

RYAN S. NIXON, SOPHIE K. HILL



ABSTRACT

In this paper we present a flood of new water cycle resources created by a team of scientists, educators, and creatives to address existing limitations in water cycle resources. These resources can be used to add more details to your instruction, add context to the water cycle, be more intentional about including humans, and teach science literacy skills.

Key Words: resources; water cycle.

○ Why do we need to revamp water cycle education?

Water is critical for human existence. Women and children walk miles to collect it and political battles are fought to secure it. You interact with water daily and as you read this article, there is almost certainly water somewhere nearby. Our daily lives are influenced by, and influence, the quality and availability of water.

Nonetheless, humans are often omitted from instruction related to water issues such as the water cycle, hydrosphere, or Earth's resources. What students are expected to learn and do related to these topics are captured in Next Generation Science Standards performance expectations MS-ESS2-4; 5-ESS2-1; and 5-ESS2-2, 5-ESS3-1 (NGSS Lead States, 2013). In an analysis of hundreds of water cycle diagrams, researchers found that representations almost universally omit water quality, less-visible water sources (e.g., groundwater), changes in climate, and the presence of humans altogether (Abbott et al., 2019). Considering how the water cycle impacts humans and how humans impact the water cycle, it is crucial to reconsider and improve how water issues are taught (e.g., Forbes et al., 2015). One important step in making these improvements is by improving the water cycle resources used in classrooms. In this paper we present a collection of new water cycle resources and present ways these resources could be used in classrooms, particularly in middle school grades.

○ What makes these resources different?

This collection of water cycle resources was created by a team of scientists, educators, and creatives to address limitations of existing resources. Specifically, these resources

1. show water from a human perspective, focusing on ground-level views of water on a landscape;
2. highlight where water is hidden, such as groundwater, atmospheric rivers, and virtual water use; and
3. emphasize the interactions of humans and water, including issues of water quality.

○ How can you use these resources?

We have shared these resources with teachers and observed how they were used. From those observations, we noticed four ways teachers use the new resources.

Adding Details

Teachers use these improved water cycle resources to add important details to their instruction. Water cycle instruction can become focused on the three most basic processes—evaporation, condensation, and precipitation. However, this leaves out important processes such as transpiration and infiltration, which are essential to replenishing water supplies in our aquifers and reservoirs. Because many of the new water cycle resources include these processes, we found that teachers added these details into their instruction.

For example, the “Water Cycle Vocabulary” (Figure 1) poster could be used in a middle school class to help students have a more detailed understanding of the water cycle (MS-ESS2-4). This poster includes the processes of transpiration and infiltration—important processes in the water cycle that are often glazed over in instruction—alongside precipitation, condensation, and evaporation. This poster also includes details about what is happening in each process at the molecular level. For example, water droplets are shown gathering around a piece of dust or ash in the box for condensation. The box for evaporation indicates that water can be less than boiling

