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ABSTRACT

Scientific inquiry has been stressed as necessary for all students in science education reform efforts. "I Wonder: The Journal for Elementary School Scientists" provides a unique opportunity for elementary school students to disseminate their scientific investigations in the analog form of print journals. The Heron Network has published this journal annually since 1992, and the articles published facilitate scientific discourse for the students and teachers involved in the Heron Network. This paper presents an analysis of 617 student inquiry articles published in "I Wonder" between 1992 and 2000. This study specifically focuses on those articles that are scientific or engineering=based and explores the topics selected for investigation by students, methods used to conduct the investigations, and whether the inquiry represents scientific or engineering thinking. (Contains 31 references.) (YDS)

INQUIRY-BASED RESEARCH PUBLISHED IN *I WONDER: THE JOURNAL FOR ELEMENTARY SCHOOL SCIENTISTS* (1992-2000)

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Science education reform efforts in the USA stress the need for students at all levels to conduct and report scientific inquiry (AAAS, 1993; National Research Council, 1996). Typically, this reporting takes the form of a student or small group of students explaining their inquiry project in front of their classmates or writing a lab report for their teachers. There are few mechanisms for students to communicate their investigations of science beyond the walls of their classrooms. *I Wonder: The Journal for Elementary School Scientists* is unique in that it provides a mechanism for disseminating elementary students' investigations of science in a form that is analogous to printed journals within the scientific community *(Note: I Wonder* was published from 1992 until 1995. From 1996 to the present, *I Wonder* appears as one section in *Great Blue: A journal of student inquiry*, see Beeth & Wagler, 1997).. Our analysis of the 617 student inquiry articles published in *I Wonder* from1992-2000 offers (a) an overview of *I Wonder* as a tool to promote authentic student inquiry (Andersen, in review) and (b) an examination of the research questions and investigative procedures used by these students. We are particularly interested to know if the type of student generated inquiry represented in *I Wonder* articles is "scientific" or "engineering." Analysis of the articles published in *I Wonder* provides an excellent opportunity to see how these elementary students are responding to instruction presented as inquiry.

The Heron Network (a group of elementary school teachers and students in the Madison [WI] Metropolitan School District and surrounding area) has published *I Wonder* annually since 1992 (Beeth & Wagler, 1997). The purpose of *I Wonder* is to promote scientific discourse among elementary students through the publication of their research in a journal, similar in some ways to the scientific discourse within a community of scientists. Articles published in *I Wonder* facilitate scientific discourse for the students and teachers involved in the Heron Network in two ways. First, *I Wonder* serves as an outlet for students to communicate their science inquiry projects to others. The journal is distributed annually in paper form to students within the Network as well as via the Internet (http://danenet.wicip.org/heron/Description.html). Teachers in the Heron Network help students write articles for dissemination–an uncommon genre of writing in most elementary schools. Preparing articles for publication in *I Wonder* helps these students understand the essential role that communicating one's research to others plays in professional scientific communities. Second, past issues of *I Wonder* serve as a repository for topics that students in the classrooms of Heron Network teachers have investigated. In a sense, past issues represent what students collectively learned and how they conducted their scientific investigations. Each Heron Network teacher requires his or her students to read past issues of *I Wonder* before proposing a new investigation. In this way, students emulate the activities of professional scientific communities by determining what is already know about a topic before they begin an inquiry project. In this paper, we analyze articles published in *I Wonder* from 1992-2000 to determine which science topics are selected for investigation and, more importantly, the methods students used when conducting and reporting an investigation. We were interested to know if the inquiry reported in *I Wonder* more closely represented "scientific" thinking or "engineering" thinking.

Theoretical background

The research literature in children's scientific thinking suggests several routes of analysis for the student inquiry articles published in *I Wonder*. Bybee's (2000) interpretation of Joseph

Schwab states that there are three main sources for children's questions: first hand manipulation of physical materials; printed resources such as textbooks or earlier editions of *I Wonder* journals; and students' life experiences. In the first of these, children use or manipulate physical materials in ways that allow them to answer questions about the materials themselves. Second, print resources frequently suggest questions for students to study in a "cookbook" type manner where the answer is usually assumed to be predetermined. Last, children are naturally curious about how things work. When children are allowed to investigate their own questions they tend to use what they already know to stimulate additional thoughts and actions resulting in the generation of new knowledge (Chiappetta, 1997). As will be demonstrated in this paper, students draw upon their personal experience for inquiry projects more frequently than any other category. (see Table 2).

