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ABSTRACT

A simple model of scientific inquiry was developed using non-technical language. One group of elementary school teachers was introduced to the model during a two-week summer institute where the model was used in conjunction with activity-based approaches to teaching. Participants applied the model in planning and facilitating activities for children enrolled in a summer science camp. Another group of teachers was introduced to the model during a series of workshops for teachers and principals. The model was introduced as the central heuristic device for designing and developing science lessons and units of study. A survey was conducted two years after the most recent summer institute. The purpose of the survey was to determine: (1) the extent to which the model was understood; (2) the degree to which it was being used to plan and implement instruction; and (3) the extent to which it facilitates desired effects among students. Survey results provided evidence that: (1) the model is well understood by most teachers and facilitates an understanding of the nature of scientific inquiry; (2) the model facilitates an activity-based, inquiry-oriented approach to science teaching; and (3) teachers report that students react favorably to instruction based on the model. The survey instrument is appended. Contains 16 references. (Author)

Study of a Field-Developed Model of Scientific Inquiry

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Abstract

A simple model of scientific inquiry was developed using non-technical language. One group of elementary school teachers was introduced to the model during a two-week summer institute where the model was used in conjunction with activity-based approaches to teaching. Participants applied the model in planning and facilitating activities for children enrolled in a summer science camp. Another group of teachers was introduced to the model during a series of workshops for teachers and principals. The model was introduced as the central heuristic device for designing and developing science lessons and units of study. A survey was conducted two years after the most recent summer institute. The purpose of the survey was to determine: (a) the extent to which the model was understood, (b) the degree to which it was being used to plan and implement instruction, and (c) the extent to which it facilitates desired effects among students. Survey results provided evidence that: (a) the model is well understood by most teachers and facilitates an understanding of the nature of scientific inquiry, (b) the model facilitates an activity-based, inquiry-oriented approach to science teaching, and (c) teachers report that students react favorably to instruction based on the model.

Purpose of the Study

This work was undertaken to develop and assess the pedagogical utility of a simplified model of scientific inquiry. The intent was to design a model that authentically represents the scientific approach to understanding, yet can be presented in non technical language and be used at any educational level. It seemed most critical, however, that the model be easily adapted to the needs of elementary school teachers who may not have strong academic backgrounds in the sciences or familiarity with the tecnical aspects of scientific inquiry. The critical questions of the study became: (a) Does the model convey an easily understood and authentic view of scientific inquiry? (b) Does the model help teachers design and implement inquiry-oriented science lessons? and (c) Does use of the model in the classroom have any desirable effects on student learning or attitudes?

Significance

Every major report for the past three decades has called for more activity-based, inquiry-oriented approaches to science teaching that engage students in the processes of science (see DeBoer, 1991; Rutherford & Ahlgren, 1990; U.S. Department of Education & National Science Foundation, 1992). In particular, it has been recommended (National Research Council, 1994) that students "learn science in ways that reflect the inquiry used by scientists to understand the natural world." Many who are regularly involved in schools, however, have characterized much activity-based teaching as "hands-on, minds-off," with inadequate attention being given to the content and thought processes embedded in the activities (Haury & Rillero, 1994). At the same time there have been repeated assaults on "The Scientific Method" as an artificial and debilitating notion of how people really do science (Bauer, 1992). As Cross (1990) so succinctly put it, "Talk to scientists, read what they have written. You will soon observe that how scientists actually *do* science and how we *describe* the science process don't match." Though the scientific method is a familiar concept to most science teachers, it is widely recognized that the nature of science and inquiry is far richer and more multifaceted than the traditional, linear notion of how science is done. "Scientific inquiry is far more flexible than the rigid sequence of steps commonly depicted as The Scientific Method" (American Association for the Advancement of Science, 1994).

It is also well known that the early school years are very important in terms of prolonging natural curiosity of nature, developing an interest in science, and fostering perceptions of efficacy in doing science (National Science Board, 1991). As Hazen (1991) has lamented regarding his own children, however, elementary school children learn to hate science because they get the "mistaken impression that science is difficult, boring and irrelevant to their everyday interests." Cross (1990) said, too, that "we have dehumanized science and scientists. No wonder youngsters instinctively turn away." Finally, there have been repeated calls for emphasizing an understanding of the nature of science as a way of knowing as well as a body of knowledge (National Committee on Science Education Standards and Assessment, 1992).

There is, then, a critical need for a valid but simple model that teachers can use, whatever their background in science, to bring a sense of authentic inquiry to science teaching and learning. As more emphasis is placed on school-based curriculum development, there is also a need for a model that can be applied by a teacher to any topic or organizing principle, enabling individual teachers to bring a sense of inquiry to the topics and instructional materials of their own choosing. Finally, students must have an opportunities at an early age to construct for themselves a concept of inquiry without undue dependence on words which have special, technical meanings in science, such as experiment, observation, and hypothesis.

Theoretical Basis

As Bauer (1992) has suggested, "perhaps the central fallacy is that there exists an entity called 'science' about which sweeping generalizations can validly be made; for example, that science is characterized and defined by the scientific method." It was dissatisfaction with the rigid, linear model embodied in "the scientific method" that led many to focus on individual procedures and science process skills beginning in the 1960s. The trend led to the identification of 13 processes representing the methods of science that were presented in a position statement for science teachers (National Science Teachers Association, 1982). In essence, a rigid method was replaced with an unstructured list of processes providing little guidance in how to proceed, how to participate in a search for knowledge, or how to inquire. This has led some to "throw out the instructions" (Tinnesand & Chan, 1987), and perhaps the baby with the bath water. As Novak (1964) pointed out some time ago, "inquiry is the [set] of behaviors involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious." So, inquiry involves activity and skills, but also a systematic search for knowledge and understanding. The central purpose of this research and development project has been to construct a model that lacks the artificial nature of the so-called scientific method while avoiding the lack of a coherent approach often associated with an emphasis on a list of discrete process skills.

