

Ripples of Learning: A Middle School Teacher's Application of Content and Pedagogy Learned in the ESSEA Online Earth System Science Course

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Abstract

The Earth System Science Education Alliance (ESSEA) online professional development course for middle school classroom teachers uses real-world events to develop content understandings of Earth system science, and it models best practices for age-appropriate pedagogy.

The course is structured into three, weeklong learning cycles of content exploration, extension, and application. During the first week participants work together in groups to study the impact of the real-world events on the atmosphere, biosphere, hydrosphere, and lithosphere. In the second week new teams are formed to develop interactions between the different Earth system spheres. In week three teachers apply these newfound understandings by creating classroom applications that transfer Earth system science knowledge to their K-12 students.

Each time the ESSEA course is offered by Wright State University's Department of Geological Sciences, participants are selected at random for classroom visitations to determine the efficacy of the online course on teacher content understandings, on the use of classroom inquiry, and on the implementation of classroom applications developed. A case study is presented that includes: a visitation in November 2002, text from the course's threaded discussions, and video clips of students doing Earth system science in their fifth-grade classroom. Follow-up interviews with the classroom teacher indicate that she is continuing to use inquiry-based science as a tool to develop students' content knowledge. Building these understandings make it more likely that students will pass the new high-stakes tests that will be required of all Ohio K-12 students and will lead to a scientifically literate citizenry.

Introduction

The national science education standards (National Research Council, 1996) stress the need for an inquiry-based science classroom environment with an interdisciplinary science curriculum linked by unifying concepts and processes, such as systems, order and organization, evidence, models, and explanations. The Ohio science standards (Ohio State Board of Education, 2002) state, "Students' success in meeting the expectations of the standards depends on teaching and learning as an active inquiry process. This means that all teachers need the opportunity to teach science as something in which students are actively engaged."

School districts cannot realize these national and state goals for science education, however, without a skilled staff of K-12 teachers, knowledgeable in interdisciplinary science content, pedagogy, and technology, with the classroom resources necessary to deliver inquiry-based learning to their students. The professional development activities embedded in this online Earth system science course are designed to be cohesive and synergistic and to foster understandings of Earth system concepts.

The course uses technology as a tool in inquiry-based K-12 science activities. It also

supports the development of inquiry-based science classroom applications through support from peers and project faculty.

The courses are delivered by the Earth System Science Education Alliance (ESSEA), a NASA-supported consortium of institutions of higher learning and educational resource centers. The online courses carry three semester hours of graduate credit.

As a consortium member, Wright State University's Department of Geological Sciences has delivered online Earth system science classes to K-12 classroom educators for the past four years. These courses were developed by the Center for Educational Technologies/E at Wheeling Jesuit University. A distinct Earth system course has been developed for each distinct audience: elementary, middle school, and high school in-service teachers. The courses seek to develop content understandings of Earth system science, model inquiry methods suitable for the designated student age groups, and foster the use of Internet technology in K-12 classrooms.

This paper focuses on the structure of the middle school online course and how that structure builds support for the development of inquiry-based Earth system classroom activities. In addition, the paper contains an example of a lesson plan and streaming video of the classroom application developed by one of the coauthors during the online ESSEA course.

The Middle School Online Course

The middle school version of the online Earth system course for teachers of grades 5-8 uses the real-world events of rainforest deforestation, volcanic eruptions, hurricanes, and Antarctic ice shelf degeneration as platforms to achieve the course objectives. A primary concern during course design was to create an online learning environment of inquiry where interdependence among participants provided the glue necessary for a successful community of learners. Bereiter's discussion of inquiry (1992) was used in the design of the course to provide a framework for supporting inquiry. He describes the scientific approach to inquiry as the commitment to:

- * Work toward a common understanding satisfactory to all.
- * Frame questions and propositions in terms of evidence.
- * Expand the body of valid propositions.
- * Subject any belief to examination.

Rogers and Laws (1997) addressed the challenge of building an online community by supporting extensive discussions and providing opportunities for cooperative learning. Jigsaw cooperative learning structures (Grisham & Molinelli, 1995; Aronson et al., 1978) provide a useful method for creating interdependence by having team members form temporal ad hoc groups to become "experts" on a content area, then return to their original team to share their expertise. Cooperative learning such as that required in the jigsaw method requires interaction among students on learning tasks. The belief is that the interaction in itself will lead students to construct knowledge (Damon, 1984; Murray, 1982; Wadsworth, 1984). "Students learn from one another because in their discussions of the content, cognitive conflicts arise, inadequate reasoning is exposed, disequilibrium will occur, and higher-quality understandings will emerge" (Slavin, 1995).

