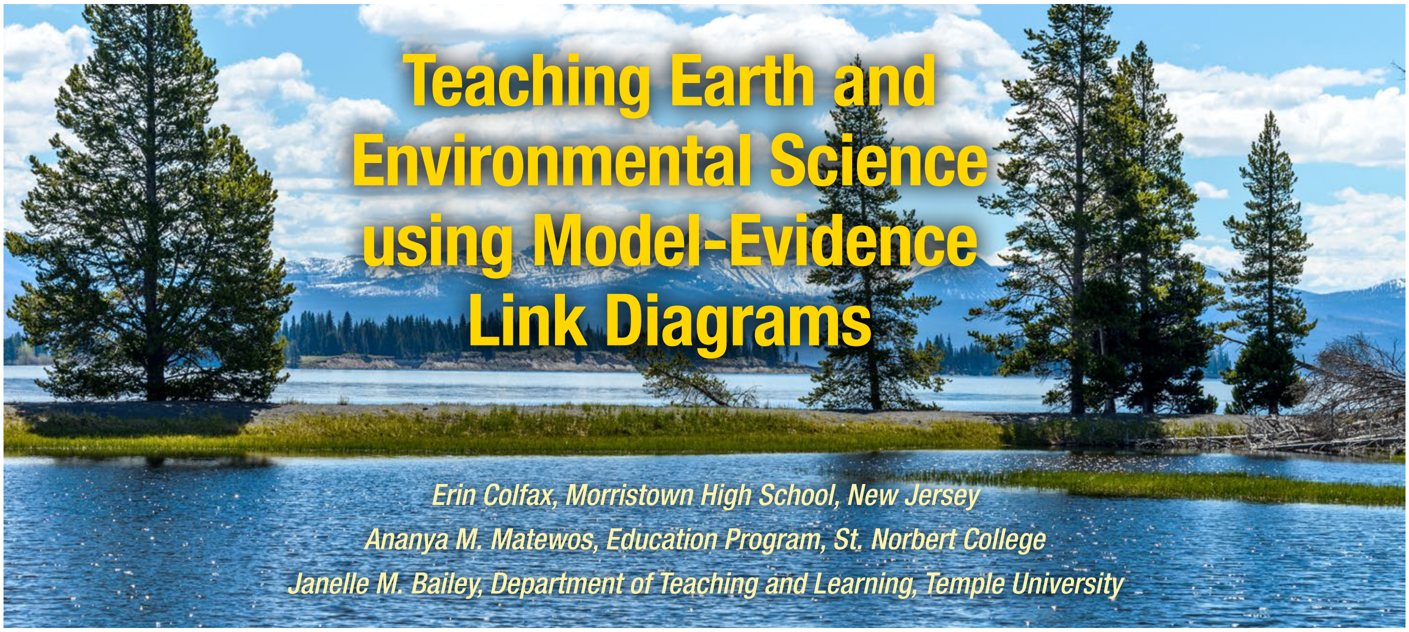

Teaching Earth and Environmental Science using Model-Evidence Link Diagrams

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Abstract

High-quality science education is essential for students to become scientifically literate. Model-Evidence Link (MEL) diagrams and build-a-MEL (baMEL) diagrams are instructional scaffolds that create an opportunity for students to build scientific understanding through the evaluation of the connections between evidence and alternative explanations of a scientific phenomenon. The MELs and baMELs allow for a natural incorporation of three-dimensional learning that has been recommended by the *Next Generation Science Standards* to enhance students' comprehension. Through this science teaching methodology, students are able to see that by diagramming and then writing about one's thoughts about the connections between evidence and explanations, one can deepen their understanding of scientific concepts.

As attendees of the summer 2019 Earth and Environmental Science (EES) Educators Institute, middle and high school EES teachers were introduced to a methodology that explored two instructional scaffolding techniques: Model-Evidence Link (MEL) diagrams and build-a-MEL (baMEL) diagrams. The MEL and baMEL diagrams promote students' scientific thinking when confronted with controversial and/or complex Earth and space science topics. These instructional scaffolds facilitate critical thinking, evidence-based reasoning, construction of scientific explanations, and collaborative argumentation (Lombardi, 2016; Science Learning Research Group, 2020; see also the other articles in this issue).

The MEL and baMEL diagrams facilitate student learning by presenting material in three science learning dimensions (i.e., scientific practices, disciplinary core ideas, and crosscutting concepts; NGSS Lead States, 2013), and capitalizing on the intrinsic interest and natural curiosity of students. Students examine the underlying crosscutting concepts, depict disciplinary core ideas, and make use of science and engineering practices in an intertwined means in order to make sense of phenomena that are explained by alternative models (Science Learning Research Group, 2020).

