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ABSTRACT

For students to develop a more realistic picture of how scientists practice science, there must be well-researched understanding of how scientists do science. A model for the process of scientific inquiry that more closely reflects actual scientific practices can provide a means of dispelling some of the myths about scientific inquiry. This paper presents an analysis of the presentation of the scientific method that is in a group of current science textbooks. Combined with this analysis are new results from a separate study of research scientists' conception of scientific inquiry. From these results, a new model for the process of scientific inquiry was developed that was called the inquiry wheel. In this paper, the traditional scientific method is compared and contrasted with the model of the inquiry wheel. (Contains 60 references.) (Author/MVL)

A SCIENTIFIC METHOD BASED UPON RESERACH SCIENTISTS' CONCEPTIONS OF SCIENTIFIC INQUIRY

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Within science education, clarifying the definition of inquiry has tended to focus on equipping teachers with methods to teach inquiry (Martin-Hansen, 2002; Colburn, 2000, Lederman, 1998). A key goal of science education reform, however, is to improve student understanding of scientific inquiry and ability to do scientific inquiry (National Research Council, 1996). A significant challenge to providing students with the opportunity to model how scientists do science is the persistent description of the scientific method. The literature contains papers written for teachers that foster a traditional understanding of the scientific method and encourage its use in the classroom (some recent examples include: Nelson, 1988; Haines, 1997; Siebert & McIntosh, 2001; Giunta, 2001). On the other hand, recent criticism of the traditional scientific method model asserts that it is not reflective of how real science is accomplished (Bauer, 1996; McComas, 1996; Lederman, 1998).

Textbooks written for students represent an important vector for the perpetuation of the traditional scientific method (Finley & Pocovi, 2000). The traditional presentation of the scientific method is in the form of a linear checklist leading to the formation of a theory. Taylor (1962) notes that the scientific method has tended to emphasize verification stages rather than science as a creative process. "The core of scientific process is better described by the usual steps in the creative process than by traditional textbooks' descriptions of the specific sequences in the scientific method" (p. 599).

Textbook presentations of science can have a powerful impact on teachers and their students in part because textbooks are often the main resource for teachers and for students to access information about science. Teachers and students naturally assume information in textbooks is an accurate portrayal of science. This provides science textbooks with a powerful influence over how teachers teach science and how students perceive science and scientific practices. If textbooks present science as a static endeavor where investigations invariably lead to theories then students may assume that all scientists conduct science in such a manner.

Gallagher (1991) studied the relationship between textbooks and teachers' perceptions of science. In his study, textbooks tended to describe science as an objective body of knowledge. Similarly, all 25 secondary science teachers adopted the same view of science. Eliot (1989) also expressed concerns that students were primarily getting information about the nature of scientific inquiry only from lectures and textbooks.

The Biological Sciences Curriculum Study (BSCS, 1963) voiced their concern over textbooks that tended to treat biology as stable facts without the human side of scientific investigations. Schwab (1962) also expressed concern with textbooks portraying science as consisting of "empirical, literal, and irrevocable truths." This portrayal of science in the textbooks did not match the changing perceptions of the accumulation of scientific knowledge. Scientists' views of scientific knowledge had shifted from a deterministic mindset where scientific laws and theories were either proven or disproved to a mindset where knowledge is probabilistic and laws and theories are subject to revision as new evidence is considered. Thus, "the knowledge won through enquiry is not knowledge merely of the facts but of the facts interpreted" (Schwab, p. 14).

For students to develop a more realistic picture of how scientists practice science, there must be a well-researched understanding of how scientists do science. A model for the process of scientific inquiry that more closely reflects actual scientific practices can provide a means of dispelling some of the myths about scientific inquiry. This paper presents an analysis of the presentation of the scientific method that is in a group of current science textbooks. Combined with this analysis are new results from a separate study of research scientists' conception of scientific inquiry (Harwood, Reiff, and Phillipson, submitted). From these results, we have developed a new model for the process of scientific inquiry that we call the "inquiry wheel." In this paper, we compare and contrast the traditional scientific method with the model of the inquiry wheel.