The online course slowly introduces participants to its structure before plunging fully into graded, fourth week collaborative activities. Starting slowly has several advantages. It allows non-technical users to learn about cyberspace and for everyone to become accustomed to the layout of the course web site. During weeks two and three participants introduce themselves to others assigned to their teams, name their "event" teams, and are

introduced to Earth system science.

During week two the 1988 Yellowstone National Park fires are used as an event that impacted upon Earth's interacting and interdependent spheres. Using a graphic depiction (Figure 1), participating teachers are presented with a tutorial on how to examine positive and negative feedback loops and dynamic equilibrium.

During week three participants work with their teams to develop a study of the interactions between the atmosphere, biosphere, hydrosphere, and lithosphere as a result of the meteorite impact on the Yucatan Peninsula 65 million years ago. Participants also reflect on their progress in content knowledge and pose questions in a journal space folder in the discussion area. This is a weekly requirement and serves as a space for one-on-one discussions with the course facilitators.

Graded work begins in week four. The course is structured into four, three-week cycles. Because the structure of successive learning cycles is identical, this paper will elaborate on the first three-week cycle dealing with the deforestation of the Brazilian rainforest.

To begin the deforestation discussion, "event" teams are jigsawed into new groupings, called "sphere space" teams. This means, for example, that in an event team of four, one person goes to the atmosphere sphere group discussion, one to the biosphere group discussion, and so on. The objective of the sphere group discussion is for each member to become as knowledgeable as possible about deforestation's impact on his or her sphere. At the end of the cycle's first week, participants have collected and discussed information concerning their sphere and participated in a group analysis of how the event has impacted the sphere they have been studying. Course facilitators grade the report using the same rubric (Figure 2) available to the participants to assist them in the development of the report.

During week five the original event teams reassemble to study the impact between the different spheres and the event. They develop a written study of the causal chains of connections between the spheres and the event. This work is completed in "event space." Each member is counted on for knowledge developed during the previous week's sphere group discussions. Course facilitators follow the online dialog, intervening only to ask thought-provoking questions or respond to requests.

Week six provides the teacher-participants opportunities to reflect upon and share classroom activities they will use with their middle school students. The lesson plans are posted to "classrooms applications space." After posting their proposed classroom activities, participants reflect upon each other plans and offer suggestions or incorporate features into their own lesson plans. Then they teach them in their classrooms.

Classroom Application

A course participant (and eventual coauthor of this paper), was chosen at random to have her classroom application videotaped. Her lesson was aligned with the national science education standards and the Ohio academic content standards. In the fifth grade students must meet grade-level indicators for Earth system science and inquiry-based science. Her goal was to have students investigate the impact of a volcano on Earth's spheres. Among her objectives were to:

- * Have students work in groups to investigate the effect of volcanoes on the Earth's spheres.
- * Cooperatively develop a demonstration showing the impact on the sphere that the group was studying.
- * Develop a group presentation containing specific information about the event to

sphere interaction, including the demonstration to the rest of the class.

The following excerpt from the threaded discussion area of the ESSEA online Earth system course shows the genesis of the lesson plan:

Lesson Motivation: Previous to my experience with the online classes, I developed science lessons around experiments and demonstrations given in our textbook. I was not confident enough myself to develop a lesson on my own because I did not know what the results might be. The online course forced me to develop lessons on my own that included more than just one basic concept. After doing inquiry-based lessons developed during the course, I realize how much more effective they are than the lesson outlined in a textbook. The students are extremely engaged and they took ownership for their own experiments. This allowed everyone to discover and learn things as we explored different concepts. One of the most exciting elements of the lessons I have done so far is the idea that I actually learned right along with the students. I was not a provider of all the knowledge, and, therefore, the material become more meaningful for the students. I also realized through ESSEA that by connecting lessons to all spheres of the Earth, the students begin to realize how applicable learning science truly is to their lives today. Therefore, as I plan my science lesson today, I am willing to take a chance and explore experiments that are not outlined in a textbook, and [I have learned] that those lessons seem to be the concepts that my students remember the most about.