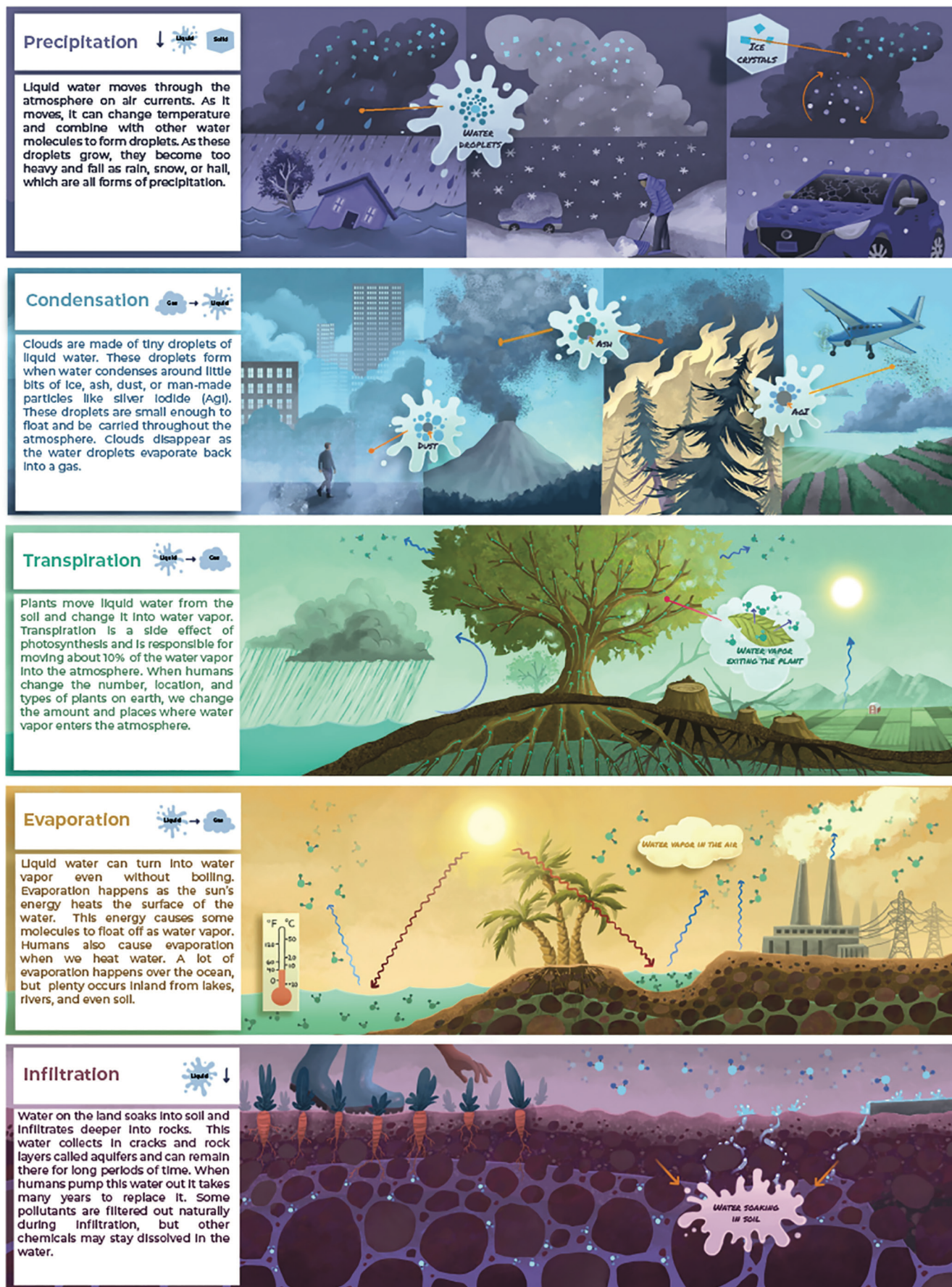


Figure 1. The Water Cycle Vocabulary poster shows five common water cycle terms and includes human interaction and influence on each process.

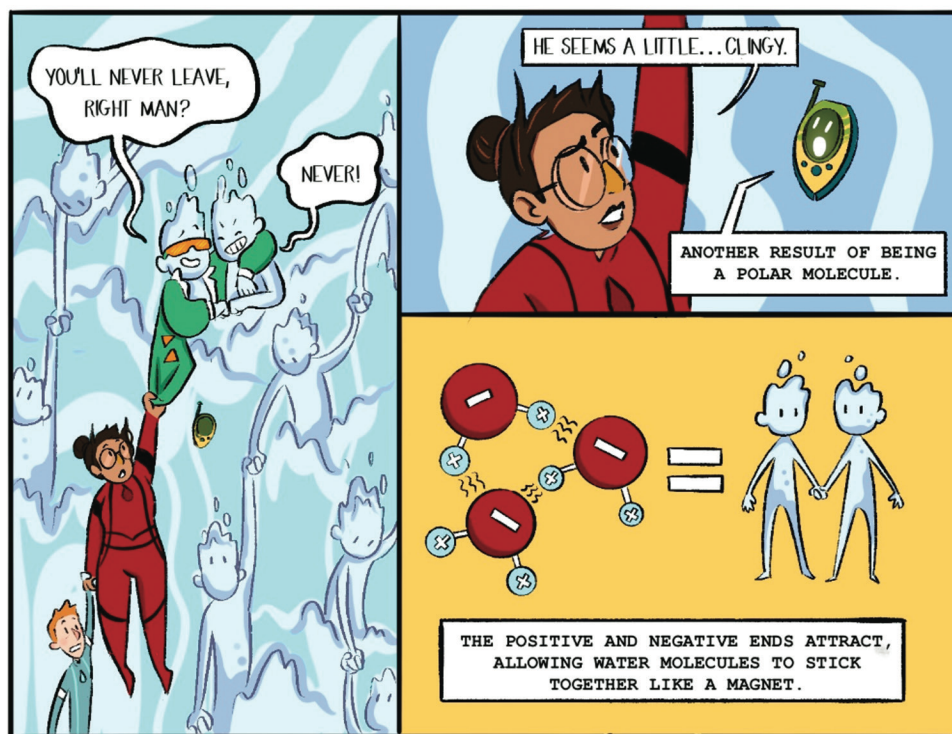


Figure 2. One image from the Camp C.O.R.E. graphic novel showing a personification of water.

temperature when evaporation occurs. These details are an important part of helping students meet the performance expectation's (MS-ESS2-4) emphasis on changes of state.

Another resource for helping students learn more detail about water issues is the Camp C.O.R.E. graphic novel (Figure 2), which includes two chapters on the water cycle (related to MS-ESS2-4). These chapters capture important details about the unique properties of water by presenting a personification of water. Details about the sun as a driver of the water cycle and specific water landscapes are also included. Additionally, the Camp C.O.R.E. graphic novel highlights interactions humans have with water and climate, an important part of performance expectations such as 5-ESS2-2 and 5-ESS3-1.