Methodology

In the textbook analysis phase of the investigation, we examined the scientific method presented in 40 randomly selected science textbooks reflecting science at various grade levels and subject areas. The textbooks used in our study consisted of twenty biology books, five earth science books, five chemistry, five physics, and five lower grade level science books. In each of the textbooks, accounts of the scientific method were analyzed with respect to the steps listed and the number and type of "feedback loops". These loops represent some effort by the textbook authors to be less linear (step-wise) in their presentation, a key criticism in the literature. The publication dates of the textbooks ranged from 1989 to 2000. While the scientific method may have been portrayed differently in earlier versions, we are primarily interested in the scientific method to which students are currently exposed.

What we will describe as the "inquiry wheel" emerged from an earlier study conducted with 52 science faculty members from nine departments (anthropology, biology, chemistry, geography, geology, kinesthesiology, medical sciences, physics, and environmental science) at a large Midwestern University (Harwood, Reiff, & Phillipson, submitted). The semi-structured interview protocol was designed to probe the subject's conceptions of scientific inquiry. Interviews were tape-recorded and interviewers took field notes during the interview.

As part of the investigation into scientists' conceptions of scientific inquiry, scientists would often describe how they did science. Key questions in the interview protocol that provided pertinent information included,

- What is scientific inquiry?
- What are some characteristics of scientific inquiry?
- Can you think of an experience that involves scientific inquiry?

Scientists highlighted important characteristics of an investigator, an investigation, and how they practiced science (Harwood et al., submitted). From reading transcripts of the 52 interviews, it quickly became clear that scientists practiced science in ways not depicted in common science textbooks. Moreover, several scientists spontaneously provided strong criticism of the traditional scientific method and made direct contrasts between the scientific method and their perspective of the process of scientific inquiry. The inquiry wheel emerged from the analysis of the collection of scientists' descriptions regarding how they practice science.

We explored the similarities and difference between the textbook (traditional) version of the scientific method and the inquiry wheel using a grid that listed each of the stages of the inquiry wheel. When a term described in either the text or the model matched the stage on the inquiry wheel, this was recorded. For example, in virtually every case, each textbook listed the step: forming a hypothesis. We identified "forming a hypothesis" as corresponding to the inquiry wheel's stage *articulating an expectation*, thus identifying a common feature.

Analysis of Textbooks

The scientific models presented in the textbooks closely resembled the versions of the scientific method that was widely criticized in the 1960s (for example: Schwab, 1962; Taylor, 1962). Much of the writing of the 1960s criticized an earlier portrayal of the scientific method as a five or six step process that leads directly to conclusions of science problems. These steps include: 1) defining the problem, 2) constructing the hypotheses, 3) experimenting, 4) Compiling the results, and 5) Drawing conclusions (National Society for the Study of Education, 1947).

Many of these steps outlined in the first half of the twentieth century persist in modern science textbooks. Finley & Pocovi (2000) identify six steps to the scientific method as:

1. Recognize and research the problem
2. Form a hypothesis—a statement that can be tested.
3. Conduct an experiment in which you control variables to test the hypothesis
4. Collect, organize, and analyze all relevant data.
5. Form your conclusions—which may lead to another hypothesis.
6. Present the theory…a hypothesis that has been tested again and again by many scientists with similar results each time.

This version is very similar to those found in the textbooks we analyzed. Uniformly, the scientific method conveyed by the textbooks portrayed this sort of stepwise, linear process for doing science. The result of these steps in many cases was a theory or scientific law when, in fact, many scientific studies do not result in the formation of a law or theory (Lederman, 1998). Thus, these models of the scientific method perpetuate the misconceptions that scientific achievements occur through following a predetermined path, and that science invariably leads to a theory.

Interestingly, we found contradictions between the text and figures depicting the scientific method. Most textbooks had a discussion in the text that reinforced the view of the scientific method as a procedural set of linear steps describing the process of scientific inquiry. In several instances, however, the text accompanying the figure described how the scientific method did not follow steps in a particular order. Yet, when the figure was presented, it typically depicted the scientific method in a linear way with few feedback loops connecting to previous steps. We explored the "linearity" of the scientific method by associating the number of feedback loops with the amount of linearity. Greater numbers of feedback loops were presumed to indicate lower linearity. Thus, textbooks depicting the scientific method with no feedback loops are linear. Some textbooks showed one or two feedback loops, which is a less linear depiction of the scientific method. The least linear depiction occurred in one textbook that showed four feedback loops.