Overview of the Lesson: Discuss briefly an overview of the recent eruption of Mount Etna in Sicily. This will help the students make a real-life connection to the lesson and develop an understanding of the purpose for learning the material. The students will divide up into five groups of four and begin reading the book, *Volcanoes*, by Seymour Simon (1988). This is a terrific nonfiction book that has excellent pictures and will give students a basic understanding of volcanoes. The students will read the book as a group and discuss it. When they are finished, to see how well they read and comprehended the story, they will take a short 10-question quiz on the story. This is to be sure the students understand the content before continuing to build on the concepts. Once they have successfully passed the quiz, they will be assigned a sphere to study.

Day One Lesson: The students will then go to <http://sm.k12.oh.us>, which is our school web page and will open our classroom page. They will find a page linked to our classroom page that is called Science Information under Ms. Kunk's Favorite Web Sites. This is a copy of our global changes sphere-to-sphere interactions. I have modified them a bit and put them on the Internet for the students to use. The students will then spend time researching their sphere and trying to determine how a volcanic eruption affects their assigned sphere. Each student will try and find the answers to these questions and collaborate with their group on final discussions. As a team, they have to answer questions such as these depending on their sphere:

- * **Biosphere:** How do volcanic eruptions affect animals, plants, and human life? List several ways and examples and show where you found the information. Think about what would happen to the plants and animals in an area where a volcano erupted.
- * **Atmosphere:** How do volcanic eruptions affect the air? Consider what the air is made of and what gases a volcano releases when it erupts. How would these gases and debris being released into the air be harmful?
- * **Hydrosphere:** How would a volcanic eruption affect the water sources in an area? One effect of volcanic eruptions is the possible formation of acid rain. How would acid rain affect an area? Look at all the pictures of the volcanoes in the book you read. What do you see on most of them? (Hint: it is a form of precipitation.) What would happen when a volcanic eruption occurs in an area that has glaciers or snow?
- * **Lithosphere:** How would a volcanic eruption affect the soil and surface of the Earth?

In what ways are volcanoes related to the formation of different landforms? Think about the lava coming from the volcano, mudflows, the shapes of volcanoes, and the other debris coming from the eruption.

The students will spend the rest of this class period finding information and recording it in their journals. As a homework assignment, they will individually develop an experiment/demonstration to test their ideas on the effect volcanic eruptions have on their sphere. They will be given different books to use as a reference. The students must include a list of materials, hypothesis, procedures, and data they will be collecting by conducting the experiment/demonstration. The students will be reminded that the materials need to be in the classroom and the experiment/demonstration must be able to be conducted in the classroom. They are to bring any necessary materials we do not have in the room or available at school.

Day Two Lesson: Begin the day by showing the students a few demonstrations I developed to show different elements of a volcano. My fifth-grade students are concrete learners, and to lead them to the somewhat abstract concept of the relationship between magma and the surrounding country rock beneath a volcano, I use analogies. For example, I link the abstract concept of density differences that cause magma to rise toward Earth's surface with a concrete demonstration of density differences showing the students a jar of water with food coloring and vegetable oil in it. The oil will separate from the water and float above it. I will also remind the students of the baking soda and vinegar experiment we conducted early this year to demonstrate chemical potential energy and then discuss the differences between that reaction and what happens in a real volcano. I will also continually give students suggestions of how to make their experiments/demonstrations more successful. The students will get back together in their groups and share their individual ideas for an experiment/demonstration. Together they will decide what they would like to try and actually conduct the experiment/demonstration. They must complete all steps in the scientific process and continue to record their findings in their journals. The students will complete their experiment/demonstration during this class period. They will then begin preparing their lab report of the experiment. The students will be given an opportunity to share their lab reports and results the following day in class after we have finished typing and formulating a quality report.

Day Three Lesson - Conclusion and Post Assessment: The students will present their lab reports and share their findings. I will conduct the post assessment of their reports using a rubric (Figure 3). I will also assess them on their presentation and their ideas on how they would change their experiment if they were given an opportunity to develop another experiment. The students will take notes on their classmates' presentations, and I will grade their journal when the presentations are finished.

