Pathways to Learning: The Institute for Inquiry’s Approach to Teaching and Learning Science Through Inquiry

We keep a two-panel “Calvin and Hobbes” comic strip by Bill Watterson posted in the Institute for Inquiry office. In the first panel, the boy and his tiger are looking at something on the ground, and Calvin exults, “Look! A trickle of water running through some dirt!” In the second panel, the two are hunkered down next to the trickle as Calvin says, “I’d say our afternoon just got booked up solid.”

It’s not hard to imagine what that afternoon might look like: putting rocks and sticks of different sizes into the streamlet to see what happens to the water, and to the rocks and the sticks; trying to create a tiny lake by damming up the flow; gouging out new channels in the dirt to redirect where the water goes; racing “leaf boats” of different shapes and sizes; following the water back to its source; adding more water from a garden hose; trying to find a way to get the water to flow uphill. And all the while, pointing out to each other the “cool” things they see occurring, asking themselves and each other, “What would happen if we did this, or that?” then going ahead and trying it all out.

While Calvin and Hobbes are merely cartoon characters, what strikes us about this comic strip is how true-to-life it is, how deftly and accurately it portrays the innate urge to explore and to know how the world works that is at the heart of all inquiry. What fuels this afternoon-long investigation of water flowing through the dirt is the simple, powerful phenomenon of human curiosity. It’s the same curiosity that drives the inquiries working scientists carry out at a far more sophisticated level in their laboratories or in the field. That curiosity, when shaped by an effective pedagogical structure, can also fuel and sustain students’ science learning in the classroom.

The Inquiry Approach to Learning Science

Inquiries begin when people come upon phenomena that intrigue or surprise them, perhaps even confuse them. What makes this happen? What can I do to figure out what’s going on here? That initial encounter is the beginning of the inquiry journey. From there, the inquirer develops an investigation plan and then assembles all the equipment and materials necessary to carry out the investigation—rocks and sticks and leaves in the case of Calvin and Hobbes, perhaps laboratory samples and highly specialized instruments in the case of the scientist, and for students, materials the teacher makes available for exploration and investigation.

Whether in a lab or in a classroom, investigations rarely proceed in a straight line from questions to answers. Closely examining an intriguing phenomenon frequently leads to new questions and new pathways of investigation. Sometimes those pathways lead away from the original inquiry in a variety of new directions. And sometimes those pathways come to dead ends. But usually they lead to a new perspective, an unanticipated insight into the phenomena that generated the investigation in the first place. Although they may seem to be an inefficient way for students to learn science, these meandering paths can actually provide learners with a broader experience and deeper understanding of science concepts and ideas than more linear, prescribed investigations. In addition, each new question, each new finding along the way, reinvigorates the curiosity that began and sustains the inquiry. And each new piece of information gathered contributes to the growing knowledge of the inquirer.

In Institute for Inquiry workshops, we have witnessed the excitement and intellectual thrill that occurs as learners
find their own paths, answer their own questions, and make their own scientific discoveries about the particular science concepts inquiries were designed to address. Studying science this way builds a sense of ownership, which helps to keep learners strongly motivated as they carry out their inquiries.

Structuring the Inquiry Experience
At the Institute for Inquiry, we design inquiry experiences based on a structure that helps learners build an understanding of specific science content by tapping into their own curiosity. These experiences are meant to provide learners with the satisfaction of figuring out something for themselves, and to help them answer their own questions. We have spent more than 30 years bringing this approach to professional developers and to teachers of students of all ages. Our observations have served to reinforce our belief that with a well-designed structure and sensitive facilitation, inquiry is a powerful approach to teaching science.

When engaging in inquiries using this structure, learners explore simple sets of materials, encounter phenomena that intrigue them, and ask all sorts of questions about those phenomena. They choose questions to investigate and team up with others who want to pursue the same (or related) questions. They proceed to plan experiments to help them answer their questions and become completely absorbed in carrying out those experiments. Learners engage in animated discussions with each other as they work, trying to explain what they observe. And when their investigations are complete, they share their findings with each other as a way to further their understanding of scientific concepts.