A second route of analysis differentiates "scientific" thinking versus "engineering" thinking. When investigating causal systems, children tend to focus initially on producing desirable outcomes (often by trial-and-error) instead of performing systematic explorations to understand the causal structure of the task (Schauble, Klopfer, & Raghavan, 1991). Our initial analysis of the articles in *I Wonder* from 1992-2000 identified those articles that claimed to use procedures associated with experimental design or engineering approaches. Articles identified as "scientific" and "engineering" were further examined to determine whether these investigations produced only the desired outcome or whether they also generated new scientific knowledge for the author(s). Our analysis couples this information with the source of students' questions to support conclusions regarding overall change in the nature of science learning represented in *I Wonder* from 1992-2000.

Methodology

All articles published in *I Wonder* between 1992 and 2000 (N=617; see Table 1) were read by both authors of this paper. Information in the text of each article was coded for the source of the student(s) question, topic investigated and method(s) of gathering data (see Tables 2, 3 and 4 respectively). Definitions for all codes are presented in Appendix A and examples of selected titles placed in some topic categories are found in Appendix B. The entire list of codes represents, for us, lines of inquiry that make sense to the students and their teachers, although they may not exactly represent scientific notions. For example, the codes "animal-pet" and "animal-behavior " are not mutually exclusive. However, the distinction we made with respect to these topics indicated whether an animal was being trained to perform a predetermined task -- "What tricks can cat's do best?" (Turnbull, 1999) or "The effects of exercise on how fast mice can get through a maze" (Benish, Fleming, & Whitaker, 1996); or observed in a natural setting -- "Observing squirrels" (Wichert & Casale, 1995). This degree of flexibility in our coding system was also necessary as teachers in the Heron Network occasionally directed students to specific topics if they failed to come up with one of their own (i.e., observational studies of their backyards in 1996 and 1997).

Descriptive statistics for the complete data set are presented in Tables 2, 3 and 4 below. Each cell in these tables contain two numbers – the number of articles placed in a category followed by the proportion (in parentheses) of all articles that category represents for that a given year. This is followed by descriptions of articles that illustrate "scientific" thinking versus "engineering" thinking. In addition, several of the examples clearly show the importance of discourse between students and their completion of the project. A series of articles on the "Pulley Project" is then presented that illustrate change in the sophistication with which several groups of students investigated this topic over a number of years. Our analysis illustrates the extent to which articles published in *I Wonder* represent inquiry-based investigations that are scientific versus investigations that employ engineering approaches. There are no obvious trends in the data for source of student question(s). However, it should be noted that students who published in *I Wonder* were not relying on one source to the exclusion of all others.

Table 1

Articles Published in *I Wonder* (1992-2000)

Year	# Articles
1992	16
1993	63
1994	93
1995	93
1996	70
1997	56
1998	85
1999	87
2000	54

Table 2

Source of Student Question(s) (1992-2000)

	Year								
Source	92	93	94	95	96	97	98	99	00
I Wonder Journal		7 (.10)	7 (.08)	9 (.10)	6 (.08)	3 (.05)	7 (.09)	2 (.02)	5 (.09)
Teacher	7 (.40)	9 (.11)	4 (.04)	20 (.22)	20 (.30)	19 (.34)	13 (.16)	2 (.02)	7 (.13)
Peer		4 (.06)	7 (.08)	14 (.15)	10 (.14)	8 (.14)	10 (.12)	3 (.03)	4 (.07)
Parent/other adult	1 (.10)	2 (.03)	2 (.02)	3 (.03)	3 (.04)	3 (.05)	1 (.01)	2 (.02)	2 (.04)
Experience	3 (.20)	30 (.50)	30 (.33)	32 (.34)	14 (.20)	17 (.31)	30 (.36)	9 (.10)	19 (.35)
Pop culture			5 (.05)	4 (.04)	3 (.04)	3 (.05)	6 (.08)	1 (.01)	0
Unknown source	5 (.30)	11 (.20)	38 (.40)	11 (.12)	14 (.20)	3 (.05)	12 (.15)	68 (.79)	17 (.32)
Total	16	63	93	93	70	56	85	87	54

