LESSON PLAN Prepared for River Field Studies Network

Title: A STEAM Approach to Investigating the Hydrologic Cycle

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Abstract: The purpose of this experiential lesson is to teach introductory to mid-level undergraduate students how to make detailed hydrologic field observations and transform them into visual representations, similar to a conceptual model. Students should have prior knowledge about the hydrologic cycle and the hydrologic budget. The lesson contains three parts. Part I is the field component where students develop observational skills in the field. Students make detailed observations about key processes of the hydrologic cycle near a river while canoeing, kayaking, or hiking. Students document these observations through writing and sketching. Part II is an outdoor art-lab lesson where students review the hydrologic cycle, critically think through the intersection of science and art, and are introduced to conceptual models. They will take their observations and sketches from Part I and create a painting to further explore one of five processes of the hydrologic cycle. Part III is a post-lesson written assignment that provides an opportunity for students to reflect on their experience and demonstrate their knowledge about the hydrologic cycle in relation to the local hydrology. Equipment needed include a field notebook, paints, a canvas, and handouts. This lesson would be well-suited to an introductory earth science, hydrology, or hydrogeology course and can be helpful when introducing the concept of scientific models. The lesson can be applied across different rivers, regions, stratigraphy, etc. Alternatively, the lesson format and painting practice could be applied to explore content other than the hydrologic cycle. The primary benefit of this lesson is that it gives students the opportunity to integrate their field experience, explore their conceptualization of complex processes, and communicate that understanding visually.

Tags/Keywords: Hydrologic cycle, hydrology, hydrogeology, field studies, field observations, STEAM, art, painting

Instructor Notes:

1. Target audience level

This lesson is targeted at introductory to mid-level undergraduate students in earth science, hydrology and/or hydrogeology. Students should have prior knowledge about the hydrologic cycle and components of the hydrologic budget. They should also be comfortable exploring their own creativity through the medium of paint.

2. <u>Summary of the lesson</u>

The purpose of this experiential lesson is to teach introductory to mid-level undergraduate students how to make detailed hydrologic field observations and transform them into visual representations, similar to a conceptual model. Students should have prior knowledge about the hydrologic cycle and the hydrologic budget. The lesson contains three parts. Part I is the field component where students develop observational skills in the field. Students make detailed observations about key processes of the hydrologic cycle near a river while canoeing, kayaking, or hiking. Students document these observations through writing and sketching in a field notebook. Part II is an outdoor art-lab lesson where students review the hydrologic cycle, critically think through the intersection of science and art, and are introduced to conceptual models. They will take their observations and sketches from Part I and create a painting to further explore one of five processes of the hydrologic cycle. Part III is a post-lesson written assignment that provides an opportunity for students to reflect on their experience and demonstrate their knowledge about the hydrologic cycle in relation to the local hydrology. By the end of the lesson, students will have a deeper cognitive and tactile understanding of hydrologic processes. Equipment needed include a field notebook, paints, a canvas, and handouts. This lesson would be well-suited to an introductory earth science, hydrology, or hydrogeology course and can be helpful when introducing the concept of scientific models. The lesson can be applied across different rivers, regions, stratigraphy, etc. Alternatively, the lesson format and painting practice could be applied to explore content other than the hydrologic cycle. The primary benefit of this lesson is that it gives students the opportunity to integrate their field experience, explore their conceptualization of complex processes, and communicate that understanding visually.

3. Student context factors

Worldview – Depending on a student's worldview, they may relate to science or art and/or identify as a scientist or artist more readily. Given the perceived separation between art and science in society, this lesson offers the students the opportunity to reflect on their perception of art and science and how art can help to inform science and vice versa.

Interests - Students that enjoy experiential learning and inter- and transdisciplinary studies will enjoy this lesson, as will students with a strong connection to nature, appreciation of the outdoors, and/or interest in exploring art. Students that are more specialized in their interests, have little experience outdoors, and/or little interest in art may struggle to relate to this lesson given their unfamiliarity/discomfort and the broad topic of focus. Students with different capabilities can participate in this activity by focusing on the senses accessible to them. The instructor should adjust the evaluation component of this lesson accordingly.

