Disappearing Dipoles:
The Irrigation Evaporation Enigma

3D-Student Science Performance *Diedre Young, Soybean Science Challenge*	
Grade: 10-12th Grade Integrated Chemistry and Engineering **Lesson Topics:** • **Evaporation** • **Water Phases** • **Solvation** • **Water Dipoles** • **Engineering and Water Retention**	**Disappearing Dipoles:** **The Irrigation Evaporation Enigma**  **THIS IS A MULTI-DAY LESSON**

Performance Expectations (Standard) from State Standards or NGSS:

Cl-ESS2-5: Plan and conduct an investigation of the properties of water and its effects on earth materials and surface processes. [Clarification Statement: Emphasis is on mechanical and chemical investigations with water and a variety of solid materials to provide the evidence for connections between the hydrologic cycle and system interactions commonly known as the rock cycle. Examples of mechanical investigations include stream transportation and deposition using a stream table, erosion using variations in soil moisture content, or frost wedging by the expansion of water as it freezes. Examples of chemical investigations include chemical weathering and recrystallization (by testing the solubility of different materials) or melt generation (by examining how water lowers the melting temperature of most solids).]

Cl1-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. [AR Clarification Statement: Examples of real-world problems could include waste-water treatment, production of biofuels, and the impact of heavy metals or phosphate pollutants on the environment.]

Cl-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems. [AR Clarification Statement: This PE is fully addressed in this course. Emphasis is on the impacts of human activities on physical systems. Examples of data on the impacts of human activities could include the quantities and types of pollutants released (fertilizer, surface mining, and nuclear biproducts). Examples for limiting future impacts could range from local efforts (reducing, reusing, and recycling resources) to large scale engineering design solutions (nuclear power, photovoltaic cells, wind, and water generated power).]

Cl3-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criterial and constraints for solutions that account for societal needs and wants. [AR Clarification Statement: Examples of the applications could include renewable energy resources (solar cells and wind farms). The Haber process for the production of fertilizers and increased fuel efficiency of combustion engines.]

CCSS Connections:
Reading:

Connections to Arkansas Disciplinary Literacy Standards:

WHST.9-12.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

WHST.9-12.9: Draw evidence from informational texts to support analysis, reflection, and research.

RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address a question or solve a problem.

RST.11-12.8: Evaluate the hypothesis, data, analysis, and conclusions in a science or technical text, verifying information.

RST.11-12.9: Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Connections to the Arkansas English Language Arts Standards:

SL.11-12.5: Make strategic use of digital media in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Connections to Arkansas Mathematics Standards:

MP.2: Reason abstractly and quantitatively.

MP.4: Model with mathematics.

HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas, choose and interpret the scale and origin in graphs and data displays.

HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling. HSN.Q.A.3: Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.	
Lesson Performance Expectations: • **Students will design and implement an irrigation prototype to compare to Poly-Pipe irrigation in regard to water loss through evaporation, focusing on how this water interacts with earth processes and surfaces.** • **Students will understand how an alternative irrigation technique could decrease global commercial crop water usage.** • **Students will present and defend their findings in a round-robin to the class.**	
Elicit: Start the lesson by asking students "What is evaporation?" and then "How does evaporation tie into the water cycle?" Get students thinking about evaporation and plants by inquiring "What do plants need to grow?" Students should mention water as an essential need for plants. Ask the question "How do plants receive water?" Comments such as rain, underground springs etc. will come up. Query the students, "If they are growing a garden, what will they need to do to	**Student Science Performance** ***Phenomenon:*** **Water exposed to the atmosphere will evaporate. In farming, evaporation means less liquid water to crops with more irrigation needed. This leads to erosion, salt/mineral build up (irrigation water contains dissolved minerals and salts so as it evaporates, those excess salts and minerals are left in the soil) and run-off. Can we water crops with less water loss due to evaporation?** ***Gather*** *(In this section students will generally be asking questions, obtaining information, planning, and carrying out an investigation, using mathematical and computational thinking, or using models to gather and organize data and/or information.)* 1. Students will ask the question "Can a better irrigation method than poly-pipe be developed to limit water loss through evaporation? 2. Students will do a literary search on various irrigation types and their ability to retard water loss during irrigation. 3. Students will come up with a research question, hypothesis, and engineering plan to address the problem of how to irrigate crops with less water loss using an alternative to poly-pipe irrigation. 4. Students will build an irrigation prototype, test it on soybean plants and compare their data to a poly-pipe control group. ***Teaching Suggestions:*** ***Teacher Note****: Ideas for designs could be different types of materials rather than plastic straws. Other ideas include insulating the straws, use thicker straws or make the holes smaller (reduce heat transfer). Another thought is to cool the water (increase the temperature difference). Students could also cover the straws and soil to increase condensation back to the soil.* Show the video *Irrigation for Agriculture* https://www.youtube.com/watch?v=24LJSJqpYuY to get students engaged in the project. Break the students into groups and, based on what was seen on the video and what was just covered, have the students do literary research on different irrigation techniques. Students