Table 3

Topic investigated (1992-2000)

Topic	Year: 92	93	94	95	96	97	98	99	00
Animal (behavior)	1 (.06)	1 (.02)	8 (.09)	4 (.04)	6 (.09)	2 (.04)	2 (.02)	4 (.05)	7 (.13)
Animal (insects)		3 (.05)	1 (.01)		1 (.01)	2 (.07)	4 (.05)	1 (.01)	
Animal (invertebrate)			2 (.02)	1 (.01)		1 (.02)	1 (.01)	5 (.06)	
Animal (macro)	2 (.13)		5 (.05)	7 (.15)	2 (.02)	4 (.07)	2 (.02)	1 (.01)	
Animal (micro)			2 (.02)	1 (.01)		1 (.02)		1 (.01)	1 (.02)
Animal (pet)			3 (.03)	4 (.04)		1 (.02)		5 (.06)	6 (.11)
Animal (vertebrate)		7 (.11)	12 (.13)	14 (.15)	11 (.16)	5 (.09)	12 (.14)	10 (.12)	
Chemistry	1 (.06)	8 (.13)	6 (.07)	8 (.09)	3 (.03)	5 (.09)	8 (.09)	17 (.20)	6 (.11)
Earth Science		3 (.05)	4 (.04)	9 (.10)	4 (.05)	4 (.07)	6 (.07)	16 (.18)	3 (.06)
Engineering	1 (.06)	2 (.03)		5 (.05)	5 (.07)	1 (.02)	3 (.04)	4 (.05)	3 (.06)
Environment	4 (.25)	4 (.07)	5 (.05)	2 (.02)	10 (.14)	4 (.07)	11 (.12)	7 (.08)	9 (.12)
ESP	1 (.06)		1 (.01)	1 (.01)		1 (.02)			
Human Physiology		1 (.02)	2 (.02)	3 (.03)	2 (.02)	1 (.02)	4 (.05)	3 (.03)	3 (.06)
Learning	1 (.06)	2 (.03)	3 (.03)	1 (.01)				1 (.01)	

(Table 3 continued)

Memory		1 (.02)	1 (.01)	1 (.01)	1 (.01)	2 (.02)	5 (.06)		
Mold		1 (.02)	2 (.02)		1 (.01)	2 (.02)	3 (.04)		2 (.03)
Personal Preference	1 (.06)	5 (.08)		5 (.05)	2 (.02)		1 (.01)	3 (.03)	1 (.02)
Physics		6 (.10)	13 (.14)	9 (.10)	11 (.16)	8 (.14)	7 (.08)	1 (.01)	9 (.12)
Plants	4 (.25)	19 (.30)	18 (.20)	14 (.15)	9 (.13)	9 (.16)	11 (.12)	7 (.08)	4 (.07)
Psychology			5 (.05)	1 (.01)	2 (.02)	2 (.04)	5 (.06)		
Other				3 (.03)		1 (.02)		1 (.01)	
Total	16	63	93	93	70	56	85	87	54

Table 4

Method(s) of investigation (1992-2000)

	Year								
Method	92	93	94	95	96	97	98	99	00
Experimental	12 (.75)	38 (.60)	16 (.17)	23 (.25)	19 (.30)	20 (.36)	21 (.25)	22 (.25)	10 (.30)
Invention			6 (.07)	7 (.07)	7 (.01)	6 (.10)	9 (.10)	3 (.03)	5 (.09)
Literature search	1 (.06)	1 (.02)	8 (.09)	7 (.07)	3 (.04)	2 (.04)	12 (.14)	25 (.29)	2 (.03)
Observation	2 (.13)	11 (.17)	34 (.40)	30 (.32)	30 (.43)	22 (.40)	22 (.40)	21 (.24)	21 (.40)
Survey		4 (.07)	15 (.16)	2 (.02)	3 (.04)	2 (.04)	10 (.12)	7 (.08)	3 (.06)
Trial and error	1 (.06)	9 (.14)	4 (.04)	20 (.21)	4 (.05)	4 (.07)	6 (.07)	9 (.10)	11 (.20)
Total	16	63	93	93	70	56	85	87	54