Identity - Students who identify as "observant" and/or "creative" may have an easier time connecting to this lesson. Students who do not identify as "observant" or "creative" will be challenged to test that self-identity. Students who link science to specialization, or art to quality rather than quantity will be challenged. This lesson is taught from a STEAM perspective equalizing the value of science and art and showcasing how art can inform scientific methods.

Prior knowledge and skills - Students should have prior knowledge about the hydrologic cycle and the different components of the hydrologic budget. This will prepare them to be able to make observations about the components of the hydrologic processes in the field. Student should also have a basic understanding of the scientific process. Students will need to have an open mind and willingness to try new experiences as this lesson is not a standard lesson included in scientific courses.

Motivation and expectations – This lesson may be difficult because many students may be more "technically" inclined and may have little experience with art, expression, experiential learning or reflection on tactile experiences. Communicating that this experience may be different but is an opportunity for them to explore another aspect of themselves and/or ways of relating to the world can be helpful. It is also helpful to have them observe their own discomfort and encourage them to reflect on it. Ultimately, the lesson may facilitate students' connection to creativity.

Prior Experiences - Previous experience with field studies and art is advantageous, but not mandatory. Students who have prior experience learning - or the desire to learn - scientific concepts outdoors are well-suited to this lesson. Students with an art background will have an easier time applying the painting medium to communicate concepts.

Personal Needs – Oftentimes, scientific students may identify as "not artistic." The instructor needs to be aware that some students may struggle with being open to painting if they do not have prior experience and may need additional attention. Students who do not have prior experience in the field may also need additional attention.

4. Approach to engagement

- Engage The lesson engages the students' sensory perceptions (sight, sound, smell, and touch) in the process of observing. The student then engages with writing and sketching these observations. The student engages their imagination in the process of transforming these observations into a visual understanding of a hydrologic process.
- Explore The lesson explores the preconceptions we have about science, art, and human/water interactions. What assumptions do we make about science and scientists? Art and artists? How do we understand the hydrology budget? Have students made close observations about individual components of the hydrologic budget? Students may become aware of their biases about art/science and/or how their level of experience making detailed observations in nature. Students also explore hydrologic processes more deeply, paying attention to fine details and how that affects their understanding.
- Explain The lesson explains how field studies, hydrology, and art can be complementary by showcasing how we can better understand the hydrologic cycle, hydrologic budget components, and/or surface water and groundwater systems through the process of painting. We may be able to recognize holes in our understanding during the painting process. Similar to conceptual or quantitative models, a painting can help us learn about a system in part by showing us what we do not know. It also showcases how assumptions about art and science can prevent us from experiencing the value of its integration for learning and developing a deeper understanding of systems.
- Elaborate the lesson gives students the opportunity to elaborate on their understanding of the hydrologic budget and the ways that human activities may impact water systems. It also allows students to elaborate on the connection between science and art and how those concepts relate to their identity. Through group discussion and a

follow-up writing assignment they can demonstrate their ability to integrate what they have learned.

5. Evaluate

This lesson evaluates students' ability to make observations with their sensory perceptions, document them, reflect on them and integrate that understanding through an art practice and shared group discussions. Ultimately, the lesson helps to foster awareness about our perceptions and understanding of hydrologic processes. It also evaluates a students' ability to connect the perceived societal divide between art and science and provides an opportunity for students to explain how they see art as part of/not part of the hydrologic scientific process. After this lesson, students may think about how they can incorporate art into scientific studies whether through conceptual models or communication of concepts through figures.