The classroom observation and videotaping occurred during the day two lesson. Using the team structure of the ESSEA online Earth system science course, the fifth-grade students shared their individual ideas for classroom demonstrations and worked with each other to, as one student said, "take the best ideas that different people had and put them together." In this way plans for the demonstrations were finalized. All four of the sphere groups built models of volcanoes, complete with baking soda and vinegar eruptions. The group studying an eruption's impact on flora and fauna arranged M&Ms around the cone and showed that the erupting lava would affect some, but not all, life living near the eruption. Another group studying the land (lithosphere) used a cutout cardboard "ocean" to show that as lava spilled into the water, land would build outward. Groups studying the atmosphere and hydrosphere also developed demonstrations that showed interactions between volcanic eruptions and their spheres.

Reflection on the Lesson: The students developed their own experiment design that included a purpose, hypothesis, demonstration procedure, data collected and analyzed, and conclusions. The students also had to write several individual questions that they were trying to answer through the demonstration. They had to justify their demonstration by

explaining how it would help them answer their own questions about the spheres of the Earth. The questions to students that I stated in my lesson plan were simply guidelines to help them stay on the right track. After completing the demonstrations, the students also developed a flipbook shaped like a volcano that contained one page for each of the spheres. The students were asked to summarize what they learned about each sphere on the appropriate pages. They were also asked to write a conclusion at the end of their book describing how the spheres all impact one another. It was extraordinary to see their ability to apply what they had learned. The students were so good at seeing the connections among the spheres that when I was working on my final project for one of the ESSEA courses that I took, I asked the students for their opinion on how the event would affect the four spheres. They had some great ideas that I had not thought of. I think the element I learned the most through the ESSEA courses is to never underestimate the ability of your students. My small-town fifth-grade students were able to understand and successfully master science content standards that are labeled at the ninth-grade level, such as: "Explain the relationship of the oceans to the lithosphere and atmosphere." We conducted these demonstrations in the autumn of 2002, and the students were still using Earth system concepts in other inquiry-based investigations months later. The skills and content the students learned doing inquiry-based science are at the heart of the Ohio proficiency tests. These high-stakes tests are modeled on the national science standards and test student knowledge of the process of inquiry-based science. The students will take the Ohio proficiency test in science in March 2004.

Conclusions

This case study suggests that the ESSEA online Earth system course for middle school teachers is successful in increasing teacher content knowledge, the use of technology in the classroom, and the development of inquiry-based classroom applications. K-12 students are motivated to learn about the Earth system because of their ownership of the development of the classroom activities. They were drawn into the process of science by asking their own questions, developing ideas as a team to strategize effective methods to answer those questions, made their thinking visible by constructing effective demonstrations for their classmates and then employing those demonstrations to teach Earth system science to their peers. In addition to Ms. Kelly Kunk, several other course participants were interviewed and videotaped during the 2002 course offering and subsequent academic year. Although beyond the scope of this paper, those interviews and visits revealed that she and other course participants developed standards-based Earth system science activities and continued to use the pedagogical methods modeled in the ESSEA course for other inquiry-based science activities during the school year.

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Outline

Earth System Science Course

Module One: An Introduction to an ESS Analysis

Earth system science is conducted by examining each event to sphere, sphere to event, and sphere to sphere interaction. This approach is referred to as an "Earth system science analysis" or an "ESS analysis."

An ESS analysis is done in three steps, which include looking at

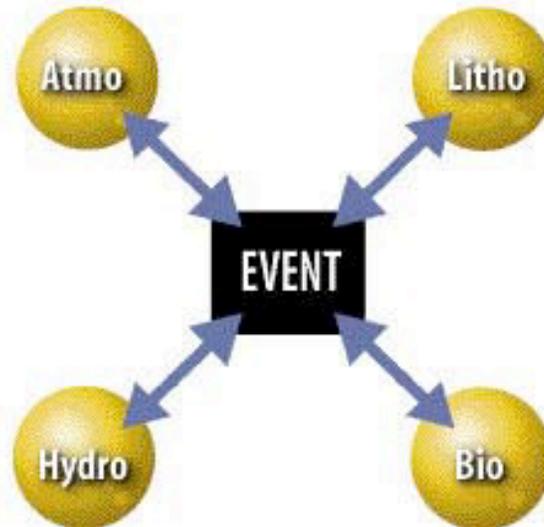
- how the event affects each of the spheres;
- how the spheres affect the event; and
- how the spheres affect each other.