Scientific versus engineering thinking

Data in Tables 2, 3 and 4 above characterize the 617 articles published in *I Wonder* at a nominal level. Articles we selected to illustrate "scientific" thinking versus "engineering" thinking are presented below. These articles represent either (a) a single article that contains elements of scientific or engineering thinking or (b) a series of articles that build on one another as they investigate a topic. In the later case are multiple articles across several issues of *I Wonder* on topics such as batteries, acids and bases, observation of natural phenomena in students' backyards, the growth of crystals, or building some object for a specific task. On the other hand, individual articles that contained elements of scientific or engineering thinking were ubiquitous. Our purpose here is to present only select samples of the articles that we believe represent these two categories.

What makes people sneeze?

Limaye's (1995) question ("What makes people sneeze?") came from watching a presentation by high school biology students in his district. Watching this presentation made him curious to investigate this topic and he began by first asking the biology teacher for help with his inquiry project. The high school biology teacher provided Limaye with a box of materials he would need to set up his experiment. He designed an experiment to test the reactions of his classmates to pepper, dog hair, chalk dust, and household dust. Each test item was presented to 26 subjects. Subjects rated their reactions to each item as sneezed, tickled, hurt, burned, nothing or other. Data were summarized across all 26 cases and displayed in a bar graph of reactions to each substance versus number of reactors. What is particularly interesting is that Limaye's analysis of his data led him to reject his original hypothesis as incorrect. Limaye stated, "I learned that pepper doesn't always cause a reaction, let alone a sneeze. I believe that a lot of sneezing happened due to an allergic reaction." In effect, Limaye demonstrated ability to reason from data to conclusions – in this case, rejecting his initial hypothesis that pepper causes sneezing.

Taste Buds

Barber (1996) published an article that addressed the question, "Where are taste buds strongest?" This question was posed after reading Gould-Werth's (1995) inquiry article. Barber tested three different liquids: saltwater, sugar water, and lemon juice. Her procedure clearly tested one liquid and one student at a time. Barber asked subjects to report where on their tongues the taste was strongest. Data were discussed anecdotally in the text of the article but and not displayed in tabular form. What was particularly interesting in this case is that Barber actually talked with Alix Gould-Werth about revising the study she published in 1995. Barber reported, "I think I improved it a little, she [Gould-Werth] thinks I improved it a lot". The opportunity for Barber to speak with Gould-Werth before revising her work is a fundamental activity in science, one that was captured by these two authors as the these two *I Wonder* articles as well as many others.

Rolling Balls

West and Kress (1996) cited a prior *I Wonder* article ("Ramps and Racing" by Cotton & Osuocha, 1995), in their article on "Rolling balls." In addition to adding on to the information gathered in *I Wonder*, Kress had also done projects on momentum. With both of these experiences the students were able to plan their experiment. The students hypothesized " the higher the ramp got, the farther the ball would go." They measured the height and angle of the ramps as well as the distance a ball traveled down each ramp 100 times. West and Kress stated, "We had 'sets' and 'trials'. There were 10 trials in a set. There were 10 sets all together or 100 trials." These students showed their understanding of controlling a limited number of variables, and they collected a large data set from which to draw conclusions. In the end, they gave several suggestions of additional variables that might be interesting to study in the future, like the texture of the ball. West and Kress demonstrated understanding of scientific procedures and conclusions based on their study.

Crystals

The formation and observation of different types of crystals is an inquiry repeated several times in *I Wonder* journals. The original publication of research about crystals began with two different studies in 1993. First, Lee and Moffett (1993) began their research about how to make crystals. Soon they learned that Moore (1993), a student in another classroom was also interested in the same topic. The two groups of students were able to share their research notes and work together on two different studies of crystals. The use of discourse between students working on similar projects added to the general knowledge base of both groups. Moore states "I got a lot of information from them. The information I got from them showed the different kinds of crystals you could make." She also went on to discuss additional resources like a university professor who helped the students gather the materials needed to complete their research. The result was two similar but different projects with Lee and Moffett (1993) implementing a charcoal garden and Moore (1993) the more traditional string and sugar method.