6. Materials needed

Part I: Field Excursion

- Journal
- Pen/pencil
- List of questions for reflection written in their journal

Part II: Discussions, lecture and art-lab

Discussions and lecture

- Flip chart and stand (instructor)
- Markers (instructor)
- Handouts (2) (instructor)
- Paper (student)
- Pen/pencil (student)
- Seating e.g., picnic table, chairs, blankets (student)

Art lab painting practice

- Acrylic paint (5+ colors)
- Paint brushes (range of sizes)
- Canvases (suggested 8" x 10" OR 10" x 12")
- Paper towels
- Cup for water
- (Optional) blankets for students to sit on ground

Part III. Written reflection paper

- Paper copy or electronic version of written reflection paper assignment
- Computer access for students to type written reflection papers

7. Further reading for the instructor

- Benesch, O. 1943. Leonardo da Vinci and the beginning of Scientific Drawing. *American Scientist*, 31(4), 311–328. <u>http://www.jstor.org/stable/27826007</u>
- Doherty, J. and Simmons, C. 2013. Groundwater modelling in decision support: reflections on a unified conceptual framework. *Hydrogeology Journal*. 21, 1531–1537.
- Elliott, K. 2022. Values in Science: How can we manage values in science responsibly? Chapter 4. Cambridge University Press. DOI: 10.1017/9781009052597
- Gurnon, D., Voss-Andreae, J., and Stanley, J. 2013. Integrating art and science in undergraduate education. *PLOS Biology*, *11*(2), e1001491. https://doi.org/10.1371/journal.pbio.1001491
- Healy, R.W., Winter, T.C., LaBaugh, J.W., and Franke, O.L. 2007. Water budgets: Foundations for effective water-resources and environmental management: U.S. Geological Survey Circular 1308, 90 p.
- Perignat, E., & Katz-Buonincontro, J. 2019. STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity*, *31*, 31–43. <u>https://doi.org/https://doi.org/10.1016/j.tsc.2018.10.002</u>
- SciArt Initiative: <u>https://www.sciartmagazine.com/integrating-art-and-science-perspectives-from-a-professor-and-a-student.html</u>

Learning Outcomes:

- Field skills. Students will demonstrate the ability to make detailed field observations.
- *Scientific*. Students will be able to describe the five processes of the hydrologic cycle and how they apply to a local river.
- Interdisciplinary. Students will be able to compare and contrast the methods of scientific data collection to methods of data collection for art.
- Interdisciplinary. Students will be able to describe how art can inform scientific investigation.
- Scientific. Students will be able to define a scientific conceptual model.
- *Scientific*. Students will demonstrate how to transform their observations and conceptual understanding of hydrologic cycle processes into visual representations.

Assessment of Learning Outcomes: The student will deliver: 1) field observations, 2) a painting, 3) a verbal presentation of painting, and 4) a 2- to 3-page written reflection.

Deliverables	Stage/purpose	Prompts	Rubric
Field observations	Part I: Pre- assessment used to document students' observations and reflections	See Handout 1	Did they complete 3 journal entries and 3 sketches? Did each entry provide an observation about a hydrologic process?
Painting	Part II: Embedded assessment	See Handout 3	Did the student complete the painting? Did they use the entire canvas? Did the painting answer the question prompts and build on concepts related to their journal entries/sketches?
Verbal presentation of painting (1-2 min)	Part II: Embedded assessment to practice speaking in group settings	Describe what process you chose to focus on. What were the key factors affecting the process? What are key characteristics of the process? What, if any, scientific insights did you have during the process of drawing and painting?	Did the student present and share a scientific insight?
Written reflection paper	Part III: Summative	See Handout 4	Does the written reflection contain these three components: 1) a detailed description of the painted hydrologic process of focus, 2) specifics about this process in the local hydrology, and 3) how the painting practice affected their scientific understanding.

Assessment of this lesson is achieved with multiple deliverables:

Lesson Content: Procedure

Part I. River observations: reflections in field journal (total time: 1 hr + travel time)

Students should be provided with a field notebook for recording field observations. This field notebook could be used for other lessons in addition to this one. Prior to the field exercise, distribute the "Field Notebook Prompts and Questions" and "Prior Knowledge" handouts to students.