Because you will be performing ESS analyses in this course, you should read through the following information as it provides an overview of how to do each step of the ESS analysis. The purpose of this introduction is to get you thinking about the types of interactions that can occur. The forest fires that occurred in Yellowstone National Park, Wyoming, in 1988 is used as the event for this introduction. As you go through the step-by-step process, you should post your ideas for each of the steps in your journal.

When posting your analysis ideas, abbreviate the event with the letter "E" and abbreviate each sphere using the first letter of its name (atmosphere = A; biosphere = B; etc). Use a single-headed arrow (>) to indicate the direction of effects. For example, the effects of the event on the hydrosphere should be written as "E >H".

Step 1: Event > Sphere Interactions

How could the event (Yellowstone fires) affect each sphere? The answers to this question are the event > sphere impacts. Refer to the Earth System Diagram below to help you think about the types of interactions that could occur.



Consider how the Yellowstone fires might affect the spheres, beginning with the atmosphere. Remember to write your additional ideas in your journal.

E > A

The fires created tremendous heat, developed fast rising columns of heated air, which in turn brought in more air at the base of the fires, dropped the humidity in the area of the active fire to near zero, and made dense smoke, which actually traveled hundreds of miles.

There were certainly other impacts on the atmosphere besides this one. What ones can you think of that might be added to the list?

E > H

Ash from the fires fell into the ponds, lakes, and streams.

What impacts might you expect the event to cause in the hydrosphere? Is the effect of burning embers from the falling debris landing in the streams worth considering?

Don't worry about getting "all" the interactions; you probably won't be able to. Just focus on identifying one or two impacts. And remember, the impacts on some spheres will be more numerous than on others. That's not a problem.

E > B

The fires burned and killed the plants and trees, as well as the animals who could not escape, in the area.

How else did the fires affect the biosphere at Yellowstone National Park? There are the obvious "destructive" effects on plant and animal life as well as on habitat. You might also consider the "beneficial" effects of burning off accumulated debris on the forest floor and similar occurrences that might be considered advantages of the burning. Add some of these to your journal.

E > L

The forest fires burned the parts of the soil where the plants put down their roots.

Lastly, what effects might these fires have had on the lithosphere? Here, you might consider the effects on soils, or perhaps even on the water levels of the geysers and hot pools the Yellowstone National Park is so famous for.

Step 2: Sphere > Event Interactions

How could each sphere affect the event? The answers to this question are the sphere > event impacts.

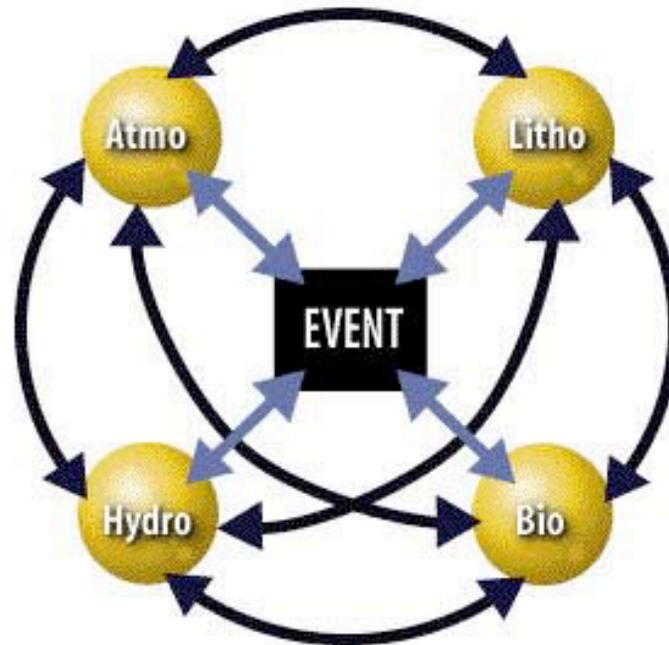
Take another look at the Earth System Diagram above. Notice that the arrows go not only from the event to each sphere but also from the spheres back to the event. While looking at the diagram, ask yourself, "If this happened to the biosphere because of the fires, how might that have an effect on the fires themselves?" For example, if the fires cause the forest floor debris to be burned off in the biosphere, how might that impact the fires themselves? Clearly, the fires would be removing the fuel necessary to keep them burning. So, a statement like, "The leaf litter was burned by the fires, thus diminishing the amount of fuel available to keep the fires burning in that area" might be an appropriate B > E interaction.