In teaching science using this structure, the teacher determines the topic of study. In order to achieve the science content learning goals, teachers cultivate learners’ abilities to ask productive questions, design effective experiments, propose and test explanations of the phenomena they observe, and interpret the data they collect. In effect, teachers play the role of facilitators, providing support and guidance, and giving information when necessary. Facilitation always has the aim of helping students take responsibility for their own work and become self-motivated, independent learners.

Working from the way students think and learn is at the heart of effective inquiry facilitation. Teachers keep in mind the importance of learner ownership, and are careful not to superimpose their own ideas onto students’ inquiries. Gauging the type of help that learners need, teachers give the minimum assistance necessary for learners to move forward, toward the science content goals of the inquiry.

Besides being a powerful and effective way to learn science content, inquiry learning using this structure helps promote the development of scientific attitudes, such as perseverance, respect for evidence, and risk-taking. Students who are “in charge” of their own science inquiries, who “own” their own learning, and may choose their own pathways of investigation, develop a first-hand understanding of the importance of those attitudes. They experience the value of persisting, even through rough patches, moving through confusing places or apparent dead ends to some new understanding. And when they see that they need to use evidence from their experiences to arrive at a tentative explanation of what they’re seeing, students learn to respect evidence. They also recognize how risk-taking—starting off on an entirely new pathway—can reward them with important new (and sometimes surprising) information and insights into the phenomena they are investigating.

How the Structure Works
As the diagram below indicates, in the inquiry structure used by the Institute for Inquiry, learners move through three phases of the inquiry process—Inquiry Starter, Focused Investigation, and Sharing Understanding. (For a more detailed version of this diagram, go to http://exploratorium.edu/ifi/about/philosophy.html and click on “Inquiry Structure.”)
Inquiry Structure for Learning Science Content

**Inquiry Starters**
- Learners explore materials, make observations, and raise questions related to content goals

**Focused Investigation**
- Learners plan and carry out investigations based on their questions

**Sharing Understanding**
- Learners share investigation findings with each other to further understanding of scientific concepts

*Inquiry Starter*

In the Inquiry Starter phase, learners explore intriguing materials and phenomena designed to arouse their curiosity and generate questions that they will want to answer by doing their own investigations. The teacher carefully selects materials that will exhibit phenomena related to the inquiry’s science content goals. The Inquiry Starter is intended to provide learners with a variety of possible directions to pursue in their investigations.

In this phase, learners work together in small groups, observing and interacting with materials and phenomena that are interesting and a bit puzzling to them. Close observation of intriguing materials and phenomena naturally elicit all kinds of questions that could lead to investigations. There is a lot of talk within groups about what they are seeing and how it might relate to similar things they have seen before. As questions, observations, and ideas arise, students record them. Older students might write in science notebooks, which they can continue to use throughout their investigations. Younger students might tell their questions to the teacher, who will write them down. At the end of the Inquiry Starter, all students’ questions are displayed for everyone to see.

In the Inquiry Starter, the teacher plays a limited but important role—encouraging learners to explore materials freely and to raise and record all of their questions.

*Focused Investigation*

The Focused Investigation phase comes next. It is an extended period of time during which learners identify questions they wish to pursue and conduct experiments to try to answer those questions. Learners also discuss and debate ideas and explanations.

As students transition from Inquiry Starters to the first part of this phase, the teacher helps them identify questions they can investigate and those they won’t be able to pursue. Some questions cannot be pursued because they do not fit with the topic under study; others would require more time, material, and resources than are available.

As students consider which questions interest them, the teacher helps them connect with others and form small investigation groups that will plan and carry out investigations of the questions they selected. Group members start off by discussing how they want to begin their investigations and what materials they might need. The teacher helps them find the right materials and set up a workspace. Some groups may not yet be certain of their exact focus and need more time to explore. They will continue to “mess about” with the materials, looking for what they find most interesting, what they can’t explain, or what they can change or manipulate. Other groups may be ready to produce an investigation plan right away.
so they begin gathering and setting up the necessary materials as soon as they have a place to work.