Add Context to the Water Cycle

Teachers can also use these new water cycle resources to help students see the water cycle in context. Water cycle diagrams often portray the water cycle occurring at a generic, unknown location that students have never experienced. By identifying the water cycle in contexts that are familiar to them, students are more likely to see how their lives influence and are influenced by the water cycle. In addition to helping students understand the processes involved in the water cycle (MS-ESS2-4), these can also help students see how humans can influence “Earth’s resources and environment” (5-ESS3-1).

The “Where is the Water?” series (Figure 3) is one resource that helps contextualize the water cycle. This series shows the water cycle occurring in six different landscapes students may experience from the perspective of a human standing on the ground. These include a farm (agriculture), a coastline overlook (coastal), a desert viewpoint (desert), a campsite in the forest (forest), a neighborhood park (suburban), and a city street (urban). In the urban poster (Figure 3A) we see water moving on pavement and in pipes as it is used

in a home. This is very different from the decontextualized scenes often portrayed in water cycle diagrams. These posters highlight the locations of water and state changes involved with moving among locations in a specific context.

More Intentional About Humans

It is important to be more intentional about highlighting the role of humans in the water cycle. Water cycle diagrams that include humans make it easier to include ourselves as part of that conversation. Our initial work with teachers has found that simply including humans in water cycle diagrams made students more likely to identify the role of humans in the water cycle (Hill et al., 2022).

The “Simple Water Cycle” diagram is very similar to traditional basic diagrams (Figure 4). A major difference, however, is that this resource superimposes the water cycle on a city landscape. This encourages students to acknowledge that the water cycle occurs in settings where humans live. Teachers could then take additional steps to be more intentional about showing the role of humans in each step of the basic water cycle (e.g., piping, storing, and using water).

Teach Science Literacy Skills

Finally, using these diagrams creates an opportunity for teachers to intentionally help students learn science literacy skills. This includes skills for reading visual information, using keys and labels, identifying the role of color coding, and comparing multiple diagrams for strengths and weaknesses. These are skills highlighted in the College and Career Readiness Anchor Standards from the Common Core Standards (National Governors Association Center for Best Practices, 2010) and in the science practice of obtaining, evaluating, and communicating information (National Research Council, 2012). Both documents highlight the importance of students being able to understand information from visual representations.