Chemistry textbooks had the highest frequency of feedback loops represented in models of the scientific method. In addition, chemistry textbooks had the highest number of figures depicting the scientific method than any other science discipline surveyed. Four out of five chemistry textbooks contained figures depicting the scientific method with between one and three feedback loops. In spite of these feedback loops, the chemistry textbooks still portrayed a linear, stepwise process to conducting scientific inquiry. Although one text did include the statement, "Just because results look neat and tidy does not mean that scientific progress is smooth."

Biology textbooks contained a wider range of feedback loops. Three depictions of the scientific method contained zero feedback loops, four depictions had one feedback loop, one depiction had two feedback loops, and one depiction had three feedback loops. In one textbook, the scientific method was presented as a cycle with arrows pointing in a one- way direction to the next step. Though the cycle represented another visual image of the scientific method, the one-way arrows indicated that steps were not repeated and, thus, was identified as having no feedback loops. Eleven of the twenty biology books did not even include a depiction of the scientific method. This may have been a conscious effort to avoid presenting a representation of scientific inquiry that did not represent the actual practices of science.

One biology textbook stated when referring to the scientific method, "few scientists adhere to these rigid steps." This contrasts with the more typical statement from another biology textbook that described the scientific method as "involving a series of ordered steps and is a tool used by all successful scientists." Like the chemistry textbooks, however, the figures of the scientific method clearly represent a smooth stepwise procedure.

Two of the five earth science textbooks contained depictions of the scientific method. In both of these cases no feedback loops were present. One of the earth science textbooks stated that the steps of the scientific method do not follow in a particular order. "They are not sequential steps that scientists invariably study. They are guides to problem solving." However, the earth science depictions of the scientific method did not demonstrate this flexibility.

In many of the physics textbooks surveyed, the scientific method was not mentioned in the text nor was it depicted with a figure. Only one of the five physics textbooks contained a depiction of the scientific method and this contained no feedback loops. This physics textbook introduced the scientific method with the statement, "This simple, step by step chart is easy to understand, but, in reality, most scientific work is not so easily separated." Yet the depiction found in the book contradicts this statement in the text.

In the science for lower grades textbooks, two out of five textbooks contained depictions of the scientific method. As in the biology example, one of the middle school textbooks had a cycle with one directional arrow, representing zero feedback loops. In the other depiction, four feedback loops were present. This is the only one of the 40 textbooks surveyed that had so many loops in the depiction of the scientific method. The low frequency in number feedback loops found in other 39 textbooks indicates that the image of the scientific method as a linear series of steps is still strongly present in modern science textbooks.

Among the 40 science textbooks we analyzed, the most common descriptions of the scientific method across all science disciplines included steps for constructing hypotheses and experimenting. The least frequent steps mentioned across all disciplines in models of the scientific method or in descriptions of the scientific method in the text include reflecting of the findings and communicating the results to society. Recent work by White and Frederiksen (1998) indicates the importance of reflection. In their model, however, the scientific method is depicted as a cycle with no feedback loops.

Scientists' Perspective of the "Scientific Method"

The research scientists who were interviewed in our study (Harwood, et. al., submitted) had strong opinions about how the scientific method is portrayed not only in textbooks but also in the classroom.

> The thing that happens in high school is they try to force their science project into the scientific method. You must have a hypothesis and make your predictions. It's absolute gibberish. Before you have given me information, you are trying to make me guess. That doesn't make sense. That's not science. The answer is—you have to have a question.

A biologist comments, "Children start out as scientists. We beat it out of them. Most people start out as curious. Somehow that curiosity disappears over time."