Look at each set of possible changes the fires might make on each sphere. If they occurred, how might these changes in turn affect the fires? Consider whether these changes have short-term or long-term effects.

Step 3: Sphere > Sphere Interactions

How could each sphere affect the other spheres? The answers to this question are the sphere > sphere interactions.

Now that you have a general idea of how the event and spheres can impact and affect one another, it is time to introduce one more level of interaction. Take a look at the version of the Earth System Diagram below. You will refer to this version of the Earth System Diagram when you do ESS analyses in the future. Notice the additional arrows going to and from each of the spheres. These additional arrows indicate another set of interrelationships that are influenced by the event.



If certain changes were created in one sphere by the event, how might those changes influence change in the other spheres? Once the event has had an impact on or made a change in a sphere, for example the lithosphere, how does that influence the way the lithosphere now interacts with the other spheres? As an example, the fires burned the soil (lithosphere) to a depth of several inches or more in certain "hot spots." What effect do you think that will have when it finally starts raining and there is runoff to the streams (hydrosphere)? If there were burning embers put into the atmosphere that eventually fell back into the streams (hydrosphere) how might that blackened debris have affected the aquatic invertebrates and fish (biosphere) that survived the event?

Try to see what interactions you can find among the different spheres. Think about what changes might have occurred in each sphere as a result of the Yellowstone fires. Add these effects to your ESS analysis.

If you find yourself questioning, "If the hydrosphere is damaged by the falling charred debris and that does major damage to the fish, then how does that affect the biosphere?" that's a good sign because it means you're beginning to look at the way the world works. It just seems to be one great collection of interacting spheres and then along comes a new event and the process of balancing starts over again.

At this point, you will not have all the possible interactions written down by any means. Furthermore, it is very unlikely that each of your classmates has the same set of interactions written down that you do and that is not a problem either. As you analyze events in the future, the list of interactions each one of you contributes will simply reflect your own individual backgrounds and experiences. There isn't any RIGHT answer for these ESS analyses or any COMPLETE answer that you are trying to attain. You just need to be able to explain and support why you think something may be an impact.

Keep in mind as you list the interactions that it is important for you to offer scientific reasoning or scientific explanations to explain why or how the interactions occur. Scientific reasoning and scientific explanations are prior knowledge from your own experience, learned from somewhere else, etc. Such reasoning and explanations display your understanding of the science behind the interactions. These explanations are valuable for you and others because they make your "Why?" or "How?" thinking visible, and they often lead you to think about additional ESS interactions.



Figure 1

Earth System Science Course

Intro**Assessment Overview: Sphere Study Assignment & Rubric
Modules 3, 6, and 9**

Goal: Become experts in the relationship of one sphere to an Earth event (deforestation, volcanic eruption, ice shelf disintegration).

Note: Refer to [Group & Team Formation](#) to find out which sphere you should be studying this module.

Assignment

Posting instructions for step 1

- Go to the [Classroom](#), then click on Journal Space.

1. List your questions, theories, and prior knowledge about the sphere you are studying this module. Refer to the [Journal Rubric](#).

Posting instructions for steps 2-4

- Go to the [Classroom](#), then click on Sphere Space.

2. Use the [Sphere Study Rubric](#) as a guide and work with your group to:

- Describe the sphere in detail. Explain its processes, characteristics, functions, and role in the Earth system.
- Describe the event.
- List the effects of the Event on the Sphere (E > S) with reasoning and support.
- List the effects of the Sphere on the Event (S > E) with reasoning and support.

To address the last two bullets, you may need to make a list of as many questions as you can about the sphere and the event, and do research to answer your questions. Refer to the [Module 2: An Example of an ESS Analysis](#) reading if you would like to review E > S and S > E interactions.