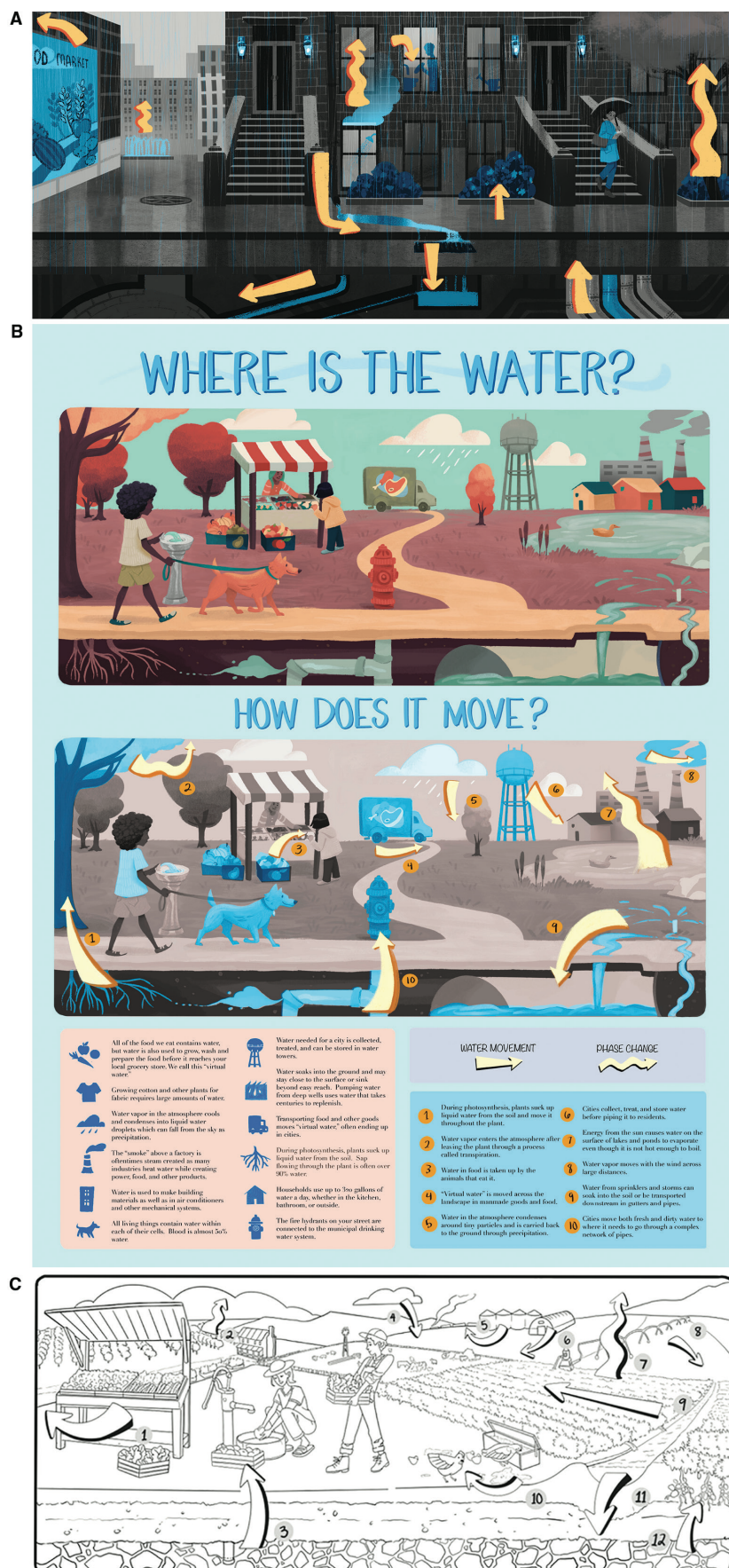


Figure 3. The Where is the Water? series shows where water is located and how it moves on six landscapes. (A) Blue shading highlights water locations, yellow arrows show how water moves. (B) The full poster contains additional information about the types of movement and where they occur. (C) Black and white versions of each image are available.

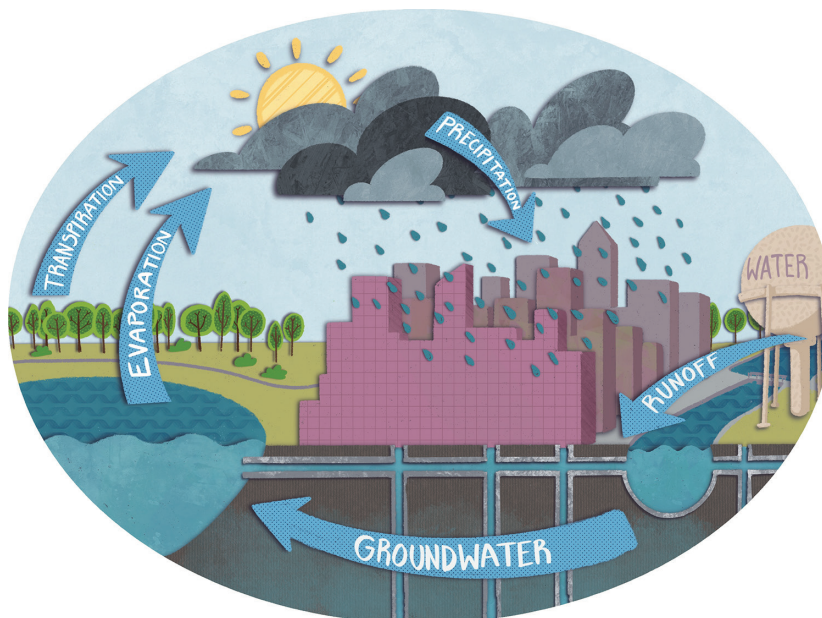


Figure 4. The Simple Water Cycle shows the basic processes of the water cycle on a city landscape.