Instructional Context: The Instructor and Classroom Environment

I (Colfax) am a high school environmental science teacher who applied to the summer 2019 Earth and Environmental Science Educators Institute because I was interested in exploring a new NGSS teaching methodology. As a former research science teacher and science poet, I am often attracted to professional learning opportunities that have students analyzing and interpreting real world data and evidence. (The second and third authors are part of the Institute teams.)

The students in my year-long college preparatory class are part of a comprehensive, four-year suburban NJ high school that serves an ethnically, racially, and socially diverse student population of more than 2000 students. Some students come from families who have attended the school district for four-plus generations while others have immigrated to the United States within the past few months. The course has no prerequisites, is not a requirement, and can be taken at any point in a student's sequence of high school science classes. Each heterogenous class section has students of varying past achievement and motivational levels and two of the four class sections are co-taught by life science teachers, one of whom has special education certification.

Instructional Process: Teaching with MEL and baMEL Diagrams

After attending the summer Institute and being trained on MEL and baMEL diagrams, I evaluated the scope and sequence of my curriculum and selected which MEL and baMEL activities I would integrate. In order to ensure that these activities were in alignment with the NGSS and taught in 3-dimensions, I made sure each activity provided a sound body of scientific knowledge and was based in evidence. This would allow students to realize that science continually seeks to extend, refine, and revise knowledge. I came to understand that the MEL and baMEL diagrams are not taught as stand-alone activities; rather they should be a part of a bigger conceptual unit and can serve to build / introduce information, ascertain knowledge, or provide closure to a sequence of lessons. I selected four instructional scaffolds to roll out throughout the year: Fracking MEL, Climate Change MEL, Extreme Weather baMEL, and Freshwater Resources baMEL. The Fracking MEL was used as a closure activity in a sequence of lessons where renewable / nonrenewable energy was taught. The Climate Change MEL was used for students to ascertain knowledge in the middle of an Earth's systems unit (Cervetti et al., 2012). The Extreme Weather baMEL was used to clarify and put closure to a sequence of lessons that examined weather and climate patterns, and the Freshwater Resources baMEL was used to have students ascertain knowledge about freshwater in a biomes unit.

The Model-Evidence Link (MEL) and build-a-MEL activities can be accessed on our project's website, https://serc.carleton.edu/mel/index.html.

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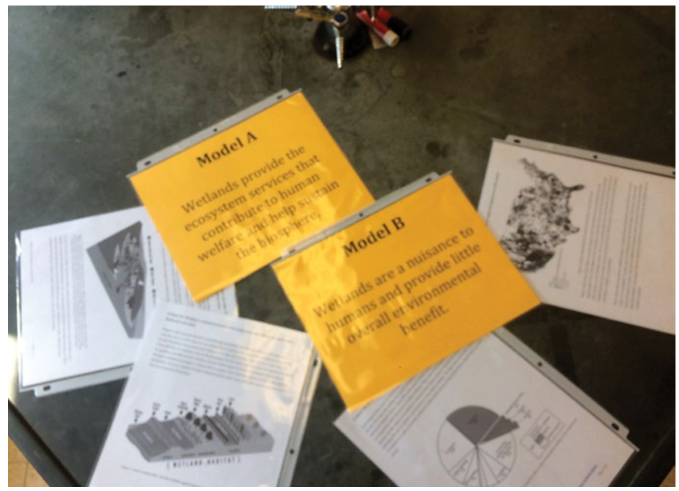
In order to develop student confidence prior to rolling out the instructional scaffolds, I opted to introduce components of the modeling diagram to students in a first quarter unit on birding. I placed 3-4 students each in a different pre-assigned group and had them evaluate and classify pieces of evidence on how they connected to bird migration obstacles. Each piece of evidence needed to be classified as: (a) strongly supportive, (b) supportive, (c) has nothing to do with, or (d) contradicts what is being studied (e.g., an explanation of a phenomenon). This simple activity helped students to better organize their thoughts when completing Claim, Evidence, and Reasoning (CER) tasks and laid the framework for communication and facilitating discussions in a small group setting prior to using the MEL and baMEL diagrams.

I decided to use the preconstructed MEL diagram activity first (i.e., prior to a baMEL) because it gave students a chance to evaluate fewer pieces of evidence at a time. This also allowed students to get used to the format without having to make as many decisions themselves. The outcome of this decision allowed me to see students build communication momentum not only as a group, but as individual learners as well.

Students stayed in the same group each time that we worked through a MEL or baMEL activity so that they could develop a communication and model analysis strategy (Horizon Research, 2013). I was able to see growth in the depth of the conversations between students. In some groups one student would emerge as a leader, directing the conversation around the lines of evidence, whereas in other groups students used pointed language to engage one another by asking for another student's opinion when their own confidence level on a particular topic was weaker.