The scientists in our study consistently described the iterative nature of conducting science. Progress in science is not linear with few opportunities to repeat previous steps but rather a dynamic process where questions and results contradictory to expectations are also valued. A biologists in our study commented that the process of science "is rarely that neat. It's usually a much messier process." In a similar vein, an anthropologist says the following about the traditional scientific method:

> Now will they always follow along a scientific protocol or step-by-step methodology? I don't think so but then science doesn't either. Hypothesis, methodology, testing results, conclusions. Things don't move around in quite that progression.

The Model of the Inquiry Wheel

Scientists frame the process of their work within the context of methods that are nonlinear. This has forced us to develop a more sophisticated model of the process of scientific inquiry than the traditional scientific method previously discussed. We frame the inquiry wheel as having questions at the hub and a cyclical arrangement of stages that are typically used by investigators as they pursue a line of inquiry (Figure 1). The importance of questions is noted in a geologist's statement:

> Every time when you ask a question, it should lead you to another question, which ultimately creates knowledge. Questions provide the transition that has to be made as you build your knowledge.

For our subjects, the inquiry wheel can be viewed as a set of stages that provide responses to questions and generate new questions. These questions and their answers are the force that moves the investigation forward. In this model, scientists have the flexibility to generate questions along each stage and to revisit previous stages whenever needed. This fluid approach is indicated by double-headed arrows on the figure and better portrays how science is practiced among scientists than the standard "check-list" found in textbooks.

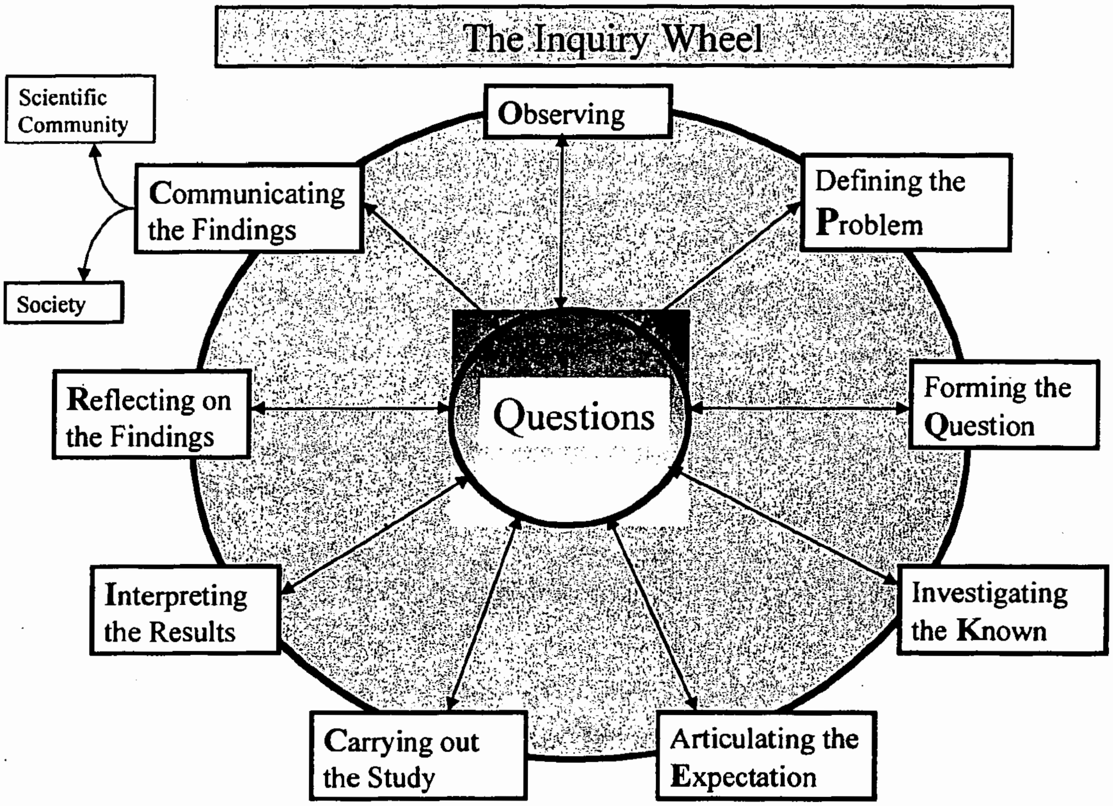

Figure 1: A proposed method of inquiry

Indeed, it needs to be emphasized that the inquiry wheel is not an *inquiry cycle*. That is, a circular set of steps such as that provided by White & Frederiksen (1998). A more related model is that provided by Krajcik et al. (1998 and 2000) as the inquiry web, which depicts the process of inquiry as going in many directions and by many paths.