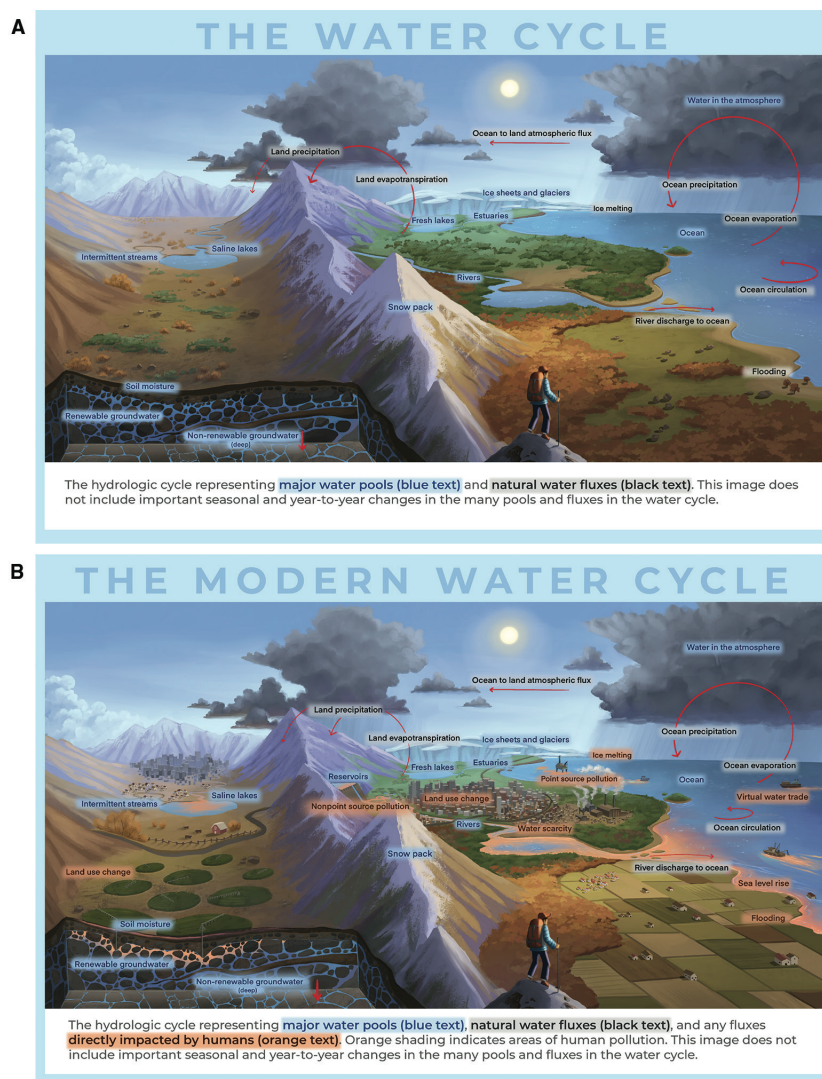


Figure 5. The Modern Water Cycle posters show a landscape without human impact (A) and a landscape explicitly showing human impacts (B).

Teachers could use the “Modern Water Cycle” posters (Figure 5) to teach this science practice and associated literacy skills. For example, this diagram includes labels that are color coded (e.g., places impacted by humans are highlighted orange; Figure 5B). The idea that these colors are both intentional and meaningful is an important literacy skill, as captured in the statement that students should “integrate and evaluate content presented in diverse formats and media” (National Governors Association Center for Best Practices, 2010, p. 35). Connecting highlighted words with the colors on the landscape is also important—the segments shaded orange correspond with the labels that are highlighted orange.

○ Conclusion

As a final note, these water cycle resources have been designed for use by teachers. They were developed to align with concepts and skills taught in schools and are open-source, freely available at watercycle.byu.edu. This website includes full posters for those who want to project or print the entire resource. The website also includes individual images for teachers who want to project or print just one segment of the resource. In addition, there are black and white versions of most images (see Figure 3C) to enable printing by teachers who do not have easy access to color printing. We hope these resources will support educators seeking to teach a more accurate water cycle with humans as active participants who depend on this global cycle to thrive.

References

- Abbott, B. W., Bishop, K., Zarnetske, J. P., Minaudo, C., Chapin, F. S., Krause, S., Hannah, D. M., Conner, L., Ellison, D., Godsey, S. E., Plont, S., Marçais, J., Kolbe, T., Huebner, A., Frei, R. J., Hampton, T., Gu, S., Buhman, M., Sara Sayedi, S., & Pinay, G. (2019). Human domination of the global water cycle absent from depictions and perceptions. *Nature Geoscience*, 12(7), 533–540. <https://doi.org/10.1038/s41561-019-0374-y>
- Forbes, C. T., Zangori, L., & Schwarz, C. V. (2015). Empirical validation of integrated learning performances for hydrologic phenomena: 3rd-Grade students’ model-driven explanation-construction. *Journal of Research in Science Teaching*, 52(7), 895–921. <https://doi.org/10.1002/tea.21226>
- Hill, S. K., Xia, Y., Nichols, S., Muncy, E., & Bailey, E. G. (2022). *Creating and testing the effectiveness of new water cycle diagrams that explicitly include human impacts* [Poster presentation]. SABER National Meeting.
- National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common core state standards: English language arts*.
- National Research Council (NRC). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies.
- NGSS Lead States. (2013). *Next generation science standards: For states, by states*. The National Academies.

RYAN S. NIXON (rynixon@byu.edu) is associate professor of science education at Brigham Young University, Provo, UT 84602. SOPHIE K. HILL (sophiehill842@gmail.com) is a post-doctoral researcher in Plant and Wildlife Sciences at Brigham Young University, Provo, UT 84602.