During the field component of the lesson, students should make at least three observations of hydrologic cycle processes in their notebooks at various points on the river with different surroundings each time. Students should be provided at least 20 minutes for each observation and sketch exercise. Students should be told that these observations and reflections will be referenced during Parts II and III of the lesson when they create a painting and a written reflection paper, respectively.

The total time for students to conduct field observations is suggested to be no less than one hour. Total time for this activity will greatly vary depending on distance from starting location to field site, type of field experience (day trip or multi-day trip), etc. Instructors should account for travel time specific to their circumstances in addition to the field observation time.

Part II. Science-art lab (total time: 3 hrs)

Logistics

To conduct this lesson, you will need an outdoor space that can accommodate seating for students to gather for a group discussion and listen to a short lecture. Students should bring their field notebooks and have a place to sit where they can take notes. At the beginning of the lesson, they should be given the following handouts: Venn Diagram Comparison of Data Collection for Art and Science, Painting Prompts, and Homework Description.

After the lecture, students will disperse in groups of two or three (depending on the availability of paint supplies) to work on their paintings. Seating could be on the ground, a picnic table, a bench, etc. If students are sitting on the ground, make sure they have blankets to sit on if there are insects (e.g., fire ants) or other sources of discomfort or distraction. Students should be provided all art supplies.

After the painting practice, the group will reconvene in the original gathering space for individual presentations and a group discussion.

Overview of Part II: Outline and Timing

- 1) Introduction and group discussion (10 min)
- 2) Lecture (20 min)
- 3) Painting practice (2 hrs)
- 4) Individual presentations (15 min)
- 5) Group discussion (15 min)

Step 1: Introduction and group discussion (10 min)

Introduction & group discussion

Once everyone is seated in the gathering space, provide an overview of the art-lab session including a description of the learning objectives.

Ask several students to describe their experiences with field observations of hydrologic processes. What processes did they focus on? What did they learn? Was sketching helpful for understanding or remembering concepts?

Describe how science was considered closely related to art in Europe during the Renaissance, as exemplified by Leonardo da Vinci. He combined exploration of the natural world with artistic expression (e.g., drawing, painting, and sculpture). More recently, science and art have been bifurcated with science usually seen as rational and analytical and art often considered subjective and emotional. Encourage the students to critically think about the similarities and differences by posing the questions below to the group and filling in the Venn diagram during the discussion. You may want to have a large poster board with a Venn diagram to fill out during the student discussion. Students should take notes of the class discussion on their handouts to help them with their written reflection homework.

To start the discussion, ask the students: What is art? What is science?

Use a Venn Diagram for comparison (use poster board if available):

• What are ways of collecting data/gathering information for science and art?

Additional questions you can pose during this discussion:

- What is the role of objectivity and subjectivity in science? In art?
- How would you describe the role of creativity in science? In art?

One point of this exercise is to show that there is significant overlap between how we collect data for art and science because, ultimately, we are human beings using our senses to understand reality. We cannot take away the subjective nature of our observations, but we can aim for objectivity in science by bringing awareness to our subjectivity and potential for bias. In addition, we can use tools and instruments to make our observations less biased.

Another point of this exercise is to talk about how science is often viewed as a passive (observing) process, while art is viewed as active (creating). Here, it is important to talk about how passive/observations and active/creating processes are used for both art and science. For example, the process of data analysis is very active and determining a narrative for understanding the results of an analysis is a creative process. For an art example, critiquing a societal norm requires acute observation and meticulous analysis of others' perspectives to then formulate a representation to create through an artistic means.

End this discussion talking about parts of the scientific process that may involve artistic skills. These include, but are not limited to, the creation of conceptual diagrams, understanding key principles and concepts, and communicating results as figures. The focus today is to explore scientific concepts with painting, similar to developing a conceptual model as will be discussed.

