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Philip A. Reed
Old Dominion University

Kurt R. Helgeson (Ed.)

Anthony E. Schwaller (Ed.)

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Inquiry in Technology Education

Chapter 8

Philip A. Reed
Old Dominion University
Norfolk, Virginia

INTRODUCTION

Technology education involves much more than instruction of the artifacts and methods of technology. The increasing amount and complexity of technology require students to know *how* to use, manage, assess, and understand technology. Inquiry is a cognitive instructional strategy that can help students learn about current technologies and also provide them with tools for investigating emerging technologies as they are encountered.

PURPOSE

The *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000) outlines an interdisciplinary approach for teaching technology as discussed in Chapter 5. As part of that interdisciplinary approach, inquiry is an ideal instructional strategy for implementing the *Standards* because it is based on a problem-solving model. Indeed, an unlimited number of learning possibilities can be created for individual students or for groups of various size through the use of inquiry. The use of inquiry instructional strategies allows for student- or teacher-directed technology activities, which can be conducted solely in the technology laboratory or integrated between or among subject areas.

This chapter defines *inquiry* as the formal process instructional planners call inquiry-training. *Inquiry-training* is a cognitive method for students to investigate their curiosities in a disciplined manner that is similar to the scientific method.

INQUIRY-TRAINING

The inquiry-training model developed by J. Richard Suchman in 1962 is the foundation for inquiry instructional strategies. Suchman created the inquiry-training model to provide a formal investigative process for the classroom. The model is based on the premise that children are naturally curious when confronted with unknown phenomena. The goal of the inquiry-training model is to teach students how to take this curiosity and focus it in a structured way using questioning and hypothesis testing. An important social component of the process is to have students present their results. The key to perpetuating the process is to have students evaluate their inquiry session to learn what works and what needs improvement. This reflection raises further student curiosities and creates new directions for learning. In Suchman's (1962) own words, inquiry-training was created to:

> Develop the cognitive skills of searching and data processing, and the concepts of logic and causality that would enable the individual child to inquire autonomously and productively; to give the children a new approach to learning by which they could build concepts through the analysis of concrete episodes and the discovery of relationships between variables; and to capitalize on two intrinsic sources of motivation, the rewarding experience of discovery and the excitement inherent in autonomous searching and data processing. (p. 28)

Suchman based the model on his own observations and the work of Jerome Bruner, Jean Piaget, and John Dewey. Bruner found that people tended to develop new ideas by linking to successful patterns of knowledge from their past. This was consistent with Suchman's observations that individuals were able to develop a style of thinking that could be used in a wide range of applications. Piaget's concept of operational thinking claimed that children went through progressive stages in the way they think. From this research, Suchman speculated that formal stages of inquiry could be developed and taught to all children. This part of the model was also based on Dewey's premise that the scientific method should be introduced to all school children (Suchman, 1962).

Inquiry-training has proven successful in various grade levels and subject areas, as well as with special needs students. In the 1960s and 1970s, inquiry-training was used by science and social studies teachers to increase interest and activity in the classroom (Weaver, 1985). Voss (1982) found that inquiry-training was effective at both the elementary and secondary levels. A third study successfully used the inquiry process with deaf children (Elefant, 1980). These studies, along with Suchman's own observations, highlight the effectiveness of inquiry-training as a cognitive tool. Following are some of the student-learning outcomes when using the inquiry instructional strategy:

1. Students acquire process skills of observing, collecting, and organizing data; identifying and controlling variables; formulating and testing hypotheses and explanations.
2. Students develop independent learning techniques that involve asking questions, testing ideas, and making decisions.
3. Students enhance their ability to express themselves verbally by asking questions. Likewise, their listening and comprehension ability improves from receiving answers and synthesizing the replies.
4. Students acquire persistence through data gathering and experimenting to solve the problem situation.
5. Students develop logical thinking skills through following an organized method of inquiry.
6. Students learn a strategy by which new knowledge can be obtained (Daiber, 1988, p. 168).