Explore the SHAPES of NUCLEIC ACIDS with

PLAYDNA!™

**Bendy, Twisty, Sturdy.
Like real DNA.**

**Have fun making models:
DNA replication...
Transcription...
Codon recognition...**

*...a lasting asset,
like real DNA!*

Find it in **CAROLINA®**
www.carolina.com

and on **TeachDNA.NET**

ASSESSMENT**SERVICES**

Educationprojects.org
Expert TA

CLASSROOM & LABORATORY SUPPLIES/EQUIPMENT

Cellular Landscape Posters/Diagrams
Carolina Biological Supply Co

DIGITAL CAMERAS

Carolina Biological Supply Co

FIELD STUDY SUPPLIES

Carolina Biological Supply Co
The DNA Store
uHandy Mobile Microscopes

HANDS-ON BIOTECHNOLOGY LABS

ADInstruments
Amino Labs - Biotechnology Education
Bio-Rad Laboratories
Carolina Biological Supply Co
MiniOne Systems
miniPCR bio
uHandy Mobile Microscopes
The Wolbachia Project

HANDS-ON AND MINDS-ON GAMES AND ACTIVITIES

Amino Labs - Biotechnology Education
Biology Magnets LLC
Bio-Rad Laboratories
Carolina Biological Supply Co
TeachDNA LLC

INTERACTIVE LEARNING TOOLS

ADInstruments
American Museum of Natural History
Amino Labs - Biotechnology Education
Animalearn
Biology Magnets LLC
Bio-Rad Laboratories
BIOZONE Corporation
Bone Clones, Inc.
Carolina Biological Supply Co
miniPCR bio
Pivot Interactives
TeachDNA LLC
uHandy Mobile Microscopes
Visible Body
Wisconsin Fast Plants Program

INTERACTIVE PROCESS OF SCIENCE KITS

ADInstruments
Amino Labs - Biotechnology Education
Bio-Rad Laboratories
Wisconsin Fast Plants Program

LABWARE

Carolina Biological Supply Co
The DNA Store
miniPCR bio

MICROSCOPES

Bio Corporation
Carolina Biological Supply Co
Foldscope Instruments, Inc.
uHandy Mobile Microscopes

MODELS (ANIMAL)

Animalearn
Biology Magnets LLC
Bone Clones, Inc.
Carolina Biological Supply Co

MODELS (PLANT)

Biology Magnets LLC
Carolina Biological Supply Co
Wisconsin Fast Plants Program

MODELS (PROTEIN, RIBOSOME & DNA)

Biology Magnets LLC
Carolina Biological Supply Co
The DNA Store
miniPCR bio
TeachDNA LLC

OWL PELLETS / PELLET KITS & SUPPORT PRODUCTS

Bio Corporation
Carolina Biological Supply Co

PREPARED KITS / SLIDES

Amino Labs - Biotechnology Education
Bio Corporation
Bio-Rad Laboratories
Carolina Biological Supply Co
Foldscope Instruments, Inc.
uHandy Mobile Microscopes

PROBEWARE

ADInstruments
Carolina Biological Supply Co

SKULLS & SKELETONS

Animalearn
Bio Corporation
Bone Clones, Inc.
Carolina Biological Supply Co

SPECIMENS (LIVE)

Amino Labs - Biotechnology Education
Carolina Biological Supply Co
Wisconsin Fast Plants Program

SPECIMENS (PRESERVED)

Bio Corporation
Carolina Biological Supply Co
Foldscope Instruments, Inc.
uHandy Mobile Microscopes

STAINS / INDICATORS

Bio-Rad Laboratories
Carolina Biological Supply Co
The DNA Store

TEST KITS

Bio-Rad Laboratories
Carolina Biological Supply Co
miniPCR bio

CLASSROOM TECHNOLOGY/MEDIA**COMPUTER SOFTWARE**

ADInstruments
Amino Labs - Biotechnology Education
Animalearn
Expert TA
Visible Body

GAMES

Carolina Biological Supply Co
Vaccine Makers Project, VEC at CHOP

INTERACTIVE MULTIMEDIA

ADInstruments
Amino Labs - Biotechnology Education
Animalearn
Bio-Rad Laboratories
Carolina Biological Supply Co
LabXchange
Pivot Interactives
Visible Body

ONLINE RESOURCES

ADInstruments
American Society of Plant Biologists
Amino Labs - Biotechnology Education
Animalearn
Carolina Biological Supply Co
Clemson University
The DNA Store
Hudson Alpha Institute for Biology
National Academy of Sciences,
Engineering, and Medicine
LabXchange
Nourish the Future
Vaccine Makers Project, VEC at CHOP
Visible Body
The Wolbachia Project

PROFESSIONAL DEVELOPMENT

Amino Labs - Biotechnology Education
 Biotility
 Educationprojects.org
 LabXchange
 MiniOne Systems
 National Academy of Sciences,
 Engineering, and Medicine
 Nourish the Future
 The Wolbachia Project

PROGRAM STREAMING / DVD

American Society of Plant Biologists
Biotility

TEACHER'S TOOLS

American Museum of Natural History
American Society of Plant Biologists
Amino Labs - Biotechnology Education
Animalearn
Biology Magnets LLC
Biotility
BIOZONE Corporation
Carolina Biological Supply Co
LabXchange
MiniOne Systems
miniPCR bio
National Academy of Sciences,
Engineering, and Medicine
Nourish the Future
TeachDNA LLC
uHandy Mobile Microscopes
Vaccine Makers Project, VEC at CHOP
Visible Body
The Wolbachia Project

