Learning Frameworks

Modeling and Forming Explanations Framework

Why are the practices of modeling and forming explanations important scientific practices?

Modeling and forming explanations are two critical ways that scientists build knowledge and then test, critique, and revise that knowledge. They are tools that scientists use to help them make sense of the world, and field-based scientists are no exception. When learners engage in field-based science, they can use the models and explanations they construct based on data and evidence to help them engage in ethical deliberation and decision-making about socio-ecological phenomena and the complex socio-ecological systems of which they are a part.

Modeling in field-based science education

There are many types of scientific models: explanatory, computational, scale, and theoretical models, just to name a few. Learners should have opportunities to generate, test, revise, and critique models as part of field-based science investigations. This is important work for many reasons, but in this framework we focus on three. First, generating and revising models of scientific phenomena associated with complex socio-ecological systems is an important part of sense-making, deliberation, and decision-making. Secondly, working with models is central to helping learners visualize and revise their own thinking. It also powerfully supports and fosters the sharing of ideas so that learners, educators, learners' peers, and their families can better understand how they are thinking about species, kinds, behaviors, places, lands, and waters, as well as the relationships among them and the various scales (space, time, size, and perspective) that are being explored and posited in learners' models. Third, generating models and using them to explore various scientific phenomena that are part of complex socio-ecological systems helps learners, in part, see and then consider power and historicity in those systems and the cascading impacts of changes in systems on a range of entities (e.g. other humans, animals, plants, waters, etc...), which will be critical to their ethical deliberation and decision-making.

Modeling in field-based science is a sense-making practice as learners understand why, how, under what conditions, etc. nature-culture phenomena happen the way they do, and how place, time, power, and human intervention influence phenomena. Learners should have opportunities to engage in modeling practices individually but also with others using a type of ensemble modeling, which enables learners to take account of others' ideas and jointly build a model that represents their collective sense-making about socio-ecological phenomena. **It is important to remember that scientific models are not static**; they are not drawings or diagrams that scientists and science learners create and then abandon in favor of the next activity. Instead, they are dynamic and ever changing based on new data and other types of information learned through investigations of phenomena, discussions with others, and new learnings from sources like media of various types. Learners should be continuously revising their scientific models, and should be supported in discussing how and why they have made revisions. Scientific models are not art projects. They are tools for prediction, exploration, and explanation. It is also important to keep in mind that models are never perfect replicas of the phenomena they represent. Instead, they are ways of thinking about, investigating, and trying to predict those phenomena to better understand and explain them.

Connections between models and explanation

Models are a type of explanation because they posit ideas about complex socio-ecological phenomena and the systems of which they are part. Scientists construct explanations for many different reasons. For example, they might need to explain their research methods to other scientists so that their research can attempt to be replicated. Additionally, scientists use data they collect and their interpretations of those data (their analyses) to help them construct plausible explanations that address their research questions (for example, investigating and then explaining a phenomenon they are studying, investigating and then explaining why a new research method is useful in examining certain types of questions). Regardless of what scientists are explaining, their explanations address "why" and/or "how" questions (for example, why an animal might be exhibiting a certain behavior when in relationship with another animal or plant, how climate and weather are in relationship with one another). Explanations are not descriptions and they are not answers to questions. They offer plausible accounts that speak to the "why" and/or "how" of phenomena. As is the case with models, there are various types of scientific explanations, such as causal explanations and mechanistic explanations. There are also pragmatic explanations, which take context into account. Tilly's (2006) framework for explanations and the reasoning undergirding them provides some examples of explanatory constructions that humans generate to make sense of the world.

- **Conventions** are explanations that we tend to accept from others (for example, I was late for my appointment because a friend was locked out of her house and I have a key).
- **Stories** are often explanations that we use to communicate events, experiences, and perspectives.
- **Codes** are explanations that dictate our actions in areas such as religion and the law.
- **Technical accounts** are explanations that are generated in the sciences, engineering, medicine, architecture, and other professions.

Connections to expert thinking:
Modeling and constructing explanations using data and evidence are core knowledge-building practices in the sciences, including field-based science. Throughout this framework, you can find examples of the types of models scientists use, examples of the phenomena they try and explain using those models as tools, and types of explanations they construct. Scientists rarely, if ever, work by themselves to construct, test, critique, and revise models and explanations. Instead they engage in ensemble practices to model and generate explanations using data and evidence from various sources and their collective sense-making.