In the conception of the process of scientific inquiry that emerged from our study, scientists may begin an inquiry investigation anywhere along the wheel. Even in the communicating the findings stage, questions posed by the scientific community could prompt another investigation. Moreover, scientists described the process of repeating stages as an important part of process of scientific inquiry. Communication, for example, occurs throughout a study in both formal and informal ways that inform the scientist and improve their ability to complete their inquiry. The inquiry wheel shows the dynamic nature of scientists repeating previous steps and generating questions during an investigation. The stages of the inquiry wheel are each outlined below. For those stages with equivalent sorts of items in the traditional scientific method, we include a brief comparison between the stage and the method step.

Making Observations

Observations occur throughout the entire inquiry wheel. Observations are essential in keeping careful records, staying focused, and serving as a springboard for the development of questions. Questions may arise from observations using the senses, reading in the literature, or from the scientist's sense of curiosity. A geologist explains the importance of observations in his field,

> Well, in our case observational skills are part of the key. Many people look but they do not see. The fundamental skill in our science for starting the inquiry process is to look and to see.

An anthropologist described how he helped students develop their observational skills by asking them, "Tell me what you see, tell me what you hear, tell me what you feel, tell me what you are observing or holding or whatever." These observations can move an investigation to another stage or serve as an instigation to begin an investigation. The latter can come about because the investigator may notice, through observation, that there is a strange or interesting occurrence. If nothing else, this may give rise to the question "what is going on here?" that can serve as the starting question of an inquiry.

Defining the Problem

Scientists define a problem based on their observations and their understanding of the literature. They must be able to decide from the observations what problems are testable, falsifiable, and that contribute to the scientific knowledge base. The ability to define a problem capable of resolution and one that's worth investigating requires a lot of work. Some scientists considered defining a problem as a natural aptitude while other scientists considered that "anybody can learn how to choose a problem and a methodology that works."

Forming the Question

While defining a problem may occur after a question arises, it appears to be more common that a problem statement is turned into a question to serve as the focus of the investigation. Articulating a question, however, can be challenging. A geologist explains, "The hardest thing to teach is the ability to ask the right questions." The importance of forming questions cannot be overstated.

> Inquiry is forming a new question. I think that what part of that means is not always having students ask questions, but having them understand that the way that information came about was through asking questions. Even if students aren't designing a new question, they still should understand that information is the result of an inquiry-based kind of process.

Questions are a natural result of curiosity that lead us toward new knowledge and new understanding. As an anthropologist observed, "not knowing is what stimulates inquiry." Questions, then, are the driving force of a scientific inquiry.

In the science textbooks the step of forming a question tended to be a result of turning a defining statement into a question. In our inquiry wheel this may also be the case, but a different order of events is also possible. One could start with a question and then define the problem and refine (if necessary) the question. Other stages could also be inserted between this sort of iterative sequence of events through two stages of scientific inquiry.

Investigating the Known

At this stage, scientists may be unsure if others have found an answer to the question under investigation. Moreover, there may be information available that will guide the study to a fruitful conclusion. Scientists gather information related to the question from reading the literature or by talking with experts in the field. The latter is one example of *Communication* occurring at an early stage in the inquiry process. This represents a contrast to the textbook scientific method where communication, when it is mentioned as a step, only refers to reporting at the end of an investigation.

Investigating the known allows scientists to define the boundary between what is already known and what is unknown about the topic. A medical scientist described this process as moving from "the certainty to uncertainty." A high value is placed on seeking answers to questions that address unknown areas in science and, therefore, have the potential to extend our understanding.