Step 2. Lecture - Connection of science, art, and creativity (20 min)

- Describe the scientific process.
 - Six steps: 1) observe a phenomenon and then ask a question about the phenomena you observe, 2) conduct background research to learn what is known about the topic, 3) construct a hypothesis, 4) experiment to test the hypothesis, 5) analyze the data from the experiment and drawing conclusions, and 6) communicate the results (reference handout).
- Review the hydrologic cycle, its five key processes, and the hydrologic budget.
 - The hydrologic cycle is the sequence of conditions through which water passes from vapor in the atmosphere through precipitation upon land or water surfaces and back into the atmosphere. It is controlled by five key processes: condensation, precipitation, infiltration, runoff, and evapotranspiration (see handout). These are the processes that you observed (or reflected on) during the field component of the lesson.
 - A water budget is way to account for water movement and change in storage the atmosphere, land surface, and/or subsurface. It allows for evaluation of how climate variability and human activities (e.g. land use change) in one part of the hydrologic cycle affect other aspects of the cycle. It can help develop effective strategies for water resource planning and management. A water budget is similar to balancing your bank account. The rate of change of stored water stored in an area equals the rate at which water flows into and out of the area. (Bank analogy: the total savings in your bank account equals the rate at which money is spent and money is deposited.) In addition, comparing water budgets from different areas can help clarify how different factors, such as geology, soils, and vegetation, affect the hydrologic cycle.
 - The hydrologic budget equation is

$$\Delta S = P - ET + GW_{in} - GW_{out} + Q_{in} - Q_{out}$$

Where

$$\Delta S$$
 is the change in storage in,
P is precipitation into,
ET is evapotranspiration out of,
GW_{in} is groundwater into,
GW_{out} is Groundwater out of,
Q_{in} is surface water into, and
Q_{out} is surface water out of the control volume.

- Describe how models are used to study these systems and developing a concept model is the first part of the process.
 - The scientific process for hydro(geo)logic systems is complex and involves investigating many variables that change over time. Because components of the hydrologic cycle are difficult to measure, we often must make assumptions about things we do not know and/or cannot see (e.g., the subsurface and its characteristics). In addition, due to the complexity of hydrologic processes, hydrologists must limit the spatial area of focus and number of variables under investigation to simplify studies – all without leaving out variables critical to the scientific question. Simplification requires a quantitative understanding of how water will interact with the predominant features in the landscape and built environment.

- Hydrologic and hydrogeologic models help to understand phenomena and systems, when other strategies (e.g., direct experimentation and observation) are impractical, impossible, or complex.
- Hydro(geo)logic models can be physical, mathematical, or computational.
 - i. A physical model is a constructed copy of an object that is designed to represent that object. It can be scaled (with same proportions) so that it is smaller or larger than the real object of study.
 - ii. A mathematical model is at best an approximation to the physical world. Such models are constructed based on certain conservation principles and/or empirical observations
 - iii. A computational (or numerical) model is a computer simulated approximation of a mathematical model.
- A conceptual model is the first step in the process of developing any model. A conceptual model is a schematic description of a system, a theory, or a phenomenon that is based on a scientist's experience, education, understanding, intention and attitude and is used to inform the development of a quantitative model. It helps to determine what is known about a topic, can aid the development of hypotheses, and can also highlight gaps in knowledge. To develop a conceptual model, you must have a basic understanding of a system (e.g., what are the primary inputs and outputs? What are the primary factors affecting the system? Is the system changing over time?).
- Explain that we often need experience and field knowledge of an area prior to developing a conceptual model in hydrology.
 - The primary method for increasing knowledge of a hydrologic system is to spend time in the field. (This is why we conducted detailed observations and sketches in Part I of this lesson.) Making field observations in systems with different hydrologic properties can help scientists develop intuition about landscapes of study.
 - The next steps for developing a conceptual model are to conduct back of the envelop calculations and create diagrams that describe the system of focus.
- Referencing your field observations and sketches, you will now explore your understanding of one of the hydrologic cycle processes that you observed through painting on a canvas, a beginning to developing a conceptual model of this process.