Though this attempt to develop a simple-but-authentic model of scientific inquiry raises epistemological issues, there has been no deliberate attempt to align the model with one of the competing epistemologies of science advanced in recent years. As has been noted (Martin, Kass, & Bouwer, 1990), the diversity of epistemological positions on the nature of science has led to a diversity of meanings for the concept of *authentic science*. The focus here has been on aligning school science as a search for meaning with the approaches taken by scientists. The model developed here has been influenced to some extent, however, by the ideas of Polanyi (1958) and Toulmin (1972).

Design and Procedures

This ongoing research and development endeavor has spanned several years and passed through four phases: (a) a school-based exploration of needs, (b) the conceptualization of a model, (c) pilot testing and refinement of the model, and (d) an assessment of the effectiveness of the model in fostering classroom inquiry. Being largely a field-based development project, the methodology has shifted from that of the researcher being a participant-observer in the early stages of the ongoing study to that of a descriptive survey. The emphasis in this paper is on two phases of the process: conceptualization of the model, and assessment of its usefulness.

Phase 1: Participant-Observer. For the first two years of this study, the author spend one full day each week in the elementary school classrooms of a transitional, middle-class community. There was no set agenda other than to be of help to teachers in any way possible to facilitate an inquiry-oriented approach to science teaching. The participating school district had decided to revamp its science program to emphasize activity-based learning without the use of textbooks. During this period, observations were made, notes were taken, and ideas were suggested to teachers. I regularly taught lessons jointly with classroom teachers at the elementary and middle school levels, and I participated in many planning meetings at all levels.

Phase 2: Conceptualization of a Model. After the two years of participation with teachers, I discussed the idea of a model of inquiry with a school principal in the district and with the Science Coordinating Team, comprising both teachers and administrators. The idea of a simple model in non-technical language had appeal, so I drafted a model based on a synthesis of information from four sources: (a) the education literature on science process skills, critical thinking, problem solving, and decision making; (b) concepts gleaned from contemporary writing on the epistemology of science; (c) informal discussions and readings about how scientists characterize their work; and (d) observations of how teachers operationalize inquiry in their classrooms. The result is a model that has been coined the *Circle of Inquiry*. The model and a rationale for its elements are presented in the section devoted to findings.

Phase 3: Pilot Testing and Refinement of the Model. The model was first introduced to teachers in the schools where observations were first made. The model was described and presented in conjunction with sample activity-based lessons that incorporated components of the model. The model was then used to "interpret" or critique the lessons. Teachers of grades K-8 were asked to try the model and develop their own activities. The model was refined on the basis of teacher feedback, then the model was used in a variety of inservice activities, from district inservice days to summer institutes. Finally, the model was used as the organizing principle for a year-long series of workshops for school teams, sponsored by a state-wide principal's association. After each implementation of the model, comments and suggestions were solicited from teachers. The current model is the result of refinements made over a two-year period of pilot testing.

Phase 4: Descriptive Survey. The usefulness of the model to teachers was examined during the Spring of 1993. Participants in institutes offered during the summers of 1988 to 1991 were surveyed using an 19-item instrument that I and my assistants designed (see Appendix A). The instrument combined items in a Likert format with three open-ended questions. Respondents were also asked to provide descriptive information about themselves and their school role. Results from the survey provide indicators of the degree to which participants understand, use, and realize benefit from the model. Items and item clusters from the survey instrument were operationally defined as providing indicators of the following: (a) understanding of the model, (b) degree of implementation of the model, (c) extent to which the model is used to plan lessons, (d) time invested in instructional planning, (e) teacher planning style, (f) teacher assessment of student effects, and (g) effects on student management. Item definitions and clusters are presented in Appendix B.

Findings

Phase 1: Participant-Observer. Regular participation with teachers in their classrooms over a two-year period led to many findings and outcomes relating to instructional practices, curriculum planning, and professional development. Given the focus of this paper on the development of a model for inquiry, discussion here will be limited to a few salient findings that influenced the design of the model. Following are eight concerns and tendencies that were repeatedly noted during interactions with individuals and groups of teachers during this period:

Strong preference for activities and "hands-on" approaches to teaching. With the noted exception of a few teachers in grades 5 and 6, the overwhelming preference of teachers was for activity-based approaches to science teaching. Counter to what one might expect based on the professional literature, I found teachers very receptive to experiential approaches to teaching. There was some concern about noise, messes, and materials, but most expressed a desire to overcome such challenges. Teachers very often expressed a desire to make science "fun" for students, and many would frequently say something like "kids learn best by doing." The teachers who were less enthusiastic for the approach tended to teach the upper elementary grades, show a strong preference for textbooks, and express concern that students leave elementary school "knowing what they need to know."

Desire to emphasize science process skills over subject matter content. Parallel with a preference for activity-based teaching was a desire among most teachers to engage students in the processes of science. Some of the motivation for this orientation seemed to have been stimulated by the school administration, both the superintendent's office and the building principals who strongly expressed the expectation that process skills would be emphasized. It became very clear, however, that many teachers did not know how to emphasize process skills, how to connect the skills together in coherent ways, or how to construct a lesson that features attention to skills. The typical listing of skills provided no sense of direction for teachers, and individual process skills were treated as discrete skills with little reference to an overall notion of how one "does science."