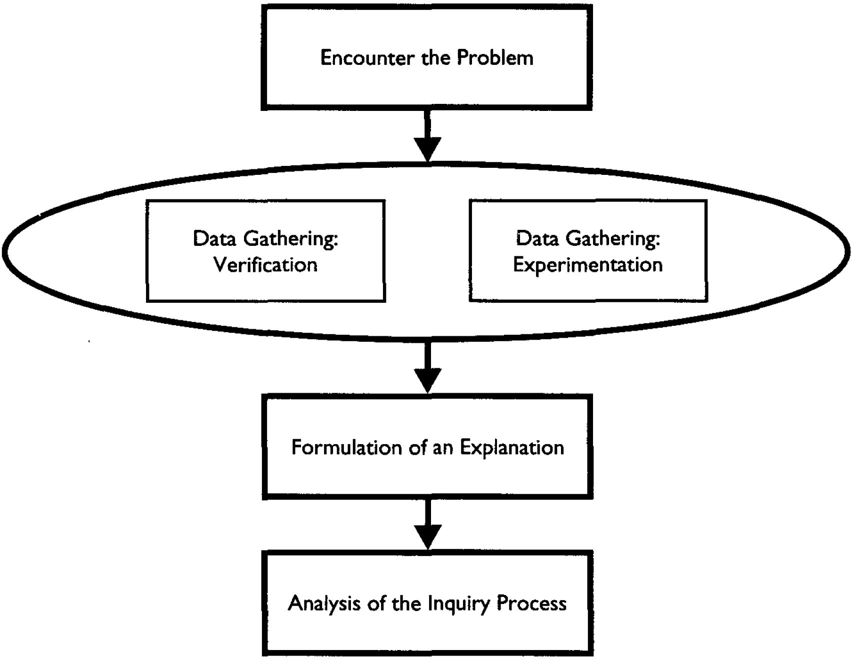
Phases of the Inquiry-training Process

Initially, Suchman (1962) included four types of student action within the inquiry-training model: searching for information, data processing, discovery, and verification. Although these four steps were not new cognitive concepts, putting them together in a model was unique. When used together in the inquiry process, they form a cycle of operation that can be learned and used in various technology learning situations. The evolution of inquiry-training has established a model with five phases (Joyce, Weil, & Calhoun, 2000). It is important to note in **Figure 8-1. The Inquiry-Training Model** that the inquiry process is not entirely linear. The data gathering phases, verification and experimentation, often occur simultaneously.

Encountering the Problem

The first phase of the inquiry process occurs when the teacher presents the students with a problem. Beginning problems will be simple until students understand the inquiry process. However, care should be taken to present a problem that is sufficiently challenging. Objectives and background information, as well as demonstrations, are presented at this time. The structure of the inquiry process should also be reviewed, especially acceptable questioning, data gathering techniques, and respect for other students.

Figure 8-1. The Inquiry-Training Model.



Gathering Data—Verification

During this phase, students learn the nature of the problem situation. This usually involves an exchange of questions between the class and teacher. Students should be reminded to ask only simple "yes" or "no" questions. If a question requires an elaborate answer, the instructor usually asks the student to rephrase the question. This form of questioning allows students to gather enough data to verify the problem but not enough to form premature conclusions that may be inaccurate.

Gathering Data—Experimentation

The third phase often runs concurrent with the second. At this point, students are ready to isolate variables and run tests to verify or refute questions they formulated in the verification phase. Hypotheses are now formulated based on the results of experimentation.

Experiments can be either exploratory or direct testing. Explorations are used to see what will happen to a variable and are often conducted without the guidance of a hypothesis. These can be thought of as sub-tests that will help establish theories. Direct testing is associated more closely to the overall problem and directly tests hypotheses (Joyce, Weil, & Calhoun, 2000).