Crystal research did not end in 1993. Several students have continued to study the formation of crystals with different materials. For example, Powell (1995) published results from the use of different spices, such as sugar, salt, and pepper. Powell set up several different trials and compared the results. Wroblewski (2000) made additional changes by altering the number of food coloring drops added to give the crystals color. She hypothesized that "the more food coloring I added, the smaller the crystals would be." She went on to discover the amount of food coloring did not have an effect on the size of the crystals that were grown.

Examples of Engineering Articles

Combustion Engines

Payne (1999, p. 94) published an article that asked: "How does gas make an engine work?" This question is similar to other engineering type projects that ask questions about material objects. To answer this question Payne examined resources in the library and on the Internet. Ultimately he obtained the information he desired from an encyclopedia, information that was then confirmed by a knowledgeable parent. In a section of his article titled "Problems and New Directions" Payne stated, "My problem was no book except the encyclopedia had any information..." Payne's *I Wonder* article represents, for us, an approach to inquiry that relied on analyzing (reading?) known information without engaging him in doing hands-on inquiry related to this topic. However, searching existing literatures is an essential first step in science inquiry.

Making a Cat Food Machine

Frankowski and Yang's (1995) project, "Making a cat food machine", started with the question: "Can we make some sort of machine that lets a cat feed itself?" The final product in this case is a device that, if perfected, would solve a problem for these students. The idea for this project resulted from a conference with their teacher after their initial idea ("...about how cats and fish hear") was determined to be too difficult to study. These students built, tested, and re-tested their cat food machine on actual cats and themselves (because the cats failed to cooperate in the testing of the machine). Their prototype cat food machine included a cardboard box, popsicle sticks, and a cat toy that delivered cat food to a food bowl. In the end, they suggested changes to the cat food machine to get it to drop food more accurately into the bowl ("The cat food machine kind of worked but after the experiment there was cat food all over the kitchen floor"), and to their choice of materials ("If we had to do the whole experiment over again, we would make the cat food machine a little stronger and the box a little more tilted..."). The project these students completed represents several aspects of engineering in that they knew what they wanted to produce, they built, revised and tested a working model, and they made suggesting for improving their final product. Engineering projects similar to the one described here were also authored by Lawrence and Yang (1995, "Making a light bulb"), Evans (1995, "Can fish go through a maze?") and Kress and Luck (1998, "Making and destroying balsa wood bridges").

Making a Pulley System Down to the Office

The Pulley Project, as it came to be known by teachers in the Heron Network, represents several significant points about engineering projects publishing in *I Wonder*. First, Heikkinen and Hunter approached the building of a pulley system to the office as an engineering task in 1992. These students spent considerable time determining how much string would be needed and gathering different kinds of pulleys to build a prototype that was functional. In subsequent years, after reading articles published by previous students, the questions posed were much more sophisticated in that they began to ask fundamental questions about the physics underlying the construction of the pulley system. After reading the article by Heikkinen and Hunter (1992), Klein, Jeanne and Smalls (1993) decided to measure the force required for lifting an object with one, two and no pulleys as a prelude to designing their final system. Their question moved the pulley project away from an engineering task and toward a more scientific investigation of the mechanical advantages of pulleys. Cole (1998) and Medina and Sinderbrand (1996) continued this work on the pulley project by investigating different configurations of pulleys – fixed, movable, and block and tackle.

The pulley project held the interests of a considerable number of students from 1992 through 1998. Undoubtedly, this project challenged students to solve a practical problem for them – conveying the attendance card to the office and back, thus saving time and effort. The first group of students approached the Pulley Project as an engineering task – investigating the physical capabilities of string and pulleys, measuring the distance to the office, assembling all the necessary materials, and then building a prototype that was functional. Later groups of students investigated this problem in ways that are similar to those within the scientific community, namely by reading previous research and modifying the question, their methods of investigation or both to enhance fundamental knowledge about the system of interest. In this way, students' use of *I Wonder* paralleled the use of published scientific literature by those in a scientific community.