Most activities were called "experiments." The language of science was used very loosely, with most student activities being called "experiments." In general, words that have very specific meanings in science lost the richness of meaning that science educators typically associate with words such as observation, hypothesis, theory, inference, prediction, and so on. There seemed to be, however, a desire to do "experiments" and use the language of science. Teachers would very often draw attention to words associated with science as students progressed through activities.

The "scientific method" was held in high regard, but seldom implemented in any systematic way. Most teachers seemed to have great respect for the scientific method, but saw very little opportunity to really incorporate it into their lessons. There was a tendency to think that the scientific method required certain types of facilities and equipment that they did not have, or required students to have a sophisticated vocabulary they had not yet developed.

Activities tended to end with little discussion or interpretation of outcomes. Teachers seemed to truly enjoy doing activities, particularly if students had fun and materials were efficiently distributed and retrieved within the lesson period. Though most teachers exhibited great skill in managing student behavior, there tended to be little time devoted to group or individual discussion of activities or the ideas generated by students. Though teachers expressed concern about what students were supposed to "get out" of many activities, they generally spent little time using small group or large group discussions to bring meaning to the experience.

Teachers expressed feelings of discomfort with their level of science knowledge. Many teachers were self-critical of their science backgrounds and felt a sense of inadequacy when students asked questions they could not answer. There was discomfort among some with open-ended questioning strategies because students would get "off track" and teachers would not know how to get them back on track. There was a strong sense that most questions have "right answers," *particularly* in science, and teachers do not know many of those "right" answers.

Questions about what subject matter content is most important. There was a desire among many to have a clear outline of what students were "supposed to know" at each of the grade levels. There was a strong sense that "someone" must know what everyone needs to know and the order in which concepts and principles should be learned. The concern seemed to associated with a genuine desire to have students adequately prepared for what would be expected of them in months and years to come.

Concerns about how to assess student performance. There was considerable concern among teachers that there be some valid and fair way of assessing student performance for purposes of assigning grades. How do you test proficiency with science process skills? How do you measure the outcomes of activity-based learning?

From the concerns and tendencies noted, it seemed evident that teachers were very motivated to emphasize process over subject matter content in the elementary grades, but there was little sense of how to go about it. There was uncertainty about how the process skills relate to each other, there was little sense of how the process skills relate to the overall search for understanding, and there was uncertainty about what students were actually supposed to learn from many activities. It was also evident that science vocabulary was "getting in the way" to some extent; there was a preoccupation with knowing the right words to use in talking about doing science rather than actually engaging students in inquiry.

Phase 2: Conceptualization of a Model. Through talking with one of the school principals, it became clear that a simple model of scientific inquiry would be very useful, a model that did not rely on technical language and could be used to provide a sense of direction in planning and consistency in instructional approach among the teachers of the district. The science curriculum and instruction for the district was coordinated by a Science Coordinating Team, so the idea of developing a model of inquiry was discussed with that group, and the group endorsed the idea. To develop the model, I attempted to blend ideas gleaned from the professional literature in education, descriptions of how scientists do their work, the literature on epistemological issues in science, and my own observations in classrooms. Following are the central features that the model was designed to exhibit:

- Low to no reliance on technical language.
- Functionality as a heuristic device to guide planning and instruction.
- Fidelity to what we know about the nature and practices of science and inquiry.
- Linkages to the many vocabularies relating to problem solving, critical thinking, decision making, and the processes of science.
- Compatibility with constructivist notions about learning.
- Supportive of cooperative learning strategies and activity-based learning.

The resulting model, the *Circle of Inquiry*, comprises four interacting components: wondering, collecting data, studying data, and making connections. At first, these components were conceived as four basic phases of inquiry, with the traditional process skills of science being distributed among them. *Collecting Data*, for instance, encompassed such skills as observing, measuring, recording, identifying, and so on.

Initial attempts to use the model to guide planning and instruction, and discussions with teachers, led to an early refinement. The four components were spatially arranged in a circle (see Figure 1) to connote the ongoing, cyclical nature of inquiry and to explicitly avoid the connotation of inquiry being a linear process. The model is intended to convey the idea that doing science is a continuously ongoing process that involves wondering, collecting data, studying data, and making conceptual connections, but the components do not necessarily flow in a standard sequential fashion. Collecting data, for instance, may lead to wondering; studying data may lead to collecting more data; or making connections may lead to any of the other three components. But, scientific inquiry always involves each of the components somewhere in the process.

Phase 3: Pilot Testing and Refinement of the Model. As mentioned above, the model was immediately refined from a linear set of phases to a circular array of components on the basis of the initial attempts to use the prototype model with teachers in classrooms. The next refinement of the model was to make linkages between the four core components of inquiry and the many vocabularies found in the literature and professional development materials. Specifically, the vocabularies associated with problem solving literature, critical thinking literature, decision making literature, and lists of the science process skills were collected, and individual terms were distributed among the four core components of the model (see Figure 2). The purpose of this refinement was to help teachers fit the competing vocabularies into the simplified model and provide specific examples of the types of process or skills that are part of the core components. When teachers want to know specifically what studying data might include, they can see from the model that it may include calculating, comparing, analyzing, graphing, searching for patterns, or similar types of activities. The intent was not to establish a rigid categorization of terms, but to relate the general idea of each core component to specific processes that are commonly presented in education literature and professional development materials. As a final refinement, some terms were moved from their original placement in the model on the basis of teacher feedback and critique. In presenting the model to teachers, however, it has always been pointed out that many of the terms fit in more than one of the core components or overlap the boundaries of the components.