ensure growth?" Water should be one of the answers. Examine the question "if it doesn't rain then what does a farmer do to keep plants from dying?" Irrigation should be the obvious response. Do a KWL chart about what students know about irrigation. Questions such as types of irrigation techniques and amount of water used should be addressed in the chart. **Engage:** Show the video *Irrigation for Agriculture* https://www.youtube.com/watch?v=24LJSJqpYuY to get students engaged in the project. **Explore:** Farmers are constantly aware of the amount of water they use to irrigate their crops. Water costs money and irrigation is a huge	should include research on how to manually decrease evaporation through engineering a way to block water loss. Students should come up with a research question, hypothesis, and engineering plan. If the engineering plan is doable and measurable, then a student group can try it. Students will need to present how they built their prototype and its success or failure at reducing water loss from evaporation compared to the poly-pipe irrigation at the end of the lesson. **Reason** *(In this section students are generally: evaluating information, analyzing data, using mathematical/computational thinking, constructing explanations, developing arguments, and/or using models to reason, predict, and develop evidence.)* 5. Students will compare their prototype data to their poly-pipe control data in a table and graph, constructing an explanation as to why their irrigation alternative works better than poly-pipe irrigation 6. Students develop an argument using evidence that supports the explanation (claim) that their irrigation prototype is the best alternative to poly-pipe irrigation. ***Class Discussion:*** *Questions to initiate Discussion:* *Q: What is evaporation?* *Q: How does evaporation tie into the water cycle?* *Q: What do plants need to grow?* *Q: How do plants receive water?* *Q: If you are growing a garden, what will they need to do to insure growth?* *Q: If it doesn't rain then what does a farmer do to keep plants from dying?* Farmers are constantly aware of the amount of water they use to irrigate their crops. Water costs money and irrigation is a huge business when it comes to crop production. Farmers are always looking for ways to conserve water; lower water usage means less cost, better sustainability, and less erosion. It is the students' job to design and implement an alternative to current irrigation techniques. This will require groups to brainstorm a project, acquire the necessary materials, build the prototype, and experimentally implement the prototype with soybean plants. Student groups will be looking for an overall decrease of evaporation from the control group. Have students brainstorm measurement ideas. Some ideas for measurement can be using a humidity tester or drying the soil of both the control and experimental plants and calculating the difference. Once measurements are complete, student groups will present their findings in a round robin setting.

business when it comes to crop production. Farmers are always looking for ways to conserve water; lower water usage means less cost, better sustainability, and less erosion. It is the students' job to design and implement an alternative to current irrigation techniques. This will require groups to brainstorm a project, acquire the necessary materials, build the prototype, and experimentally implement the prototype with soybean plants. *Student groups will be looking for an overall decrease of evaporation from the control group.* Have students brainstorm measurement ideas. Some ideas for measurement can include using a humidity tester or drying the soil of both the control and experimental plants	*This would be a good time to cover the properties of water; its uniqueness (excellent solvation, dipole characteristics, different phases within a narrow temperature range, cohesion, and surface tension, etc.) and its crucial role in life.* There are several types of irrigation. The most common are surface irrigation (such as water running in ditches between rows), sprinkler systems and poly-pipe (pipes with holes in them run down rows to reduce evaporation and gets water to the plants at the spot). Of the three, poly-pipe is the best for water conservation, but can we do better? Can an alternative irrigation method be found that decreases evaporation to a lower level than poly-pipe? ***Communicate*** *(In this section students will be communicating information, communicating arguments (written and oral for how their evidence supports or refutes an explanation, and using models to communicate their reasoning and make their thinking visible.)* **1. Students in groups, in a round robin setting, will use their data model and prototype to present an argument for their choice of irrigation alternative.** Students will do a round robin about their findings, presenting their engineered prototype and their data collected from the engineering experiment compared to the poly-pipe control. A research paper on the prototype and a reflection paper on what they learned will be handed in by each student.

and calculating the difference. Once measurements are complete, student groups will present their findings in a round robin setting. **Explain:** Irrigation literally feeds the world. It has opened the doors for large crop production and multiple season growths. The downside to irrigation is it comes with a lot of water evaporation. Evaporated water, while great for the water cycle, doesn't get to plants and this means more water is needed to add to crops to adjust for water loss. Increased water means more erosion, more runoff, an escalation of salts in the soil and an increase of cost to the farmer. *This would be a good time to cover the properties of water; its uniqueness*	