During this initial part of the Focused Investigation, the teacher begins by checking in with each group and doing a quick assessment based on early investigation plans and steps the groups are taking. Teacher assistance may come in the form of asking questions, making suggestions about materials or the design of experiments, or simply providing encouragement.

As the investigations continue, learners’ work becomes more and more intently focused on the phenomena they are trying to understand and explain. This work takes place at varying levels of sophistication and could include, based on the developmental level of the students, some or all of the following experiences. Learners continue to interact with materials, make additional observations, and ask new questions. They record their experiments through writing and drawing in their notebooks. They get into discussions—and sometimes disagreements—as they try to explain to each other what they are seeing. They look at what other groups are doing, and share their observations and ideas. They make predictions and figure out how to test those predictions.

When groups gather enough information and have enough experiences, learners begin to notice patterns, and propose explanations for what they see. They may create a simple model that explains the behavior of the phenomena that they are investigating; for example, using a string to represent the straight-line path that light takes.

Communication during investigations is continuous, and it plays an important part in the learning. The give-and-take of ideas—argument, explanation, use of evidence to support ideas, creation of shared models—plays a crucial role in learning new science concepts.

Discussion is particularly important and powerful within the course of an investigation because learners can test ideas by returning to the materials.

As we noted earlier, investigation is a fluid process that changes throughout its course. Groups start with an initial plan, but as they begin to carry it out and conduct a variety of experiments, new information and observations emerge. Often, discussion among group members about what this new information means leads to changes in the original plan. One group may find that there is an important variable to experiment with or control. Another may see the need to simplify an experiment. Still another may answer their initial questions right away, or come to a “dead end,” and in both cases conclude that they need to pursue different questions from the ones they started with. Their experience may even suggest that seeking the answer to a new question may be more fruitful.

Groups often go through a repeated cycle of planning, experimenting, considering what they found out, and then modifying their plan and trying again.

In the earlier part of the inquiry the teacher moved quickly from group to group, interacting very little, providing support and encouragement. During this part of the investigation, facilitation is much more focused. The teacher’s job now is to develop an understanding not only of what each group is doing, but also of what and how students are thinking about the phenomena they are dealing with. In doing this, teachers need to spend more time with each group, watching what a group is doing and listening to what students are saying to each other. To get more information about their thinking, teachers can ask group members to explain what they’ve done up to the current point, what they are doing now, and what they plan to do next—and the reasons they have for doing it. Once they have a sense of what learners are doing and thinking, teachers may point out something that learners haven’t noticed; may suggest trying a new material or a different experimental configuration; may recommend visiting another group working on something similar; or may raise questions about the group’s thinking, requesting clarification of ideas or asking for the evidence behind a group’s tentative explanation.
When providing assistance, the teacher is careful not to give learners “the answer” when learners themselves have the resources to figure out the answer on their own. If a teacher supplies an answer, the learners’ focus shifts toward trying to understand the explanation rather than trying to understand the actual phenomena they are investigating. However, there are times when it is appropriate for the teacher to provide information. This information that would not be accessible or would take a long time to discover through first-hand investigation and without which the learner could go no further. When learners get to a point in their investigations at which they need a critical piece of information, the facilitator can present information in the form of a mini-lecture, demonstration, or directed activity. When presented at the proper time, this information is understandable and useful to the learners because they have had sufficient experience with the phenomena to make sense of it.

One of the primary tasks of the teacher during the investigation phase is to help students effectively use the process skills of science (observing, questioning, predicting, etc.) in learning science content. The most useful kind of support usually involves asking questions that focus learners’ attention on elements of their work that might need rethinking—the design of an experiment, controlling variables, making predictions based on evidence, coming up with a tentative explanation (hypothesis) for what they are observing, and testing that explanation.

Toward the end of the Focused Investigation phase, learners are asked to prepare to present to the whole group their findings and the evidence supporting those findings. Students review their sketches and notes and then create drawings, charts, diagrams, graphs, or demonstrations to try to convey their understanding to others. Older students do this on their own, while younger students will need help from the teacher. This process is an important part of the learning experience. It requires that learners think about and explain very clearly and specifically what they figured out and what their evidence is for these conclusions.