Following these few refinements, the *Circle of Inquiry* was tested in a variety of settings for a variety of purposes. The outcomes of the testing did not lead to further refinement of the model itself, but led to the identification of a variety of uses for the model. The following uses were commonly noted:

- *Use as a planning guide.* The model was originally developed as a heuristic device for planning lessons and activities and has been successfully used by teachers in a variety of settings to plan individually and collectively.

Circle of Inquiry

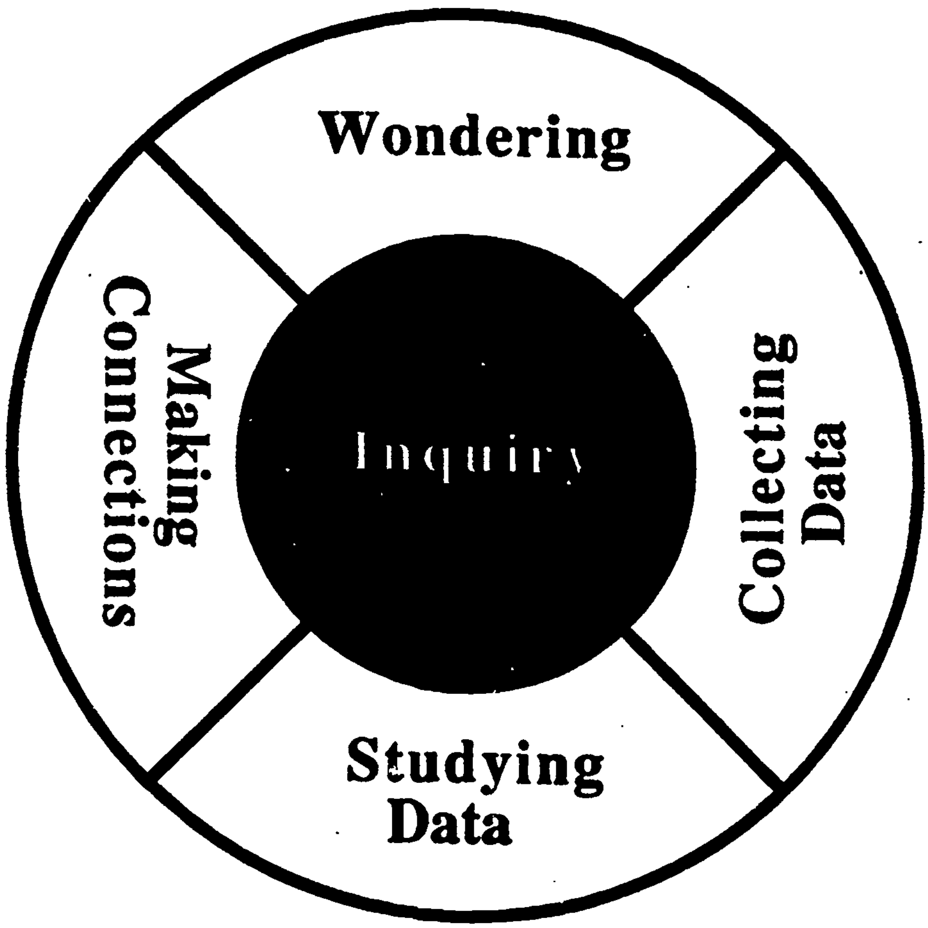

FIGURE 1

The Circle of Inquiry

A Model of the Scientific Approach to Understanding

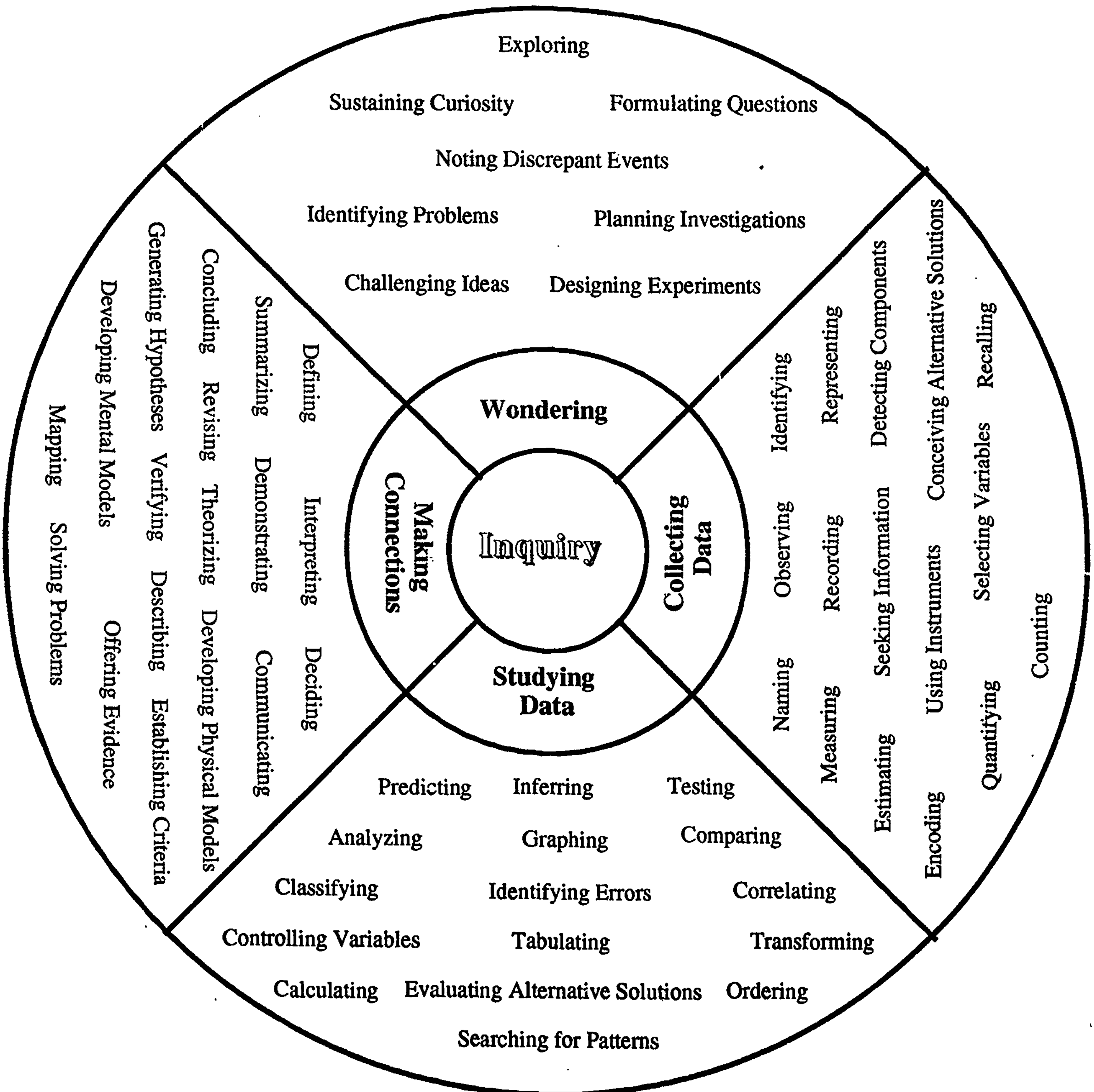

Figure 2

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- *Use as a instructional guide.* In addition to using the model to plan lessons and activities, many teachers have used the model as an instructional device, using the model to talk about inquiry with students and to dynamically adapt the sequence of learning experiences to outcomes achieved during the instructional process.

- *Use as an instructional aid.* Though never expected or intended, the model has been used as an instructional aid with students. In several classrooms the model has been enlarged, placed on the wall, and used as a reference for students who need some new vocabulary to express or interpret what they are doing during various components of inquiry. The model has become a way for some teachers to introduce vocabulary in a consistent manner as it becomes needed to express ideas.

- *Use as an assessment rubric.* Though it was intended that the model provide some guidance in identifying the skills associated with the inquiry process, it was unexpected that the model would actually be used as an assessment rubric. Several teachers have used the *Circle* as a way of checking both their own success in incorporating the components of inquiry in lessons and student capability to identify or demonstrate the components of inquiry in their activities.

- *Use as a heuristic device in teacher education experiences.* The model has been used in a variety of settings to introduce the idea of inquiry to teachers and provide guidance in ways to design and develop inquiry-oriented lessons and activities. The model has been successfully used in curriculum courses, inservice workshops, and summer institutes both to interpret the components of inquiry within instructional activities and to develop inquiry-oriented instructional activities. The model has also been used in graduate classes to discuss the nature of science, inquiry, and the generation of scientific knowledge.