The first MEL I rolled out was on hydraulic fracturing (aka, fracking). Prior to the MEL, students had been introduced to related disciplinary core ideas via interactive lecture; they then participated in an environmental design challenge where students worked in pre-selected teams to design a "protest sign" that represented their position and support for an energy resource. They found a peer-reviewed journal article of a *current* research study (2010-2020) that either "strongly supported" or "opposed" their selected energy resource to support their position. After the design challenge, students took to the streets outside of the school and protested, documenting their participation as an environmentalist. Students then completed a photovoice on the environmental protest actions their group considered important. (A photovoice is an assessment technique where the learner showcases a scientific concept or phenomenon that they consider important by taking a picture and composing an explanatory semi-structured narrative; Stroud, 2014.) Next, students uploaded the image, wrote a semi-structured narrative, and answered questions that delved into their perception of the best renewable/nonrenewable energy resource (Stroud, 2014). The fracking MEL followed these lessons and was used as a closure activity in this sequence exploring renewable/nonrenewable energy.

Figure 1. Lab Station Setup for the MEL.



When students attended the 80-minute Fracking MEL class, they sat in their pre-selected teams whom they had been working with for the past several class periods (Horizon Research, 2013). We warmed up with a quick review of related disciplinary core ideas. After discussing and completing the model plausibility ratings, student teams were assigned to one of six identical stations that were spread throughout the room. Every station had in the middle of the table two clear acetate sleeves containing the two models printed on colored paper in large font; white board markers; and clear acetate sleeves containing each of the different evidence texts (Figure 1). Students arrived at the table with a pencil and were given the MEL diagram.

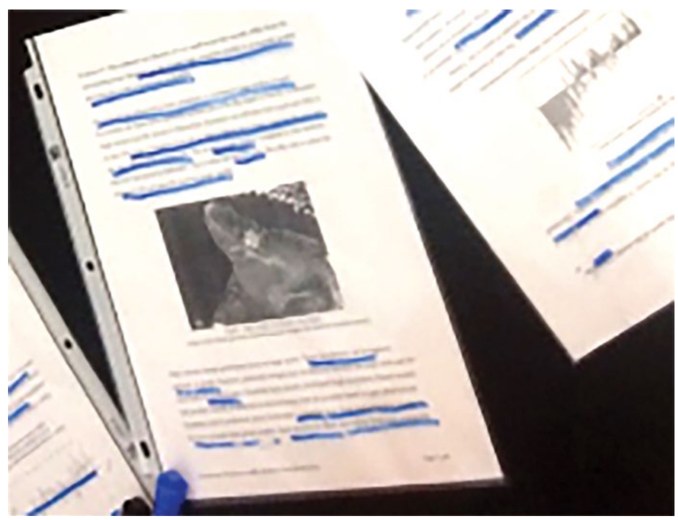


Figure 2. Students Used White Board Markers to Identify Key Aspects of the Evidence.
Note. The white board markers allowed students to underline, circle, and draw connections to information to help them better determine and draw connections to a line of evidence that (a) strongly supports the model, (b) supports the model, (c) has nothing to do with the model, or (d) contradicts the model.

I began by going over how to read and use a MEL diagram, focusing particularly on the use of the arrows and the direction in which they point and then discussing the models on the table and how to use the evidence documents. After providing some additional guidance and documenting examples from the previous interactive lecture on the board, students were then given work time. They initiated the process by discussing the models and making sense of the evidence provided. Students were encouraged to use the white board markers to write on the clear acetate sleeves of the evidence documents as they brainstormed and classified the pieces of evidence (Figure 2). They arranged the evidence physically around the models, drawing arrows to represent whether each evidence (a) strongly supports the model, (b) supports the model, (c) has nothing to do with the model, or (d) contradicts the model. I walked around the room facilitating and engaging in dialogue to help students through this process.

After about 15-20 minutes of brainstorming and discussion, the energy in the room shifted and the analytical writing process was well underway. Students were asked to fill out an explanation task and use the completed MEL diagrams to clarify their model-and-evidence connections, construct understanding, make sense of their reasoning, and provide justification for the strength of their selected evidence (Katz, 2010). I had students hold onto their explanation tasks until the last ten minutes of class to share out to the larger group as part of the lesson closure (Horizon Research, 2013). There were times when the students' scientific explanation was highly developed and other times it was not; in some cases a student struggled just to come up with one solid explanation of an evidence-to-model connection. The level of explanation was highly dependent upon the background of the student and their confidence level with evidence classification. I found that students who had familiarity with FRQs (free response questions) from Advanced Placement courses, particularly in history, were the strongest with this process. Students who had many informal science learning experiences outside of the traditional classroom setting were also more at ease and confident in their evaluation of the evidence presented (NSTA, 2012). Ultimately, I hope that the students walked away from the MEL lesson knowing that scientific evidence and analytical writing "cross fertilize" one another and that by diagraming one's thoughts about evidence one can deepen their understanding of scientific concepts (Lederman, 2014).