Formulating an Explanation

This phase in the inquiry process requires students to formulate a conclusion and present their results. Students at this point should understand that many technological problems can have multiple solutions. Some inquiry sessions might even result in non-technological conclusions. Teachers can use this step in the process to discuss the impacts of technology and to allow for student discussion. Creativity and higher-level thinking is often fostered by allowing students to use a wide variety of presentation techniques and tools. Time should be spent reviewing how to analyze, synthesize, and evaluate the new knowledge.

Analyzing the Inquiry Process

The final phase requires students to evaluate the inquiry process that just occurred. Students should look for questions and experiments that were effective, as well as for ways to improve the process. The teacher can review teamwork skills, observe behaviors, and even re-create experiments. Joyce, Weil, and Calhoun (2000) suggested the use of repetition to reinforce the process and to review the cognitive and social benefits of the model.

Analysis of the inquiry process is unique and vital to the success of inquiry-training. Other problem-solving models often end at the presentation process, thus omitting lesson opportunities and important socialization skills. Reflection helps foster student curiosity for future inquiry. Analysis of the process also helps students learn their strengths and weaknesses while helping them become aware of the importance of life-long learning.

Role of the Teacher

The teacher's role during an inquiry-training session is much more complex than that of a facilitator guiding student interest. The instructor must know the subject matter, each student's strengths and weaknesses, as well as each student's varying progress throughout the inquiry session. Suchman (1966) outlined the following five duties that the teacher must focus on during the inquiry-training:

1. **Stimulate and challenge the students to think.** Situations should be designed to raise student curiosity and cause them to take action. If

the problem can be readily answered or found in a text, it does not cause the student to look outside of their existing body of knowledge. It is important for the teacher to let students know that complacency is unacceptable. The instructor must maintain an awareness of student efforts and remediate when necessary to bring back student interest. Suchman (1996) stressed the importance for students to be aware that the human body of knowledge is always changing. Existing knowledge changes not only from new discovery but also from social and cultural influences. An important goal for the inquiry-training teacher is to incorporate lessons based upon the *Standards* that explain the interaction between social and cultural factors and technology.

2. **Ensure freedom of operation.** Since inquiry-training is a cognitive process, a primary goal is to build student autonomy. The students should not feel pressure to achieve or have a fear of failure. This component not only builds student confidence but also helps build respect for differing views. To nurture these concepts, the teacher should take time to review techniques for working in groups. Professional communication, respect for others, and listening skills are all important to help students develop self-confidence.
3. **Provide support for inquiry.** Teachers need to guide student inquiry so that answers are discovered, not given. Since data collection and questioning guide the inquiry process, the teacher needs to provide avenues for gathering data and furthering the questioning process. Many materials and situations can be anticipated since the inquiry process begins as a teacher-directed experience. When the students move into the data gathering phases, however, the instructor will need to be flexible in order to support the students. At this point, the activity shifts from being a teacher-directed to a more student-directed activity.
4. **Diagnose difficulties and help the students overcome them.** The teacher must have an understanding of student strengths and weaknesses in order to help on an individual basis. Differences in personality, analytical ability, and the method in which a student handles new information are crucial to the success of the inquiry model. If the teacher is not an effective diagnostician, the student will lose confidence and direction.

5. **Identify and use the "teachable moments."** The effective teacher knows when new content can be introduced most effectively. The loss of student motivation is the risk of introducing a concept too early. Teachers flirt with student confusion and frustration if they let a teachable opportunity go by. Data provided at the right time, however, will keep student interest focused.

INQUIRY-TRAINING IN THE TECHNOLOGY EDUCATION CLASSROOM

Technology education has historically incorporated inquiry into laboratory instruction. Early forms of this instructional strategy, however, focused more on tools, materials, and technical processes (e.g., Earl, 1960, and Olson, 1963) rather than a structured cognitive process. The *Maryland Plan: Industrial Arts Program for the Junior High* (Maley, 1970) was one of the earliest programs that utilized an inquiry instructional approach in order to focus on the cognitive benefits of technology education. These cognitive benefits were first discovered by Maley in 1952 and were synthesized in *Research and Experimentation in Technology Education* (Maley, 1986) after decades of classroom testing and revision.