In summary, two years of pilot testing led to minor refinements of the model and the identification of several uses for the model. During this time there was no deliberate attempt to formally test the success of the model in terms of its uses among a variety of audiences. As insights were gained through experiences in classrooms, the model was refined or defined as appropriate. By 1988, the model was sufficiently developed to formally incorporate into professional development opportunities for teachers.

Phase 4: Descriptive Survey.

Subjects. The subjects for this phase of the study comprised representatives of two groups: a group of teachers and principals from a single urban school district, and a group of teachers and principals from a diverse set of rural, suburban, and urban schools. The subjects from the single urban school had participated in a summer institute that focused on activity-based science instruction for elementary schools, and the *Circle of Inquiry* was used to describe inquiry, critique activities, and plan lessons for elementary students participating in a science camp. The teachers and principals from the diverse set of schools had participated in a year-long series of five workshops that focused on developing activity-based, inquiry oriented science lessons and programs for elementary schools.. The summer institute was sponsored by a University through funding provided by the U.S. Department of Education's Eisenhower program, and the workshop series was sponsored and funded by a statewide professional association of school principals. None of the subjects in this case study were from schools where the model was initially developed.

Survey instruments were distributed by mail to 100 representatives of the two groups, and 55 usable instruments were returned. Characteristics of the participating subjects are presented in Table 1.

Table 1

Subject Characteristics

Gender:	45 Females	10 Males	
School Role:	49 Teachers	4 Principals	2 Specialists
Grades Taught:	33 Primary Grades	22 Upper Elementary	
Years of Experience:	Mean = 20 years	SD = 7.1	Range = 4-34 years
Years of College Science Coursework:	One year or less	18	
	Between one and three years	27	
	Three years or more	10	

Data. The data for this study consists of both quantitized responses to survey items, and written responses to open-ended questions presented on the survey instrument. In addition to the descriptive information presented in Table 1, several variables were operationally defined as responses to items or clusters of items on the survey instrument. The survey instrument is presented in Appendix A, and definitions of variables derived from some of the items are presented in Appendix B. Descriptive statistics for the derived variables are also presented in Table 2.