During this time, the teacher helps groups think through their presentations, making sure that they plan to talk about the important ideas that they have uncovered, along with the evidence they have for their ideas.

Sharing Understanding

In the Sharing Understanding phase of the inquiry, learners explain what they did and present their findings to the entire group. In the case of very young students, sharing may be as simple as students making statements about their observations. As students mature, their presentations include more generalizations and evidence. These presentations help further everyone’s understanding of the scientific concepts that the inquiry was designed to address.

Hearing a number of different people talk about their experiences and ideas plays a central role in learning the science concepts. In listening to the presentations of other groups, learners may encounter important pieces of information that they didn’t come across in their own investigations. They may hear others express similar ideas to their own in slightly different ways that provide them with a deeper understanding of what they themselves discovered. And they will likely have their own discoveries confirmed by the findings of one or more of the other groups.

Repeatability of results is an important test in science. When two groups do the same experiment and get different results, learners might not trust either result, suggesting that further experimentation is needed. On the other hand, if they get the same result, the learners’ trust in that result is strengthened. Multiple examples can provide evidence that the phenomena or concepts are not just the chance product of one group’s work. In addition, multiple examples can help determine the generality of a phenomenon or idea. Learners may see the same effect.
over a range of conditions. Finally, multiple examples may allow the learner to see patterns that can only be revealed by observing a large number of trials.

During the presentations, the teacher asks questions to elicit and clarify ideas, and to make connections between various groups’ presentations. Where appropriate, the teacher adds information or ideas to illuminate and tie together the groups’ findings. Learners may also raise questions and ask for clarification from the presenters.

After the presentations, the teacher builds on the foundation of knowledge and experience communicated by the investigation groups with a synthesis that relates the presentations to each other and to the conceptual goals of the inquiry. First, the teacher gives a broad overview of the major science concepts addressed in the session. Referring to particular presentations, the teacher shows how those science concepts and the applications of those concepts emerged from everyone’s work during the investigations. In pointing out the connections among various presentations and in identifying the scientific concepts the presentations addressed, the teacher introduces scientific terminology. The teacher may also show ways of applying the concepts to explain everyday phenomena that learners are likely to be familiar with.

Finally, if there seems to be anything missing from learners’ understanding of the inquiry’s science concepts, the teacher has the opportunity to add ideas or important examples to complete the picture. Through the synthesis, the teacher can help the learners tie together the ideas that they developed themselves or heard from other groups to help create a unified picture of the inquiry’s science content.

**Conclusion**

A central driving force for human beings is the desire to grapple with an intellectual challenge and solve it for themselves. Encountering a new (and perhaps puzzling) phenomenon or idea, wrestling with it to try to make sense of it, and finally arriving at some understanding of it, produce a tremendous sense of satisfaction. This is the way scientists “do science,” and it’s a powerful way for students to learn science in the classroom. Learning this way satisfies the deep human need to construct knowledge from experiences. But in order to be effective in classrooms, where teachers have specific educational goals for their students, this kind of learning requires a structure that supports students’ thinking and experimenting.

Not only does that structure provide teachers with a way to organize inquiry-based experiences, it also gives them a new way to think about teaching. Massachusetts Institute of Technology physicist and educator Philip Morrison writes eloquently about this new way of thinking and the student’s path of learning, “I think our instruction has been single-pathed. You’re in a forest, you walk carefully along the path, and you reach the chest of doublings on the other side and solve the problem. And that is the way we, I too, teach physics. But the kids that try it get lost at each turning of the path. The trouble is that they think there is only one safe path, that they have to stick to it as close as they can, and they’re afraid to go off into the deep woods. I think that the only way to teach path finding is to make them get lost many times, to make all the false starts, to try out all the alternatives. Of course, you can’t learn many paths that way, but you can learn a way of going down a path. Then, if someone gives you another start, you might be able to find a way for yourself.”

By its very nature, inquiry science provides students with the opportunity to create their own pathways leading to an understanding of science concepts. It gives educators a way to follow Philip Morrison’s advice, to teach path finding, so that in addition to learning science, students can develop as independent, self-motivated learners.


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