Step 4. Painting practice (2 hrs)

This portion of the lesson is a reflective process that allows for a deeper exploration of hydrologic processes students observed in the field. Students are tasked with painting a one of hydrologic processes that they observed and sketched. This is a painting practice; in other words, it is less about the product and more about the process of learning through painting. Suggest to students that they can think of the painting practice as an opportunity to better understand the hydrologic cycle - building a visual model of their understanding. The painting can reflect back what they know. The painting practice also allows them to discover gaps in their knowledge.

Ask students to:

- Reflect on the observations that they made and choose one hydrologic process of focus (condensation, precipitation, infiltration, runoff, or evapotranspiration)
- Think of the canvas like a window into their understanding of this process.
- Think of the edges of the canvas like the edges of a 2D representation of a control volume illustrating this process
- Paint the primary factors affecting this process (what are inputs and outputs enter your canvas "control volume" from the top, bottom, left and right edges?)
- Paint key characteristics of this process in the area that you observed
- Use the entire canvas; fill the canvas to the edges

This practice is not about painting something beautiful. There is no right or wrong way to paint. The painting could be literal or abstract. The main criteria that the student must follow is to explore one of five hydrologic processes.

Step 5. Individual presentations and group discussion (30 min)

Have each student share their experience of field observation and painting with the group. Each individual has 2-3 minutes. As them to:

• Describe what hydrologic process they chose to focus on. What were the key factors affecting the process? What are key characteristics of the process?

If students are comfortable, display the paintings in a group showcasing the diverse spatial scales, perspectives, and processes of focus. Have a group discussion focused on the following questions:

- What, if any, scientific insights did you have during the process of drawing and painting?
- How did painting affect your understanding of the hydrologic cycle?

Part III. Written reflection (post-lesson)

Students should be physically or electronically given a hand-out describing the criteria for their 2- to 3-page reflection paper. Students will need access to a computer. For reflection paper details, see the handout.

The reflection paper can be introduced by describing the following: we have practiced bringing awareness to our observations and documenting these observations in field notebooks. Complete a 2-page written reflection focusing on the following prompt:

- Describe the hydrologic cycle process that you focused on in your painting in detail including some of the observations that you made in the field.
- Research how this hydrologic process occurs in the local hydrology. For example, how does this process change on an annual, seasonal, and daily basis? What is an equation that estimates the process?
- Explore how painting informed your scientific understanding of this process.

Data Analysis and Interpretation: The paintings and reflection paper will serve as the data analysis and interpretation of the observations.

Links to Other Lessons and Concepts: This lesson is interdisciplinary in nature. The lesson would lend well to a course in environmental science, hydrology, hydrogeology, and/or environmental modeling. This lesson introduces students to integral field aspects that are important for computational modeling. It helps them develop the observational skills and the intuition necessary to make critical decisions about a hydrologic or hydrogeologic conceptual model. Quantitative skillsets can be the focus of subsequent lessons. The lesson can be adapted to any place that has a river (or surface water body) that students can interaction with (preferably) over a multi-day period. Consider the ways in which humans have impacted the hydrology in the area of focus and vice versa so that these primary land use changes can be discussed after students share their paintings. Highlighting the prominent land use changes may help them in their reflection papers.

Further Reading for the Student

- Benesch, O. 1943. Leonardo da Vinci and the beginning of Scientific Drawing. *American Scientist*, *31*(4), 311–328. <u>http://www.jstor.org/stable/27826007</u>
- Healy, R.W., Winter, T.C., LaBaugh, J.W., and Franke, O.L. 2007. Water budgets: Foundations for effective water-resources and environmental management: U.S. Geological Survey Circular 1308, 90 p.

SciArt Initiative: <u>https://www.sciartmagazine.com/integrating-art-and-science-perspectives-from-a-professor-and-a-student.html</u>