Table 2

Descriptive Statistics of Derived Variables

Variable	Mean	SD	Range
Use	2.8	0.89	0 - 4
Understanding	6.9	1.04	4 - 8
Usefulness	9.5	1.90	5 - 12
Planning	8.7	2.35	3 - 12
Student Effects	9.6	1.76	4 - 12
Discipline	3.1	1.00	0 - 4
Planning Time	2.7	0.96	0 - 4
Planning Style	0.9	0.98	0 - 4

As is evident in Table 2, all the continuous variables, except for "Planning Style," indicate that the model is viewed positively by the subjects. The low positive value for Planning Style shows that most subjects indicated that they did **not** plan lessons in a haphazard way. The low value is interpreted to mean that the subjects do plan in a structured way.

Correlations. A number of correlations were made to determine which variables are associated with successful implementation of the model. Descriptions for each variable are found in Appendix A. The resulting matrix of associations is presented in Table 3.

Table 3

Correlations Matrix

	Exp	Grd	Crs	Use	Und	Usf	Pln	Eff	Dsc	PlT	PlS
Exp	1										
Grd	0.14	1									
Crs	**0.32**	0.06	1								
Use	0.00	-0.05	**0.12**	1							
Und	**0.24**	**0.21**	**0.13**	**0.41**	1						
Usf	**0.15**	**0.16**	0.08	**0.46**	**0.44**	1					
Pln	**0.17**	0.11	0.10	**0.72**	**0.50**	**0.75**	1				
Eff	0.11	0.10	0.04	**0.55**	**0.41**	**0.77**	**0.71**	1			
Dsc	**-0.18**	-0.04	0.04	**-0.16**	**-0.29**	**-0.14**	**-0.21**	**-0.22**	1		
PlT	0.04	0.00	**0.14**	**0.39**	**0.13**	**0.37**	**0.29**	**0.27**	-0.10	1	
PlS	0.00	-0.08	-0.04	-0.04	0.06	**-0.17**	**-0.20**	**-0.21**	0.08	0.02	1

Note. Entries in bold are statistically significant at the level of 0.05 or less.

The full labels for the variables listed are as follows:
Exp = Years of **Experience** as an educator
Grd = **Grade** level taught (primary grades or upper elementary grades)
Crs = Amount of college **Coursework** in science
Use = Degree of **Use** of the *Circle of Inquiry* model in teaching science
Und = Degree to which the *Circle of Inquiry* model has facilitated an **Understanding** of scientific inquiry
Usf = **Usefulness** of the model as an instructional tool in the classroom
Pln = Degree to which the model as helped in **Planning** science lessons
Eff = Degree to which use of the model has had desirable student **Effects**
Dsc = Degree to which use of the model has contributed to **Discipline** problems
PlT = Amount of **Planning Time** spent by a teacher
PlS = Degree to which personal **Planning Style** is less-structured

As the matrix indicates, use of the model is most strongly related to its usefulness as an instructional tool, its value as a heuristic device for planning, its help in understanding the nature of inquiry, and its contribution to desirable student effects. It is interesting to note that use of the model is not correlated with either the level of experience that a teacher has, or their style of planning. It is also worth noting that increased use of the model is weakly associated with the *lack* of an increase in discipline problems.

Regression Analysis. One of the objectives of the study was to examine whether the model aided teachers in understanding the nature of inquiry, in planning lessons, or in realizing the desired student effects in science classrooms. It was decided that merely knowing that teachers tended to use the model for various reasons was not enough. To what extent does the model's value in planning, obtaining the desired student effects, or facilitating understanding account for its use? Though the subject sample is small and all data has been self-reported, it seemed useful to see how much variance in the use of the model could be explained by its contribution to planning, understanding, instruction, or obtaining desirable student outcomes. Though each of these variables is significantly correlated with overall use of the model (see Table 3), the use of the model in planning accounts for the greatest amount of variance in use of the model. As Table 4 indicates, regression of Use on Planning indicates that the model's value as a heuristic device for planning accounts for 51% of the variance reported in its use by the teachers surveyed. Incorporation of other variables in the regression formula did not significantly increase the regression coefficient. The variables are highly interrelated, so care must be taken in interpreting this result. It seems clear, however, that the responses of those surveyed indicate that the model's use as a planning device is of primary importance.

Table 4

Regression of Model Use on Planning

Variable	Coefficient	Standard Error	T	Significance	R	R^2
Planning	0.27	0.04	7.46	<0.00	0.72	0.51
Intercept	0.45	0.33	1.40	0.17		

Free-Response Information. The survey instrument included three questions to which respondents could provide feedback in writing. The questions are presented on the survey form in Appendix A. The first question focused on the lesson planning process, the second question focused on the *Circle of Inquiry* and its representation of the "scientific process," and the third question solicited feedback on how one's views about inquiry may have changes as a result of using the model. Responses to each question were critiqued and the following patterns of response were noted:

70.9% of respondents reported using a stepwise approach to lesson planning. Many provided a specific sequence of steps they take.

Example: *(1) Check curriculum for content info.*
(2) Apply circle of inquiry for process skills useful.
(3) Make daily plans.
(4) Collect materials.

36.4% of respondents seem to use the *Circle of Inquiry* conceptually in the planning process; they mention specific steps taken that relate directly to features of the model.