VIRTUAL LABS

ADInstruments
Amino Labs - Biotechnology Education
Animalearn
Carolina Biological Supply Co
LabXchange
miniPCR bio
Pivot Interactives
Visible Body

EDUCATIONAL ADVANCEMENT

ADVOCACY

Animalearn
LabXchange
educationprojects.org

ONLINE COURSE / DIGITAL PLATFORM

ADInstruments
American Museum of Natural History
Biotility
BIOZONE Corporation
Clemson University
Expert TA
LabXchange
Visible Body

PROFESSIONAL DEVELOPMENT

American Museum of Natural History
Amino Labs - Biotechnology Education
Bio-Rad Laboratories
Biotility
Clemson University
Educationprojects.org
HudsonAlpha Institute for Biotechnology
LabXchange
MiniOne Systems
miniPCR bio
National Academy of Sciences,
Engineering, and Medicine
Nourish the Future
The Wolbachia Project

STUDENT OPPORTUNITIES

American Museum of Natural History
Amino Labs - Biotechnology Education
Biotility
National Academy of Sciences,
Engineering, and Medicine
Vaccine Makers Project, VEC at CHOP
The Wolbachia Project

TEACHER WORKSHOPS

American Museum of Natural History
Amino Labs - Biotechnology Education
Bio-Rad Laboratories
Carolina Biological Supply Co
Educationprojects.org
LabXchange
MiniOne Systems
Nourish the Future
TeachDNA LLC
The Wolbachia Project

PUBLISHERS

LAB NOTEBOOKS

BFW Publishers
Carolina Biological Supply Co.

SUPPLEMENTARY MATERIALS

ADInstruments
Amino Labs - Biotechnology Education
BFW Publishers
Carolina Biological Supply Co
Expert TA
National Academy of Sciences,
Engineering, and Medicine
Nourish the Future
Pivot Interactives
TeachDNA LLC
Vaccine Makers Project, VEC at CHOP
Visible Body

TEXTBOOK

Amino Labs - Biotechnology Education
BFW Publishers
Bio-Rad Laboratories
BIOZONE Corporation
Expert TA
Kendall Hunt Publishing Company

ADInstruments

4360 Arrowswest Drive
Colorado Springs, CO 80907
719-576-3970
Kaitlynn Arnholt
k.arnholt@adinstruments.com
<https://www.adinstruments.com>

American Museum of Natural History

Central Park West at 79th Street
New York, NY 10024
212-496-3632
Rob Steiner
rsteiner@amnh.org
Learn.amnh.org

American Society of Plant Biologists

15501 Monona Drive
Rockville, MD 20877
301-251-0560
Shoshana Kronfeld
info@aspb.org
aspb.org



Amino Labs - Biotechnology Education

93005 RR 210
Lethbridge, AB
Canada
1-647-234-4869
Julie Legault
julie@amino.bio
www.amino.bio



Animalearn

801 Old York Road
Suite 204-A
Jenkintown, PA 19046
800-729-2287
Alisa Brooks
abrooks@animalearn.org
www.thesciencebank.org

BFW Publishers

100 American Metro Boulevard
Suite 109
Hamilton, NJ 08619
866-843-3715
Thomas Menna
hsmarketing@bfpwpub.com
<https://www.bfpwpub.com/high-school/us>

Bio Corporation

3910 Minnesota Street
Alexandria, MN 56308
320-763-9094
Rebecca Hedstrom
info@biologyproducts.com
www.biologyproducts.com

Biology Magnets LLC

PO Box 20388
St. Simons Island GA 31522
912-222-6797
Tom Willis
biologymagnets@gmail.com
www.biologymagnets.com

Bio-Rad Laboratories

1000 Alfred Nobel Drive
Hercules, CA 94547
1-800-424-6723
Saswat Patnaik
explorer@bio-rad.com
explorer.bio-rad.com

Biotility

14193 NW 119th Terrace
Suite 20
Alachua, FL 32615
352-432-3181
Tamara Mandell
biotility@research.ufl.edu
biotility.research.ufl.edu



BIOZONE Corporation

18801 E. Mainstreet
Suite 240
Parker, CO 80134-3445
Toll Free: 855-246-4555
<https://biozone.com/>
info@biozone.com

Bone Clones, Inc.