The research and experimentation program was viewed by Maley as an important method for aligning technology education with accepted educational concepts. Specifically, Maley (1986) felt that education must

- be fitted to the unique needs and interests of the individual,
- reflect the culture in which it functions,
- take advantage of the natural curiosity of youth,
- cause the learner to examine the "why" of things rather than the memorization of isolated facts,
- have its roots in the psychological needs of youth,
- encourage thought and inquiry,
- take into account the developmental tasks of youth,
- be meaningful to the learner,
- be interdisciplinary in its approach to the study of any topic,
- teach people how to learn (pp. 1–2).

A key component in *Research and Experimentation in Technology Education* (Maley, 1986) was the use of student seminars. Although students presented and discussed their research projects, analysis of the project, as outlined in the inquiry-training process early in this chapter, did not take place.

Daiber (1988) highlighted a second delivery system, the project method, that could effectively incorporate inquiry-training: "By using inquiry-training as the basis upon which the project idea is discovered, designed and constructed, the project becomes technological in nature" (Daiber, 1988, p. 166). The use of inquiry-training described by Daiber makes it ideal for both doing and learning about technology. Because doing and learning about technology are key concepts in the *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000) the inquiry-training model is an excellent teaching strategy for incorporating the *Standards* at any level.

USING INQUIRY-TRAINING, WITH THE STANDARDS FOR TECHNOLOGICAL LITERACY

The *Standards for Technological Literacy: Content for the Study of Technology* defines technological literacy as "the ability to use, manage, assess, and understand technology" (ITEA, 2000, p. 7). When used with the *Standards*, inquiry-training can help teachers accomplish these goals in several ways. First, students gain experience using technology during the data gathering phases. These opportunities provide an excellent occasion for invention and innovation since the inquiry process gives students a structure to help them analyze the technologies as they use them. Second, the inquiry model allows activities to be teacher or student controlled. The teacher can guide the use and management of technology based upon student ability level and resources. Third, inquiry-training is a cognitive strategy that allows students to consciously inquire, analyze, and improve their thinking (Joyce, Weil, & Calhoun, 2000). Thus, the use of the inquiry-training process can give students a tool to systematically assess and understand current and emerging technologies.

Sample Inquiry-training Activity for Middle School

The following lesson is designed to help the middle school teacher incorporate inquiry-training and the *Standards for Technological Literacy: Content for the Study of Technology.* This lesson starts with the corresponding standard and level-appropriate benchmark. Next, student performance standards highlight the skills students will gain from the lesson. Finally, the five steps in the inquiry process outline the lesson.

> Standard 18: Students will develop an understanding of and be able to select and use transportation technologies.
>
> Benchmark G: Transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work effectively (ITEA, 2000, p. 178).

Objectives:

1. Students will explain the concept of an airfoil and Bernoulli's principle.
2. Students will conduct an experiment to compare different airfoil shapes.

Encountering the Problem. In the fall of 2000, a supersonic passenger plane crashed after a piece of debris punctured one of its tires on take-off. This accident illustrated how the swept (Delta) wing on a supersonic airplane does not provide much lift at slower speeds but helps it to achieve high speeds.

Data Gathering—Verification. The teacher should work with the students as a group to clarify terms and concepts associated with airfoils and Bernoulli's principle.

Data Gathering—Experimentation. Several experiments can be conducted to help students understand different wing designs and their applications on various aircraft. Students can work in small groups or individually to test different airfoils through computer simulation or through the construction and wind tunnel testing of airfoil designs.

Formulation of an Explanation. The instructor will need to guide student handling and presentation of data. Students at this level could be taught how to enter data into a spreadsheet and present their findings in table or chart form.