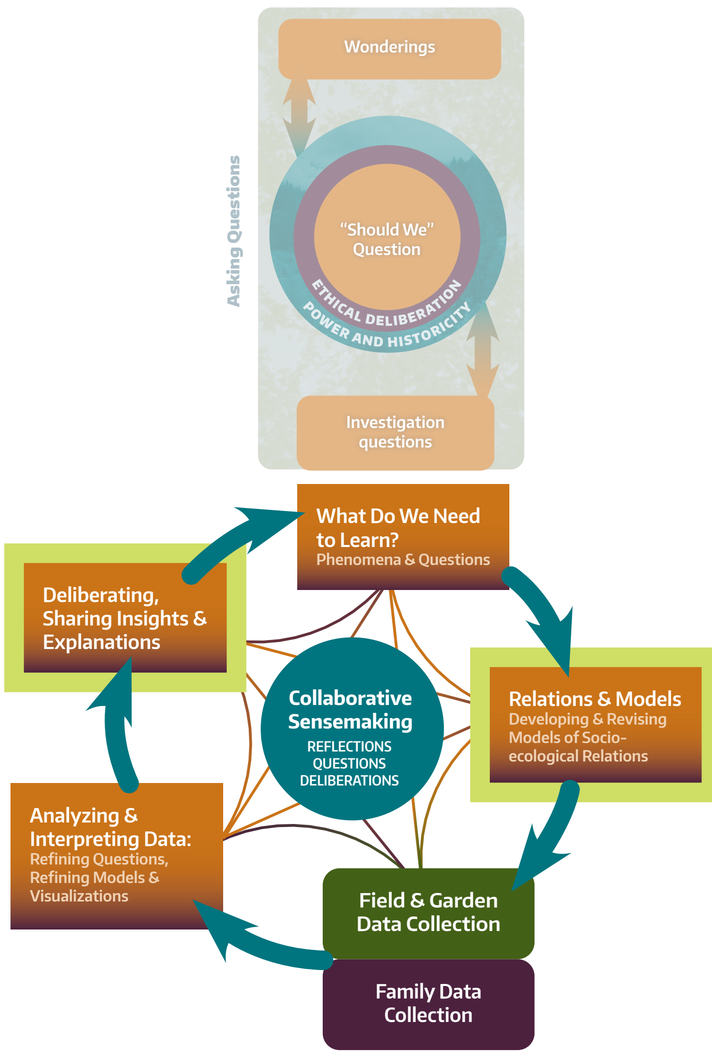
Explanation in field-based science education

Technical accounts are overwhelmingly privileged in science education, but this forecloses the other types of explanations that learners are practiced at constructing and that have deep explanatory power in their lives. No matter the type of explanation, it is important to recognize that: (a) explanations are contextual, meaning that the type of explanation that is appropriate in any given situation depends on what type of activity is taking place, where, why, who is involved, and where power resides in the context, and (b) like all human discourse, practices, and interactions, explanations are cultural, powered, and have histories. All of this has implications for both how explanations are generated in any given situation, and how explanations are critiqued. Learners of all ages should have opportunities to generate and critique scientific explanations, but again, educators should understand that learners, no matter their age, already have experience engaging in explanatory practices. Educators should be familiar with the types of explanations learners are practiced at generating and critiquing in different contexts because these could be important learning anchors that educators could use to help learners understand how to generate and critique scientific explanations when that is called for.

Dimensions of Explanation

Learners generate, test, revise, and critique explanations as part of field-based science investigations in order to:

- offer plausible accounts that speak to the "why" and/or "how" of socio-ecological phenomena using data and evidence from field-based investigations, and from other sources, such as consultations with community members and a variety of media
- interrogate their accounts using dimensions of power and historicity in socio-ecological systems, and consider what might be missing from their accounts and thus, what additional data and other types of information they might need to collect



Dimensions of Modeling

Learners generate, test, revise, and critique models as part of field-based science investigations in order to:

- sense-make, deliberate, and make-decisions about socio-ecological phenomena
- visualize and revise their own thinking, and share thinking and ideas among themselves, their families, their peers, and educators
- see and then consider power and historicity in socio-ecological systems and the cascading impacts of changes in systems

How to use this framework

Learner Sense-Making: Use this framework to plan learning activities that explicitly and purposefully ask learners to generate, test, revise, and critique socioecological-related models and explanations, and reflect on those practices as part of their sense-making. Use this framework to provide opportunities for learners to engage in these practices individually and collectively.

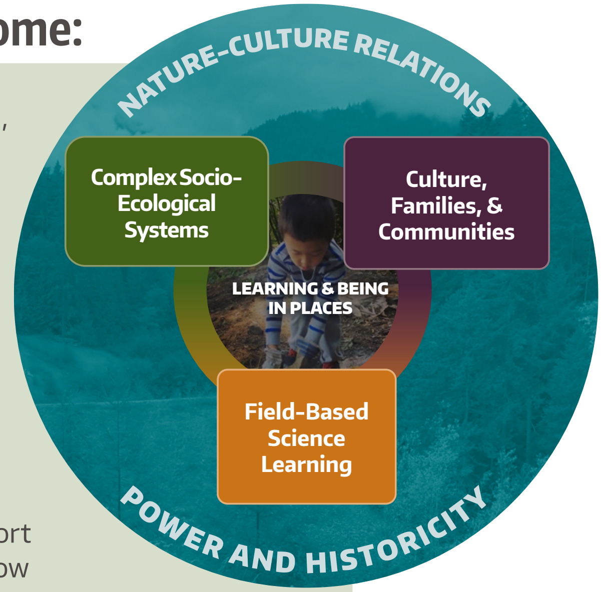
Planning and Implementation: Use this framework to guide your planning and your teaching. For example, how do you plan to learn more about what types of models learners tend to generate, revise, and otherwise use in various contexts like home, neighborhoods, museums, with their friends and families, etc.? What types of learning experiences do you plan to use to help support learners in their modeling practices (including the revisions of their models based on data) related to complex socioscientific systems and embedded phenomena? Where do you anticipate learners needing the most modeling support, and what are some strategies you will use to support them? How do you plan to learn more about what types of explanations learners tend to generate and critique in various contexts? What types of learning experiences do you plan to use to help support learners in generating, critiquing, and revising scientific explanations?