(excellent solvation, dipole characteristics, different phases within a narrow temperature range, cohesion, and surface tension, etc.) and its crucial role in life. There are several types of irrigation. The most common are surface irrigation (such as water running in ditches between rows), sprinkler systems and poly-pipe (pipes with holes in them run down rows to reduce evaporation and gets water to the plants at the spot). Of the three, poly-pipe is the best for water conservation, but can we do better? Can an alternative irrigation method be found that decreases evaporation to a lower level than poly-pipe? **Elaborate:** Break the students into groups and, based on what was seen on the video and	

what was just covered, have the students do literary research on different irrigation techniques. Students should include research on how to manually decrease evaporation through engineering as way to block water loss. Students should come up with a research question, hypothesis, and engineering plan. If the engineering plan is doable and measurable, then a student group can try it. Students will need to present how they built their prototype and its success or failure at reducing water loss from evaporation compared to the poly-pipe irrigation at the end of the lesson. **Research website suggestions:** https://www.uaex.uada.edu/publications/pdf/mp197/chapter8.pdf	

https://www.uaex.uada.edu/media-resources/news/june2017/06-21-2017-Ark-surge-irrigation-fact-sheet.aspx https://www.uaex.uada.edu/counties/greene/docs/AG-files/22-29-irrigation-tools-beds-project.pdf https://www.uaex.uada.edu/media-resources/news/november2015/11-06-2015-Ark-Poly-pipe-cost-share.aspx http://www.fao.org/docrep/T7202E/t7202e08.htm https://www.uaex.uada.edu/media-resources/news/november2015/11-06-2015-Ark-Poly-pipe-cost-share.aspx https://www.uaex.uada.edu/publications/PDF/FSA-9512.pdf **Evaluate:** Students will do a round robin about their findings, presenting their	

engineered prototype and their data collected from the engineering experiment. A research paper on the prototype and a reflection paper on what they learned will be handed in by each student. **Extend:** End the lesson with how evaporation and the properties of water have huge impacts on our food supply. After the round robin, have students debate their project's success in comparison to other projects in the classroom. Have the students do an economic impact paper on water savings using their engineering project. Have a local farmer do a presentation in the classroom of the impact irrigation has on crops and the costs involved with	

irrigation. Have the class do a presentation of their findings at the local County Extension Office.	

Formative Assessment for Student Learning

Elicit Evidence of Learning: *This box is the individual communication performance from the student prompts in Appendix A*

Evidence of Student Proficiency	Range of Typical Student Responses	Acting on Evidence of Learning
The student will use critical thinking to engineer an alternate solution to the large amount of water loss farmers deal with when irrigating their crops. The student will come up with a valid hypothesis and will find valid research for this project. *The student will perform experimentation that will validate their hypothesis and the concepts learned will be used for critical thinking on determining alternatives to poly-pipe irrigation.*	*This section provides a range of typical student responses, often using a three-point scale.* *Descriptors of grade-level appropriate student responses:* • *Full understanding: The student will engineer an irrigation alternative, do comparison experiments between the alternative and poly-pipe, and successfully present the findings in a round robin setting.* • *Partial understanding: the student will engineer an alternative and set up the poly-pipe control, but data collected is not correct and is unable to present accurately in a round robin setting.* • *Limited understanding: The student understands an irrigation alternative is necessary but does not develop an alternative or produces a sub-par alternative. Student does not correctly collect data and cannot present accurately in a round robin setting.*	*This is a brief description of the instructional actions to take based on the students' performance. When the action includes extensive descriptors and/or materials you may wish use* ***Appendix C.*** *Description of instruction action and response to support student learning.* • *Action for student who displays partial or limited understanding: Student will be partnered with an academically strong student and multiple verbal assessments will take place throughout the lesson.* • *Extensions of learning for student who displays full understanding: After the round robin, have students debate their project's success in comparison to other projects in the classroom.* *Have students do an economic impact paper on the water savings based on the project.* *Have a local farmer do a classroom presentation on the impact irrigation has on crops and the costs involved with irrigation.* *Have the students do a presentation of their findings at the local county extension office.*

SEP, CCC, DCI Featured in Lesson	**Science Essentials** *(Student Performance Expectations from Appendix C, D, E)*
Science Practices	
Planning and Carrying out Investigations. Using Mathematics and Computational Thinking. Constructing Explanations and	• Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. • Use mathematical representations of the phenomena to support claims. • Design a solution to a complex real-world problem, based on