> This, of course, very much depends on knowing what is known, and most of science is simply keeping track of where the knowledge base is. Who knows what, and so a lot of what you see in scientific writing is review. That's for the reader to know that you what you claim to know. I think scientific review, literature review if you will, is the test of your credentials because a good reviewer will be able to detect whether you are that border, whether you are going to contribute anything beyond what is already known.

True scientific inquiry was described as an accumulative process in which new questions are asked that contribute beyond what is already known. This information gathering stage may result in the investigator gaining an answer to the original question, the question may be modified to address an issue that is not yet known, or the investigation can continue to verify known results. Informed by a deeper understanding of the topic, the investigation may proceed to the next stage.

Articulating the Expectation

The information-gathering stage just completed provides material that may take the scientist back to stages we have already described to further refine or change the problem or question. A good understanding of the literature around the topic of interest also guides the scientist in developing a preliminary (unproven) answer to their question. Common forms that these preliminary answers take are a hypothesis or a prediction. Broadly, the scientist articulates an expectation for the outcome of the investigation. This may be either a formal or informal articulation.

In the science textbooks surveyed, "forming a hypothesis" is equated with this stage of the inquiry wheel. Several science textbooks defined a hypothesis as an "educated guess". Other textbooks defined hypothesis as a "possible solution to a problem" or "a statement that can be tested." A biologist in our study found this fixation on hypothesis formation limiting as well as frustrating.

> But the way that many of the textbooks force people to teach and the way my son was taught in schools to say you must have a hypothesis. You must write down your predictions. For any kinds of information that makes no sense whatsoever and kinds are turned off. They are told this is how you do scientific inquiry, but it is not. It's true for some kinds of things. But for all the kinds of stuff we do, it doesn't work that way. Why are you telling me to guess an answer before I have done anything? Before you have given me information you're trying to make me guess? That doesn't make sense. That's not science.

Carrying out the Study

Based on the literature study and the expected direction for an answer, scientists begin planning and designing the investigation. That is, they seek an evidence-based answer to the investigative question. Scientists use multiple methods or approaches to investigate their question. The scientist decides which method will be appropriate for the investigation and then selects tools that will assist in conducting the method for the study.

> Having an awareness of a given field and a background is critical to pose new scientific questions. Then I think there has to be some kind of plan of action of how you're actually going to address that question.

To gather evidence, the investigation may take the form of an experiment or a test, though other designs are also used. In instances of an experiment or a test, scientists will control variables and manipulate one variable at a time to study what is causing the problem. In other cases, such as discovery research (Lederman, 1998), scientists may make no effort to control the events in a given setting. Their choice of tools and setting, however, are influenced by their expectation that these will provide useful responses to their question.

Interpreting the Results

After data have been generated from carrying out the study, scientists examine what the results *say*. Data can take the form of measurements, field notes, observations, statistical analysis, surveys, etc., depending on the method chosen to gather data. Regardless, the scientist looks for patterns and connections within the data. If the data is inconsistent or some error has appears to have occurred in gathering the data, the scientists may decide to repeat some of the previous stages. This may lead the scientist to revising the method, refining the question, researching more information about the topic, or making additional observations. The fluid

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nature of the inquiry wheel conveys the natural process of repeating stages to arrive at sound results.

Some students may think they have finished an investigation when they have completed the data gathering stage. For some scientists, this is where science really begins. One scientist explains, "I think too many people think science is collecting data in the lab. What I tell my students is that science begins after you have collected the data." The final stages of checking procedures, going back to the literature, synthesizing data, taking a step back from the data, sharing results are places where meaningful discoveries can be made.

Reflecting on the Findings

Unlike the interpretation stage where findings deal with what the results *say*, reflecting on the findings determines what the results *mean*. In trying to find significance in the data, scientists spend many hours looking for patterns in the data and making connections to the known information. One scientist explained, "...the most underrated part of research is thinking. So you just think about it with a pencil and paper and reading some very, very basic books."

Several scientists described how the best scientists such as Einstein and Newton were able to see connections where no one else saw them. In Harwood, et. al (submitted), the most important characteristic of a scientist was the ability to make connections between the data. That is, to be able to focus on the details of an investigation but also to see the larger picture.