Analysis of the Inquiry Process. Students should look back at the questions and methods they used for their inquiry. Reflection allows the student to assimilate the new knowledge and form questions for a new inquiry. For example, to further address Benchmark G above, students could begin a new inquiry to explore the relationship between airfoils and aircraft control systems.

Sample Inquiry-training Activity for High School

The following lesson is designed to help high school teachers incorporate inquiry-training and the *Standards for Technological Literacy: Content for the Study of Technology.* This lesson again starts with the corresponding standard and level-appropriate benchmark. Next, student performance standards highlight the skills students will gain from the lesson. Finally, the five steps in the inquiry process outline the lesson.

Standard 15: Students will develop an understanding of and be able to select and use agriculture and related biotechnologies.

Benchmark L: Biotechnology has applications in such areas as agriculture, pharmaceuticals, food and beverages, medicine, energy, the environment, and genetic engineering (ITEA, 2000, p. 155).

Objectives:

1. Students will identify the positive and negative aspects of agricultural biotechnology.
2. Students will conduct an experiment to compare natural plants and plants altered through biotechnology.
3. Students should be able to explain the relationship between technology and individual preferences. The benefits biotechnology brings to one consumer, for example, might negatively affect another consumer.

Encountering the Problem. Biotechnology has been used in agriculture for thousands of years through the use of simple techniques such as animal husbandry, seed selection, and yeast for baking and fermentation. New processes that involve gene splicing and recombinant DNA, however, are controversial.

Data Gathering—Verification. The teacher should work with the students as a group to clarify terms and concepts associated with biotechnology.

Data Gathering—Experimentation. A simple experiment could have students compare the growth of genetically altered seeds to natural seeds. If vegetables are used, a taste-test could be used to gather consumer data. If time does not permit a laboratory experience, data could be obtained through student research. Each student could research a topic related to agricultural biotechnology and report their findings.

Formulation of an Explanation. The instructor will need to guide student handling and presentation of data. Students will need to be made aware that complex technologies often involve individual preferences. For example, biotechnology has created moral and ethical issues that have produced diverse philosophical and political opinions.

Analysis of the Inquiry Process. Students should look back at the questions and methods they used for their inquiry. Reflection allows the student to assimilate the new knowledge and form questions for a new inquiry. For example, to further address Benchmark L above, students could begin a new inquiry to investigate how the biotechnology on which they reported is used in a different field (i.e., agriculture, pharmaceuticals, food and beverages, medicine, energy, the environment, and genetic engineering).

SUMMARY

The inquiry-training process created by R. J. Suchman is the foundation of inquiry. Inquiry was created as a structured, cognitive method for fostering and guiding student curiosity in the classroom. The inquiry-training process is a proven instructional strategy for students in varying grade levels, subject areas, and ability levels. There are five phases in the process. The first phase occurs when the problem is introduced to the student and the steps of the inquiry process are reviewed by the teacher. The second and third phases often occur simultaneously when the students begin gathering data through problem verification and experimentation. The fourth phase occurs when students present their findings. Analysis of the process, the final phase, is important for making sense of new knowledge and creating future inquiry sessions.

Early use of inquiry in technology education focused more on the use of tools, materials, and technical processes than on cognitive processes. Now, the *Standards for Technological Literacy: Content for the Study of Technology* say students should know how to use, manage, assess, and understand technology. The rapid advance of technology and limited classroom resources, however, have made it difficult for teachers to keep up with the latest tools, materials, and technical processes. Thus, inquiry-training is an effective instructional strategy for implementing the Standards because it provides students with a cognitive strategy to learn about technology.

DISCUSSION QUESTIONS

1. Why is inquiry-training an important instructional strategy in today's technology classroom?
2. How does the inquiry-training instructional strategy relate to the *Standards?*
3. What are some of the advantages of using the inquiry-training model and why?
4. What are the five phases of inquiry-training as an instructional strategy and why are they important?

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