Designing Solutions.	scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.
Crosscutting Concepts Structure and Function. Stability and Change. Consistency in Natural Systems. Influence of Engineering, Technology and Science on Society and the Natural World.	• The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructure of its various materials. • Much of science deals with constructing explanations of how things change and how they remain stable. • Science assumes the universe is a vast single system in which basic laws are consistent. • Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. • New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.
Disciplinary Core Ideas ESS2.C: The Roles of Water in Earth Surface Processes (Cl-ESS2-5). ETS1.C: Optimizing the Designing Solutions (Cl-PS1-6). ESS3.C: Human Impacts on Earth Systems (Cl-ESS3-4). ETS1.A: Defining and Delimiting Engineering Problems (Cl3-ETS1-1).	• The abundance of liquid water on Earth's surface and its unique combination of physical and chemical properties are central to the planet's dynamics. These properties include water's exceptional capacity to absorb, store and release large amounts of energy, transmit sunlight, expand upon freezing, dissolve, and transport materials, and lower the viscosities and melting points of rocks. • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. • Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. • Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities.

Appendices: This section contains the lesson performance that students will see during the lesson and any other resources students will use to engage in the science performances. The appendices may also contain examples of student work.

Appendix A - Student Prompts

Student Prompts for the Lesson

Phenomenon: **Water exposed to the atmosphere will evaporate. In farming, evaporation means less liquid water to crops with more irrigation needed. This leads to erosion, salt/mineral build up (irrigation water contains dissolved minerals and salts so as it evaporates, those excess salts and minerals are left in the soil) and run-off. Can we water crops with less water loss due to evaporation?**

Group Performances:

1. Ask questions to plan an investigation for the usage of alternative means of irrigation to decrease water loss.
2. Plan an investigation to gather evidence for the usage of a particular chosen alternative.
3. Construct an explanation for whether the researched, built, and experimented irrigation alternative is or is not a viable substitute to poly-pipe irrigation (including constraints).
4. Use a model to show that the chosen researched, built, and experimented irrigation alternative is or is not a viable alternative to poly-pipe irrigation.

Class Discussion

Individual Performances:

1. Develop an argument for how the evidence you collected supports or refutes your explanation for the usage of a chosen alternative to poly-pipe irrigation.

***Appendix B** – preparation, time duration and materials for lesson.*

Preparation:

Soybean plants work well for this lesson. They are easy to grow and sprout in about eight to ten days. Seeds can be obtained through the SSC on-line seed store link on www.uaex.uada.edu/soywhatsup. Seeds are shipped out within a week of ordering. Students will need about a week to obtain materials for their engineering project. Another option is to have a set number of materials on hand for the whole class to use. Straws need to be glued and holes punched in them for use by students. Two straws per experimental and two for the control group should do it.

Time Duration:

Soybean plants take about a week to sprout so assume a week for the plants, a week for student brainstorming, planning and material acquisition (which can be done while waiting for plants to grow) and a week for building and experimenting. *Suggestion: to get the students invested in the lesson, have them plant the seeds in anticipation of the project.*

Materials:

- Soybean Seeds
- Plastic containers (can be margarine tubs, yogurt tubs, cut 2L soda bottles etc.), at least four per group of four students (six plants in two for experimental and six plants in another two for control group).
- Potting soil (for optimum growth)
- Plastic straws glued together with consistent sized holes in them (to simulate a poly-pipe).
- Notebook for data collection
- Various materials for engineering design. Depends on student group.
- Humidity (or water) measurement devices.

***Teacher Note**: Ideas for designs could be different types of materials rather than plastic straws. Other ideas include insulating the straws, use thicker straws or make the holes smaller (reduce heat transfer). Another thought is to cool the water (increase the temperature difference). Students could also cover the straws and soil to increase condensation back to the soil.*

Appendix C –

Research website suggestions:

https://www.uaex.uada.edu/publications/pdf/mp197/chapter8.pdf

https://www.uaex.uada.edu/media-resources/news/june2017/06-21-2017-Ark-surge-irrigation-fact-sheet.aspx

https://www.uaex.uada.edu/counties/greene/docs/AG-files/22-29-irrigation-tools-beds-project.pdf

https://www.uaex.uada.edu/media-resources/news/november2015/11-06-2015-Ark-Poly-pipe-cost-share.aspx

http://www.fao.org/docrep/T7202E/t7202e08.htm

https://www.uaex.uada.edu/media-resources/news/november2015/11-06-2015-Ark-Poly-pipe-cost-share.aspx

https://www.uaex.uada.edu/publications/PDF/FSA-9512.pdf