Some scientists reported that they spent time reflecting on the meaning and implications of their results at odd hours or locations. Theses "flashes of insight" or serendipitous moments can occur outside of the laboratory. At these moments, scientists take a step back from the data and make connections. To some scientists, the reflection stage is the most underrated part of an investigation.

> The interesting experiments are always serendipity, I think. They come in the middle of doing something. If you aren't doing anything, you can't make discoveries.

Almost all of the science textbooks (38 out of 40) made no mention, either in the text or in the depictions of the scientific method, of reflection as an important part of an investigation. This is the key modification to the traditional scientific method that is provided by White and Frederiksen (2000).

Communicating the Results

"If information is not shared with others then it may as well not have existed." This is the opinion expressed by a scientist who stressed the necessity of communicating findings to both the scientific community and to the public. Scientists stressed the importance of having good communication skills to explain to others findings in written and oral form. Communication often generates new ideas in the process of bringing ideas together and responding to inquiries.

It is important to note again that communication does not just happen at the end of an investigation. Scientists described how they collaborated with other scientists throughout the investigation.

> I think it's helpful to have people to bounce ideas off of. I mean you tend to get set in your own way of thinking and don't consider other possibilities and just by discussing things with other people you can see other alternatives.

In addition, there are several audiences for the final communication from a scientific inquiry. First is communication to peers in the scientific community. This is essential in verifying the results for validity and reliability purposes and for career advancement opportunities.

A second, and also important, audience for scientific information is the general public. The gap in the public's perceptions of science and how to obtain scientifically valid information concerned some scientists. A geologist explains,

> You could easily fool the public into really weird opinions. When you talk of chemical, everybody is scared. Everything is a chemical so that's ridiculous.

Communicating findings to the public can benefit society by increasing awareness about scientific issues, helping people make informed decisions, alleviating fears about science, and encouraging questions about everyday problems.

Though the science textbooks surveyed included communicating findings as a step in the scientific method, communication referred almost exclusively to the scientific community. Only three textbooks out of 40 mentioned sharing findings with the rest of the class or with the public. All three references to communicating scientific information with the public occurred in biology textbooks.

Questions

The inquiry wheel is again refueled by questions that spark another investigation. The cycle continues as more questions are fed into the system. One scientist described the central role of questions as:

> You should question everything. Question, question, question. Why, why, why? If nothing else, science is important for that. It keeps everybody on his or her toes. If there were more scientists, we would be on our toes. We are not on our toes.

Inquiries lead to the building blocks of knowledge. How the blocks are constructed depends on the person or society constructing the knowledge.

Conclusion

The traditional textbook depiction of the scientific method as a linear process fails to accurately portray the lively process that scientists use in approaching their scientific inquiries. Moreover, the scientific method provides a set of steps that are procedural and omit important parts of the inquiry process such as reflection.

The inquiry wheel presented here is a theoretical construct that emerges from a grounded theory-based research project examining scientists' conceptions of scientific inquiry. Because of the strong research basis, the inquiry wheel provides a more sophisticated and more authentic model of the process of scientific inquiry. Textbooks typically provide a set of five or six steps as the scientific method with little or no indication of any opportunity to return to earlier steps. In contrast, the inquiry wheel has nine stages with double pointed arrows allowing unlimited opportunity to go back and forth among the stages as often as necessary. In textbooks, the end product of the scientific method is usually a theory or law. In the inquiry wheel, however, the end result is not a theory but the chance to drive another investigation through questions. This dynamic model emerged from interviewing 52 science faculty members who described how they practiced science.

It remains to be seen, for example, what impact the use of this model will have on teacher belief and practice or on student learning of science. A limitation of our model is that it emerged from scientists' beliefs about what they do. It may be that scientists do not actually conduct their research inquiries as they believe. Thus, additional work to connect our model to scientists' actual research practices needs to be carried out. Even so, our model legitimately reflects the ideal of scientific inquiry expressed by active research scientists from a variety of disciplines. As such, it represents a set of stages that students of science should be encouraged to note and use during classroom based science inquiries. The inquiry wheel provides student with clear model for doing science as scientists do and one that is much more comprehensive than the traditional scientific method.

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