9200 Eton Avenue
Chatsworth, CA 91311
800-914-0091 or 818-709-7991
Jeffery Shaw
sales@boneclones.com
www.boneclones.com



Carolina Biological Supply Co

2700 York Road
Burlington, NC 27215
800-334-5551
Melissa Hodges
melissa.hodges@carolina.com
www.carolina.com



Clemson University Biological Sciences

132 long Hall
230 Parkway Drive
Clemson, SC 29634
864-656-2153
Terrie Jarrett
tjarret@clemson.edu
<https://www.clemson.edu>



The DNA Store

15270 Pleasant View Drive
Colorado Springs, CO 80921
719-258-8771
Doug Lundberg
lundberg@thednastore.com
www.thednastore.com

Educationprojects.org

1926 Chatfield Road
Columbus, OH 43221
313-995-1972
Susan Sherer
susan@educationprojects.org
www.educationprojects.org

Expert TA

624 South Boston Avenue
Tulsa, Ok 74119
918-949-4190
Jack Cameron
jack@theexpertta.com
https://theexpertta.com/biology

Foldscope Instruments, Inc.

2525 Middlefield Road #938
Palo Alto, CA 94306
628-400-3653
Ken Ta, Director of Sales
sales@foldscope.com
www.foldscope.com

**HudsonAlpha Institute
for Biotechnology**

601 Genome Way NW
Huntsville, AL 35806
256-327-0400
Educational Outreach
edoutreach@hudsonalpha.org
www.hudsonalpha.org

Kendall Hunt Publishing Company

4050 Westmark Drive
Dubuque, IA 52004
563-589-1075
Lynn Steines
lsteines@kendallhunt.com
https://k12.kendallhunt.com

**LabXchange**

Harvard University
114 Mount Auburn Street
Suite 200
Cambridge, MA 02138
617-384-0360
Nicole Sjoblom
nicoles@labxchange.org
www.labxchange.org

MiniOne Systems

7738 Arjons Drive
San Diego, CA, 92126
858-684-3190
Erika Fong
info@theminione.com
www.theminione.com

miniPCR bio

1770 Massachusetts Avenue
Suite 167
Cambridge, MA 02140
781-990-8727
Ezequiel Alvarez Saavedra
team@minipcr.com
www.minipcr.com

**National Academy of Sciences,
Engineering, and Medicine**

500 5th Street NW
Washington, DC 20001
800-624-6242
Zina Jones
zjones@nas.edu
www.nap.edu

Nourish the Future

1926 Chatfield Road
Columbus, OH 43221
888-737-0485
Susan Sherer
connect@nourishthefuture.org
nourishthefuture.org

Pivot Interactives

4350 Congress Street
Suite 700
Charlotte, NC 28209
651-238-9175
Peter Bohacek
info@pivotinteractives.com
https://www.pivotinteractives.com

**TeachDNA LLC**

1628 Madrona Drive
Seattle, WA 98122
731-540-2545
Morgan Goulding
mqg@TeachDNA.NET
www.TeachDNA.NET

**uHandy Mobile Microscope**

11-1F, No.171, Sec.3, Roosevelt Road
Daan Dist., Taipei City, Taiwan 10647
Jolanda Hsu
+886-2-2368-5358
service@loveuhandy.com
https://uhandy.cc/US

**Vaccine Makers Project,
VEC at CHOP**

Children's Hospital of Philadelphia,
Vaccine Education Center
3401 Civic Center Boulevard, Roberts
Center, 9th Floor
Philadelphia, PA 19104
215-590-9990
Vaccine Makers Project Team
vacinfo@chop.edu
https://vaccinemakers.org

Visible Body

492 Old Connecticut Path, Suite 501
Framingham, MA 01701
617-527-9999
Courtney Smith
courtney.smith@visiblebody.com
www.visiblebody.com

Wisconsin Fast Plants Program

Department of Plant Pathology
University of Wisconsin-Madison
Dan Lauffer
Info@fastplants.org
www.fastplants.org

The Wolbachia Project

Pennsylvania State University
Millennium Science Complex
Pollock Road
University Park, PA 16802
814-865-1152
Sarah Bordenstein
srb6253@psu.edu
https://wolbachiaproject.org



BIOZONE

Unlock the Power of your Science Curricula with BIOZONE!

Student-Centric Design:

Concise text, annotation features, and engaging infographics promote active learning and comprehension.

Student Interaction:

Captures student responses as a 'record of work', reinforcing the learning moment and enabling self-grading.

Rigorous and Engaging:

Achieve academic excellence while keeping students captivated by the interactive content.

Accessibility Features:

Text-to-translation tool and resources for visual learners empower students with diverse needs.

Real-World Examples:

Infuse your classroom with real-world data and regularly-updated content.

Adaptable Design and Flexible Format:

Seamless transition between print and digital ensures adaptability to multiple teaching environments and diverse teaching styles.

BIOZONE distinguishes itself through its innovative instructional features, student-centric approach, and a focus on engagement and accessibility. This comprehensive package makes BIOZONE a standout choice for educators seeking a dynamic and effective science curriculum.

For more information visit our website:



info@BIOZONE.com www.BIOZONE.com/us 855.246.4555