Example: *Children ask why. Curious about the way things work. The Circle of Inquiry helps me organize experiments. Scientists work the same way. First they ask questions. Then collect information and organize it. Try to make sense of it and then wonder again.*

21.8% of respondents seem to have maintained a traditional view of the scientific method that guides planning, or provided no feedback to the question on planning.

Example: *Use scientific method*
Objective
Materials
Procedure
Conclusion

45.5% of respondents expressed the view that the Circle *of Inquiry* better represents the scientific approach to understanding.

Example: *The approach to learning is the same in the Circle of Inquiry as in the scientific process - both beginning with wanting to know of find out about something.*

Example: *(1) It has all the elements required for a scientific approach.*
(2) It has an orderly, methodical approach to achieving inquiry. It is a way of thinking.
(3) It has guidelines to follow. all activities are reproducible.
(4) it is a "modified" scientific process.
(5) it follows the natural thinking process of inquiry yet it maintains the scientific procedural structure.

Example: *Circle of Inquiry incorporates the scientific process in a simple, direct manner which makes it easy to use.*

16.4% of respondents reported no noticeable change in their view of scientific inquiry or provided no response to question 3.

54.5% of respondents report using some form of inquiry, discovery, or hands-on learning in their classrooms.

Example: *The children in my elementary classroom love science. This approach has made it easy for me to use "hands on""activities to introduce and reinforce scientific concepts that could be difficult for children to understand. It works very well with cooperative learning. All of the children enjoy this approach which I have found to promote self-esteem, integration, a spirit of inquiry in all academic areas, and a like for science itself.*

41.8% of respondents found the *Circle of Inquiry* to provide a more focused and organized way of viewing scientific inquiry.

Example: *Scientific inquiry is a natural process we all experience at one time or another. When trained, our mind can think in this scientific mode of inquiry efficiently. The Circle put more logic and flexibility into scientific inquiry. We do not think in a straight line, but more in a circle. Because there is no one starting point on the circle, scientific inquiry can be less inhibiting, more spontaneous and fun. The Circle of Inquiry allows the flow of thoughts because it is not restrictive, and still has order.*

Example: *The circle represents to me how all of us, 1st graders and grown-ups, move towards solutions/answers. We start with wondering and we move in a circle of collecting data, studying data, making connections, but then we might find out we're wrong and we'll begin the circle again by wondering.*

Example: *I got more specific in what I wanted the children to get out of the lesson. I went in a more focused direction.*

Example: *It gives me great encouragement to plan lessons that provide for much more active student involvement. The circle provides much greater structure & direction for planning activities.*

56.4% of respondents found that use of the *Circle of Inquiry* in the classroom contributes to one or more of the following:

- Encourages questioning.
- Makes scientific inquiry exciting and spontaneous.
- Encourages discovery and thinking.
- Makes scientific inquiry approachable and flexible.
- Encourages hands-on and cooperative learning.

Example: *It encourages children to explore, discover, manipulate and develop their own ideas about objects or materials. This gives them a frame of reference for the instruction which follows.*

Example: *Using the Circle of Inquiry is a much more exciting approach than the traditional ways of approaching the teaching of science. It is respectful of student's intelligence and is much more in touch with today's students.*

This sampling of responses is representative of broadly held views that the *Circle of Inquiry* model has helped teachers plan and implement more activity-based, inquiry-oriented lessons that reflect the scientific approach to understanding. No respondent offered a negative comment about the model.

Discussion

Though the response rate to the survey seems somewhat low (55%), results of the survey indicate that the model has been well received by teachers and remains a part of their planning and instructional repertoire for at least two years after being introduced to the model. Analysis of both the Likert-type items and the open-ended items supports use of the model as a heuristic device for designing and implementing lessons. Teachers reported a high level of satisfaction with the model both as a representation of scientific inquiry and as an instructional tool. Most found the model useful in facilitating activity-based teaching and cooperative learning. Indeed, regression analysis indicated that use of the model in planning accounted for 51% of the variance in reported tendency to use the model. It is particularly interesting to note that the value of the model as a planning device is not significantly correlated with the classroom experience that a teacher has; it seems valuable to teachers regardless of their science background or number of years in the classroom

To return to the original questions that initiated this study, here is what has been found:

Does the model convey an easily understood and authentic view of scientific inquiry?

There are many possible perspectives on how to answer a question like this. There are epistemological issues, there are questions about how one defines "easily understood" and measures that, and there are concerns about how you collect the information you would need to formulate a reliable and valid answer that is field-based. In this study we are limited to survey responses and what respondents chose to say in written responses to open-ended questions. The best that can be said at this point is that respondents seem to *think* that they understand inquiry and the processes of science better, and they are of the opinion that the model authentically represents the scientific approach as they understand it. Support for the model as an authentic representation of scientific inquiry is provided in responses to both the Likert-type items and the questions requiring a written response. Evidence that the model is easily understood is inferred from written responses to questions. Use of the model is described by many respondents in ways that indicate a conceptual understanding of the model and its representation of scientific inquiry.

Does the model help teachers design and implement inquiry-oriented science lessons?

By every indicator available in this study, the answer is yes. A high level of use is reported for the model; use is strongly correlated with planning activities; and the majority of respondents express favorable comments about the model's use in designing, teaching, and realizing desirable outcomes from science lessons.

Does use of the model in the classroom have any desirable effects on student learning or attitudes?