Collaborative Practice: Use this framework to support model and explanation generation, testing, revision, and critique as part of field-based science practices that help learners sense-make about complex socio-ecological systems and related phenomena. Create a learning environment where learners have opportunities to practice modeling phenomena both individually and as part of the collective engaged in ensemble modeling (remembering that the practice of modeling requires that learners revise their models over time in light of new learning). Additionally, support learners in generating varied types of field-based explanations (for example, related to research methods, related to phenomena and questions they are investigating). Create tools that help learners support each other generating, testing, and revising models and explanations, because science is a collaborative and collective enterprise.

Educator Reflection: Use this framework to reflect on your own modeling and explanatory practices. What types of models have you had the opportunity to generate, revise, and otherwise use, and in what contexts and for what purposes? What types of explanation-related conventions, stories, codes, and technical accounts have you had the opportunity to use and critique and in what contexts and for what purposes? What types of support do you need to help learners engage in modeling and explanatory practices? How do you plan to seek out that support?

Co-Design and Assessment: Use this framework to guide your co-planning with other educators and families to help learners generate, test, revise, and critique models and explanations related to their socio-ecological sense-making and field-based science investigations. Use this framework to guide the use of formative assessment tools that help you understand how learners are making sense of generating, testing, revising, and critiquing scientific models and explanations as part of their socio-ecological sense-making, deliberation, and decision-making.

Connections to the Learning in Places Rhizome:



Complex Socio-Ecological Systems: Learners should be creating, testing, revising, and critiquing models and explanations that are specifically aimed at investigating and understanding nature-culture relations as part of complex socio-ecological systems. For example, perhaps learners are trying to make sense of observations that document the co-occurrence of an animal and a specific type of plant (i.e., they are trying to figure out the relationship between animal and plant), and they use models to explore that relationship and ultimately offer a plausible explanation for how that co-occurrence happens and why. Perhaps learners are exploring plant growth in a specific place throughout the seasons, and are modeling aspects of that phenomena (e.g., air and soil temperature, soil moisture), in an effort to ultimately explain why or how the plant grows as it does and how seasons impact that.

Nature-Culture Relations: Learners should have opportunities to generate, test, revise, and critique models to explore nature-culture relations with respect to scientific phenomena related to complex socioecological systems. For example, learners might need to model the relationship among an observed plant and animal species in a populated neighborhood, and then continue to revise their models over time and related to seasonal change. Explanations about complex socioecological systems offer plausible understandings and reasons for nature-culture relations. Plausibility is an important criterion for explanations to meet because although humans work to understand socioecological systems and specific, related phenomena by collecting field-based and other types of data, and analyzing those data, future data and analyses can shed new light on the workings of systems and phenomena, and thus, explanations are revised.

Field-Based Science Learning: Generating, testing, revising, and critiquing models and explanations are core knowledge-building practices in the sciences, and field-based science is no exception. For example, restoration ecologists might use mathematical models and mechanistic models to help generate explanations of population dynamics and elements of plant phenology, respectively. They might use field-based techniques (like observation) to identify forest biogeographical patterns, for example, that they can then model and explain. Learners should have continuous opportunities to practice generating, testing, revising and critiquing models and explanations as part of their field-based science learning related to scientific phenomena embedded in complex socio-ecological systems.

Power and Historicity: Modeling and formulating explanations are cultural activities that are always contextual, and thus, powered. Yet, often some types of models and explanations are privileged over others and are given more power (for example, statistical models might be given more weight than anological models in some cases, and models generated by some scientific fields like physics might be given more weight than models generated by other scientific fields like field ecology). Users of this framework should keep in mind that modeling and other explanatory practices are situated, meaning that people generating, testing, revising, and critiquing models and other explanations must do so by taking account of place, cultural activity, purposes of that activity, and the people involved. Models and other explanations also have histories, and learners should have opportunities to explore the histories of various models and other explanatory accounts in order to explore questions, such as "Who was involved in constructing these? Who do they benefit and why? Who might they harm and why? What perspectives are foregrounded? What perspectives are missing?"

Suggested Citation

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