think about their own experiences related to water availability and compare that to the experience(s) of the individual(s) in the articles. As a whole group, the students and teachers addressed barriers to the important rule "all living things need water" which was concurrently being taught in elementary classrooms. Students were able to determine some factors that contributed to these barriers, which included, but not limited to, exponential human population growth in both urban and rural areas contributing to greater stressors on current water sources, the (over) production of crops, contamination/pollution of fresh water, money/resources, drought/weather conditions, technology/infrastructure available to communities, and education of the communities about these issues. Using the Internet as a resource, students were then asked to pull information from the articles and describe how barriers to drinking water can have other societal impacts or social implications on human populations (Figure 1). Again, students generated a list from a whole-group discussion. These other societal impacts included economic, agriculture, social welfare and disease control, gender inequality, and education. Further discussion of these impacts led students to determine underlying factors that would help address the issues of water accessibility for humans. There was a consensus among the group that in order to eliminate these issues of water sustainability the overarching goal should be to educate community members about the impacts of barriers and solutions to accessible

drinking water. Students were asked to think about ways to best educate community members about water accessibility. Students discussed EfS efforts by which communities can become better informed about solutions to water insecurity, including formal education settings with students, as well as through informal settings such as community outreach programs for parents and stakeholders alike, including politicians, local business owners, and other local citizens. Issues of sustainability can be addressed though promoting sustainable practices. These ideals can become instilled in community members through formal and informal education. As additional members of the population become aware, further acceptances of sustainable practices are promoted (Feldman & Nation, 2015).

***Figure 1 (Click on image to enlarge)*. Example of student's reflection on social issues and web of barriers.**



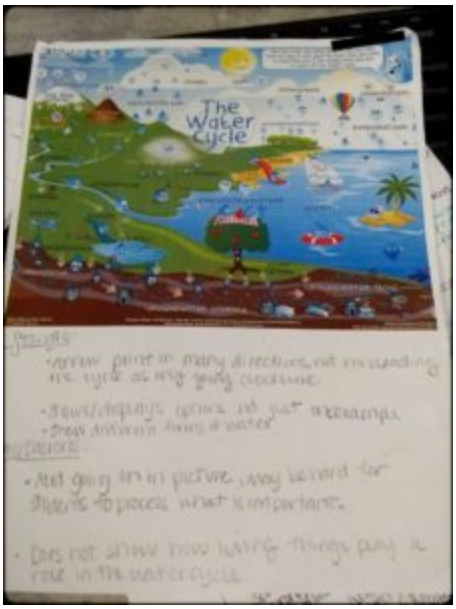
Evaluation

As an assessment of student learning, students were asked to find a published model of the water cycle using a popular search engine image search. They were asked to critically evaluate the model based on their newfound understanding of the water cycle and identify the strengths and limitations of the model water cycle diagrams as it related to the social, political, and economic implications of sustainability.

From this evaluation task we found that students were able to identify strengths and limitations of the typical water cycle diagrams that are published in textbooks and online (Figure 2). Some students noted strengths as, "shows continuous movement" and "arrows point in many directions." Limitations were identified as "missing stages" and "missing forms of water." Students were also able to recognize the impacts that limitations of freshwater had

on living organisms through discussion with their peers and evaluation of commonly published water cycle images. For example, one student identified a limitation as, “Does not show how living things play a role in the water cycle.”

***Figure 2 (Click on image to enlarge)*. Sample student work that critiques a diagram of the water cycle.**



Student Outcomes

Before the lesson preservice teachers (PSTs) were asked the following questions, “What experience(s) or knowledge of sustainable issues do you bring? Do you see a need for education for sustainability in the elementary classroom?” PSTs’ responses were more anthropocentric, a term that implies there is a hierarchal order to the natural world with humans on the top (Corbett, 2006). For example, one PST responded, “I do see a need for education for sustainability because we need certain things to be able to live our lives, if we do not teach things for students to live a sustainable life, our students will not have the tools to succeed.” Another responded, “There is always a need for sustainability, for all persons should be able to live lives that foster the basic needs in order to live comfortably.”

After completion of the lesson, students reflected on the activity through a whole group discussion. They made connections between the water cycle and water sustainability. PSTs had less anthropocentric views of sustainability, and began to consider the role of the environment when meeting the needs of humans. One PST stated, “Science is solving problems and making the world a better place by finding more efficient and safe ways of doing many things (ex: getting clean drinking water to those in 3rd world countries without destruction of the natural habitat.).” By making minor changes to currently existing lessons, teachers can use issues of sustainability to provide students with the opportunity further investigate current scientific ideas.

Later in the semester, PSTs highlighted the modeled water cycle lesson as an experience that positively impacted their understanding of science teaching and learning. One PST reflected, “I thought the water cycle was always represented as a circular cycle and that was correct because it was in the science text book. After participating in a 5E lesson about the water cycle I realized that that was yet another misconception I had regarding science.” Another PST stated, “I learned that there was no freshwater in St. Pete, even though I originally grew up there for most of my life. (I found out) water is brought (there) by way of rain.” In addition, PSTs referenced this activity as evidence for their ability to critically evaluate published images and model scientific inquiry.

Evidence gathered via discussions and work samples suggest EfS instruction in preservice science teacher classrooms can be effective in communicating the desired goals of sustainability education, greater scientific understandings of water sustainability, and the ability to use scientific models to explain and predict natural phenomena. We found that after implementation of instructional materials PSTs were more likely to reflect critically on issues of sustainability beyond impacts on the natural world. PSTs reflected on impacts to the environment and related societal issues, including political policies, economic hardship, technological advances, education, and access. They also demonstrated a better understanding of complex science concepts related to the water cycle and were able to make connections between the natural water cycle and the influence of sustainability issues. At the end of the semester, PSTs included this 5E lesson—specifically scientific modeling and issues of EfS as evidence of their learning.

Additional evidence to support the inclusion of EfS topics in science methods courses for PSTs comes from the final course assignment. The purpose of the assignment was to create a collection of work to demonstrate evidence, which supported their progress toward achieving course goals. Without prompting, we found that of the 60 students that took part in the lesson, 15 PSTs included examples of greater understanding of science content, scientific modeling, and issues of EfS through the water cycle lesson as an artifact.

Conclusion

In our ever-changing world, it is becoming increasingly important for students to have a greater understanding of the Earth and the significant impact that humans have on its natural systems. Incorporating issues of sustainability into curriculum instruction can promote essential critical thinking, communication and collaboration skills with peers, and student engagement with instructional material. EfS instruction can also help connect students to their communities and further inspire citizenship, all while preparing them for the challenges of teaching the 21st century learner (Church & Skelton, 2010). This activity does so by connecting students’ prior knowledge of the water cycle with current issues of sustainability that impact human lives both locally and globally. Through engagement of critical thinking, group discussion, and critiquing of existing curriculum materials, PSTs were exposed to new

ideas about the water cycle and impacts on living organisms that inspire them to look critically at the types of instructional materials available to them and the way in which they teach elementary students.

Supplemental Files

Go-To-the-Head-of-the-Cloud-Student-Page.pdf

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