Though this study is severely limited by the nature of its dependence on self-reported outcomes, the tentative answer to this question is yes. Desirable student effects are indicated by strong agreement to survey items, student effects are positively correlated with use of the model in planning and implementing lessons, and many testimonials were offered in the free-response portion of the survey regarding effects with students and learning.

In conclusion, this study is by no means definitive or complete. There has been sufficient developmental work and accumulated evidence in support of the *Circle of Inquiry* model, though, to merit more widespread application and study. These preliminary findings are encouraging in that a relatively simple model seems to provide just enough direction for elementary teachers that they are successfully designing and implementing activity-based, inquiry-oriented lessons. And by self-report, use of the model is contributing to the desired effects on both student and teacher learning and attitudes. As one respondent said, "I am much more interested in science and not as afraid of the scientific process." That seems like an outcome that will have desirable effects in the classroom.

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Appendix A

Survey Instrument

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Circle of Inquiry Survey

The purpose of this survey is to determine how useful the *Circle of Inquiry* model has been to you as an educational professional. Your honest responses are greatly appreciated. For the statements below, please **circle** the response that most closely reflects your response to that statement.

SD = Strongly Disagree D = Disagree N = Neutral A = Agree SA = Strongly Agree

1. *Circle of Inquiry* is a good way of providing teachers like me the basics of scientific inquiry. SD D N A SA
2. I frequently use *Circle of Inquiry* in my science lessons. SD D N A SA
3. *Circle of Inquiry* makes science lessons easier to plan. SD D N A SA
4. Using *Circle of Inquiry* contributed to discipline problems in class. SD D N A SA
5. *Circle of Inquiry* gives me the structure I need for a hands-on approach to science teaching. SD D N A SA
6. Using *Circle of Inquiry* has facilitated student learning in the classroom. SD D N A SA
7. I generally spend a lot of time planning science lessons. SD D N A SA
8. *Circle of Inquiry* is too complicated to be implemented in elementary school science lessons. SD D N A SA
9. Children find the science classes more interesting when *Circle of Inquiry* is used to plan them. SD D N A SA
10. *Circle of Inquiry* helped me understand the nature of scientific inquiry. SD D N A SA
11. *Circle of Inquiry* encourages students to question and participate more actively in class. SD D N A SA
12. My personal style of learning is eclectic, incorporating aspects from many sources. SD D N A SA
13. It is hard for me to determine exactly how much *Circle of Inquiry* has helped me in planning science lessons. SD D N A SA
14. *Circle of Inquiry* is easy to use in the classroom. SD D N A SA
15. I generally plan lessons in a haphazard way, rather than in a structured way. SD D N A SA
16. Learning about *Circle of Inquiry* has helped me plan better science lessons. SD D N A SA

-over-

Please respond to the following items in the space provided.

17. Describe the steps you go through when you plan a science lesson.

18. In what ways does Circle of Inquiry represent the scientific process?

19. Describe how your views of scientific inquiry have changed after being introduced to Circle of Inquiry?

The following information about yourself would also be helpful to our survey.
Please fill in the blank or **circle** the appropriate *italicized* response.

Gender: *female* *male* Years of experience as a professional educator:_________

Primary role: *teacher* *administrator* *specialist*

Grade levels you have taught the most: *primary grades* *upper elementary or above*

Number of years of college science coursework:
one year or less *between one and three years* *three years or more*

Appendix B

Survey Items and Item Clusters Utilized as Variables

Operational Definitions of Variables

Use (Item 2): An indicator of the degree of use of the model by teachers.

Mean = 2.8 SD = 0.89 Maximum value = 4

A higher value is interpreted to mean that the model is used frequently.

Understanding (Items 1 and 10): The teachers' assessment of the *Circle of Inquiry* as facilitating an understanding of scientific inquiry.

Mean = 6.9 SD = 1.04 Maximum value = 8

A higher value is interpreted to mean that the model has enhanced a teacher's level of understanding of scientific inquiry.

Instructional Usefulness (Items 5, 14, and the negative of item 8): A measure of the teachers' view of the usefulness of the *Circle of Inquiry* in the classroom.

Mean = 9.5 SD = 1.90 Maximum value = 12

A higher value is interpreted to mean that a teacher has found the model useful as a heuristic device or instructional aid in the classroom.

Planning (Items 3, 16, and the negative of 13): A measure of the teachers' use of the *Circle of Inquiry* to plan science lessons.

Mean = 8.7 SD = 2.35 Maximum value = 12

A higher score is interpreted to mean that the model is used to facilitate planning.

Student Effects (Items 6, 9, and 11): Teachers' assessment of the effects that the *Circle of Inquiry* has on student learning in the classroom.

Mean = 9.6 SD = 1.76 Maximum value = 12

A higher value is interpreted to mean that the model has facilitated student learning, participation, or interest in school science.

Discipline (Item 4): An indicator of the teachers' perceptions that the *Circle of Inquiry* contributes to discipline or student management problems.

Mean = 0.9 SD = 1.00 Maximum value = 4

A higher value is interpreted to mean that the model contributed to discipline problems.

Planning Time (Item 7): An indicator of the teachers' perceptions of the amount of time spent planning science lessons.

Mean = 2.7 SD = 0.96 Maximum value = 4

A higher value is interpreted to mean that a teacher spends "a lot" of time planning science lessons.

Planning Style (Item 15): An indicator of the teachers' perceptions of the degree to which they use a structured approach to lesson planning.

Mean = .9 SD = 0.98 Maximum value = 4

A higher value is interpreted to mean that a teacher tends to plan lessons in a more chaotic or less structured way.