Implications for Future Research

The publication of articles in *I Wonder* allowed these elementary school students to participate in scientific discourse within a community of scientists. In particular, it allowed these students to read and modify the previous work of their peers over the years 1992-2000, most notably in the Pulley Project. In one sense, *I Wonder* functions not just as a record of student inquiry but as a stimulus for inquiry investigations that result in the production of new knowledge – at least new to these students. This has allowed these students to build a community in which they and their peers determine what to study and how. It also results in the investigation of topics in a depth not common to the science teaching with which we are familiar.

The analysis of *I Wonder* articles as "scientific" or "engineering" in this article can easily be extended to address other questions in the future. For example, many articles in *I Wonder* contain significant questions of a personal nature (e.g., "How many times are African-American's cited in science books?", Mogaka, 1995), one is written in Spanish (i.e., "Agua sal, agua acida pura agua y plantas," Cautopozota, 1994), many contain sophisticated data presentations (see graphs of housing supply and demand before and after the 1906 San Francisco earthquake by Manuelli, 1996), and others resulted after presentation of a topic by an expert (i.e., Testing memories, Garcia, 1998). Certainly the impacts these had on students' inquiry projects should be investigated. In addition, analysis of an individual student's ability to present their scientific or engineering projects when they published more than one *I Wonder* article (168 people published more than one article) would be worthy of further investigation. When analyzing *I Wonder* as we did, we also noted that some authors used assistance from a parent or other adult. Following-up with these authors to determine the relative contributions of one or the other could also be informative. It was our intent in this article, however, to characterize all articles published in *I Wonder* from 1992-2000 as a starting point for further investigations of these inquiry projects.

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Wroblewski, E. (2000). Formation of sugar crystals. *Great Blue, 5,* 119-120.

Appendix A

Definitions for data codes

Source of question

I Wonder Journal - mentioned an article in a previous issue of *I Wonder*
Teacher - article mentioned teacher as source of idea
Peer - article mentioned a peer as source of idea
Parent or other adult- article mentioned an adult not connected with teaching as source of idea
Experience - article mentioned some previous experience as source of idea
Pop culture - article mentioned television or other media as source of idea

Topic investigated

Animal-behavior - attempts to train or naturalistic observations of an animal
Animal-insect - studies of insect life cycles
Animal-invertebrate - studies of marcoinvertebrates in classroom or natural settings
Animal-macro - studies of Daphnia (maintained by several teachers)
Animal-micro - studies of protozoa
Animal-pet - studies of a domestic animal in a controlled environment
Animal-vertebrate - studies of large animals in their natural environments
Chemistry - studies exploring the properties of chemicals, or heat
Earth science - studies of earth materials or geologic events
Engineering - attempts to make something of practical use
Environment - studies of interactions of biotic and abiotic factors in natural settings
ESP - studies of paranormal phenomena
Human physiology - studies of physiological response to a stimulus
Learning - studies of cognition
Memory - studies of recall
Mold - studies of non-vascular plants
Personal preference - studies of personal preferences
Physics - studies of motion, light, electricity, etc.
Plant - studies of any vascular plant
Psychology - studies of human perception, mood, etc.

Method of the investigation

Experimental - controlled one or more variables
Invention - intent was to make a know device better or more efficient
Literature search - summarized information in print or electronic resources
Observation - observed some event but did not try to duplicate it
Survey - collected information form others through questioning
Trial and error - repeated attempts to cause something to happen

Appendix B

Article titles categorized by topic

Chemistry - " Creating Hydrogen gas", " How to make a battery"
ESP - "ESP", " ESP concentration"
Human physiology - " Heart rates in boys and girls", " Do funny movies affect pulse and body temperature?"
Learning - "Attention in third and fifth graders", " What is ADD?"
Personal preference - " Testing sugarless bubble gum", " What are you thirsty for?"
Plant - " Cross pollinating Arabidopsis plants", " Plants in different light"
Psychology - " Food and dreams", " Before and after recess behavior

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