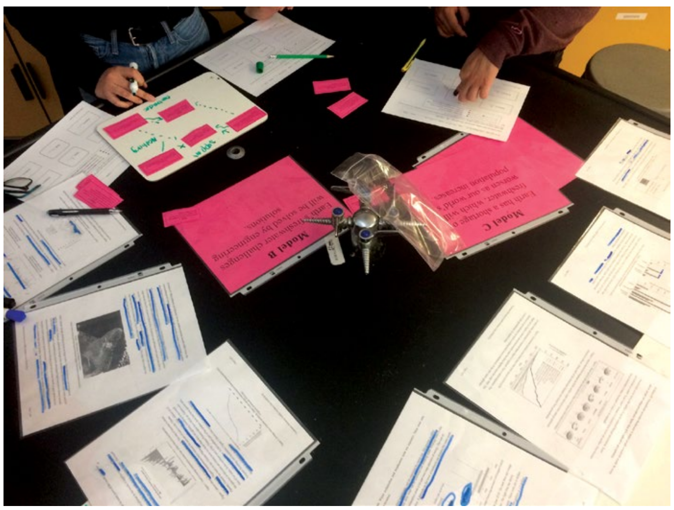


Figure 3. Students Used Small White Boards for Processing and Elimination.

While each MEL or baMEL activity had a different topic, the approach that I undertook to structure the activities were similar. The only difference between the structure and delivery of MEL and baMEL activities were the tools that the student groups were given at each lab table. When we conducted a baMEL activity, each station had three clear acetate sleeves, each containing a different model printed on colored paper in large font in the middle of the table; white board markers; clear acetate sleeves containing each of the different evidence documents; and a stack of four small white boards (Figure 3). Several student groups requested the white boards before the baMELs were conducted to help them process and eliminate evidence that they were not going to use.

After using multiple MEL and baMEL activities throughout our year-long course, we found it beneficial to assess students through a CER task. The goal for this type of assessment was not to determine the student's acquired conceptual knowledge; rather it was in their skill of justification. We provided students with an article and a singular question to reflect upon. In return, they developed a scientific claim, selected pieces of evidence from the provided source and justified the use of their evidence through a reasoning explanation.

Conclusions

The MEL and baMEL tasks use alternative and contradictory models that explain a particular phenomenon (e.g., causes of current climate change). They allow for students to strengthen their scientific reasoning skills by examining evidence and how it connects to (i.e., supports, strongly supports, contradicts, or has nothing to do with) the models in order to promote scientific thinking. They also ensure that students are learning in three dimensions; the knowledge and evidence examined provide ample opportunity for students to extend, refine, and revise their scientific knowledge. My colleagues and I intend on using MEL and baMEL instructional scaffolds to have students explore controversial and/or complex Earth and space science topics for many years to come. It is through science teaching methodologies such as these that students can dialogue and communicate using scientific evidence to deepen their understanding of scientific concepts.

References

Cervetti, G. N., Barber, J., Dorph, R., Pearson, P. D., & Goldschmidt, P. G. (2012). The impact of an integrated approach to science and literacy in elementary school classrooms. *Journal of Research in Science Teaching, 49*(5), 631–658. https://doi.org/10.1002/tea.21015

Horizon Research, Inc. (2013). *2012 national survey of science and mathematics education: Highlights report.* Chapel Hill, NC: Horizon Research, Inc.

Katz, L. G. (2010, May). *STEM in the early years* [Paper presentation]. SEED (STEM in Early Education and Development) Conference, Cedar Falls, IA. Retrieved from https://ecrp.illinois.edu/beyond/seed/katz.html.

Lederman, N. (2014). Guest editorial: Nature of science and its fundamental importance to the vision of the Next Generation Science Standards. *Science and Children, 52*(1), 8–10.

Lombardi, D. (2016). Beyond the controversy: Instructional scaffolds to promote critical evaluation and understanding of Earth science. *The Earth Scientist, 32*(2), 5-10.

Morris School District. (2019). *Morristown High School profile 2018-2019*. Retrieved April 18, 2020, from https://resources.finalsite.net/images/v1560777686/morrisschooldistrictorg/ylzmjxxn43uzyy6n5euz/Profile2018-19_Final.pdf

National Science Teachers Association (NSTA). (2012). *Learning Science in Informal Environments*. Arlington, VA: NSTA. https://www.nsta.org/about/positions/informal.aspx

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press. http://www.nextgenscience.org/

Science Learning Research Group. (Ed.). (2020, January 27). baMEL Instructional Materials. Retrieved April 18, 2020, from https://sciencelearning.umd.edu/instructional-materials/

Stroud, M. (2014). Photovoice as a pedagogical tool: Student engagement in undergraduate introductory chemistry for nonscience majors. *Journal of College Science Teaching, 43*(5), 98–107.

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