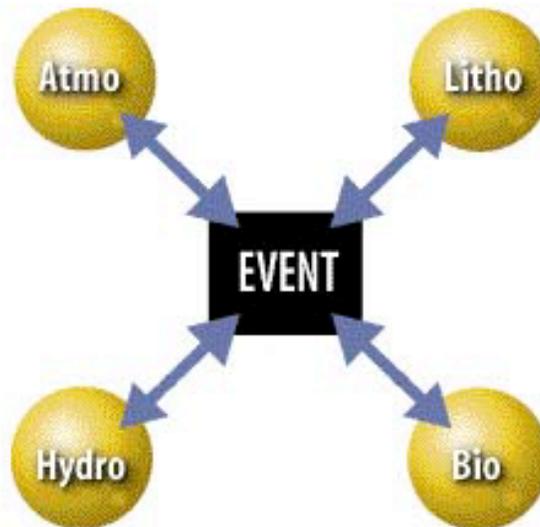
3. Think about some possible interactions that could occur between your sphere and the other spheres while you are still with your Sphere Group.

4. Prepare a summary of the most important information concerning your group's sphere and post it in Event Space so that you can share it with your Event Team next module.

Posting instructions for step 5

- Go to the [Classroom](#), then click on Journal Space.

5. Reflect on what and how you have learned. Refer to the [Journal Rubric](#).



Rubric

Your Sphere Group analysis needs to include:

- List the effects of the Event on the Sphere ($E > S$) with reasoning and support.
- List of the effects of the Sphere on the Event ($S > E$) with reasoning and support.

You should write as many interactions as you can that include accuracy, depth of reasoning, and quality of support. Use the rubric below to evaluate and improve your analysis as your work will be graded based on the rubric being applied to each $E > S$ and $S > E$ interaction you list. Each interaction that earns a 3 or 4 rating will be worth one point toward the maximum five points you can earn for this assignment.

Rubric Criteria: Accuracy			
4 Rating: Powerful, comprehensive, statements.	3 Rating: Comprehensive statements.	2 Rating: Clear, complete statements.	1 Rating: Simple statements that are partially correct.
Rubric Criteria: Depth of Reasoning			
4 Rating: Reasoning completely supports the hypothesized effect or interaction.	3 Rating: Uses scientific reasoning, concepts, and processes to explain the interaction.	2 Rating: Includes science concepts and processes in the reasons for the effect and the interaction.	1 Rating: Explains at least two reasons for the effect or interaction.
Rubric Criteria: Quality of Support			
4 Rating: Compelling use of existing research and knowledge.	3 Rating: Uses logical support that is convincing using data and authority.	2 Rating: Uses reliable data from multiple sources.	1 Rating: Uses relevant and respected authorities.

[Back to Assessment Overview](#)



Figure 2

	4	3	2	1
Hypothesis Development	Independently developed an hypothesis well-substantiated by a literature review and observation of similar phenomena	Independently developed an hypothesis somewhat substantiated by a literature review and observation of similar phenomena.	Independently developed an hypothesis somewhat substantiated by a literature review <u>or</u> observation of similar phenomena	Needed adult assistance to develop an hypothesis or to do a basic literature review.
Description of Procedure	Procedures were outlined in a step-by-step fashion that could be followed by anyone without additional explanations. No adult help was needed to accomplish this.	Procedures were outlined in a step-by-step fashion that could be followed by anyone without additional explanations. Some adult help was needed to accomplish this.	Procedures were outlined in a step-by-step fashion, but had 1 or 2 gaps that require explanation even after adult feedback had been given.	Procedures that were outlined were seriously incomplete or not sequential, even after adult feedback had been given.
Data Collection	Data was collected several times. It was summarized, independently, in a way that clearly describes what was discovered.	Data was collected more than one time. It was summarized, independently, in a way that clearly describes what was discovered.	Data was collected more than one time. Adult assistance was needed to clearly summarize what was discovered.	Data was collected only once and adult assistance was needed to clearly summarize what was discovered.
Diagrams	Provided an accurate, easy-to-follow diagram with labels to illustrate the procedure or the process being studied	Provided an accurate diagram with labels to illustrate the procedure or the process being studied.	Provided an easy-to-follow diagram with labels to illustrate the procedure or process, but one key step was left out.	Did not provide a diagram OR the diagram was quite incomplete
Conclusion/Summary	Student provided a detailed conclusion clearly based on the data and related to previous research findings and the hypothesis statement(s).	Student provided a somewhat detailed conclusion clearly based on the data and related to the hypothesis statement(s).	Student provided a conclusion with some reference to the data and the hypothesis statement(s).	No conclusion was apparent <u>or</u> important details were overlooked

Figure 3