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Microcomputer-Based Laboratories in Elementary Science: Young Children's Conceptions of the Tool and the Task

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Recently, a third grade student was asked to explain how the computerized light sensing device he was using in his classroom worked.

He confidently replied, "It sucks up light." Upon further questioning, he proceeded to explain that the light is then transported to the computer, where the computer "tells how much [light] there is".

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INTRODUCTION

Children's conceptions about science often differ from the formal ideas of scientists (Driver, 1985, 1989; Lawson, 1988; Arnaudin & Mintzes, 1985; di Gennara, Picciarelli, Schirinzi, & Bilancia, 1992; Smith, 1984; Levy, 1988). Most young children, for example, do not conceptualize "light" in the scientific sense as a distinct entity that is capable of traveling--thus they would probably not suggest that light could enter (or be sucked-up by) the eye. Rather, young children usually report that light exists at a source (i.e., light bulb) or that it illuminates objects--this being the effect that allows us to see (Driver, 1985; Eaton, 1983). Was this third grader exhibiting a more mature concept of light than would normally be expected for a youngster his age? Or did the use of the light probe simply provide him with opportunities to create "new" misconceptions about scientific phenomena?

The purpose of this study was to investigate young children's conceptions of real-time, computerized data collection and analysis tools called Microcomputer-Based Laboratories (MBL) and to explore how the use of these tools influences children's understanding of physical science concepts.

OVERVIEW

The improvement of science teaching and learning has been an issue for many decades (Hurd, 1986). The critical question has been, and continues to be, how best to prepare citizens to live in a society largely defined in terms of achievement in science. More and more, citizens are being asked to make decisions that require some measure of scientific literacy. Unfortunately, reports of science achievement within our country, as well as international comparisons, indicate that our students are not learning science (Loucks-Horsley, et al., 1990). Why has this continued to be the case?

In the early 1970's, research in science education began to focus on the conceptual models that lie behind student's conceptions of particular scientific domains. Since that time, results of numerous studies have shown that student conceptions of physical science phenomena, while naive, are often remarkably consistent and coherent (Feher & Meyer, 1992; Rice & Feher, 1987). This has led to a growing consensus that students do not enter science classrooms as empty vessels waiting to be filled with the "big ideas" of science (Driver, 1983). Rather, they come with existing conceptual frameworks that are primarily based on incidental science knowledge (that which is not taught in school) and that are often highly resistant to change (di Gennaro, Picciarelli, Schirinai, & Bilancia, 1992).

This perspective on learning suggests that it is as important for science curriculum developers and classroom teachers to consider children's own ideas as it is to give clear descriptions and presentations of accepted scientific theories (Driver, 1983). A currently accepted approach to the achievement of conceptual learning in science is to confront the novice students with enough evidence to make them realize both the limitations of their own theories and the value of conventional scientific theories (Vosniadou, 1988). In practice, this could involve: 1) giving students opportunities to make their own ideas explicit through individual or group reflection about their ideas (i.e., discussions, drawings, written descriptions, etc.); 2) introducing discrepant events or some other type of situation which produces conceptual conflict about the naive conception; 3) providing opportunities for students to discuss their ideas with a focus on reconstruction; and 4) encouraging students to generate a range of conceptual schemes and practice using them in a range of situations. Today, the use of instructional technologies in science classrooms may provide opportunities for students to engage in just this type of learning experience.

The use of technological tools for scientific inquiry has long been commonplace for scientists in laboratories, but it is only in recent years that computers have been used in classrooms to enhance science instruction (Pease, 1991). Chiu (1990) reports that one particular tool may be among the most promising innovations in science education--the Microcomputer-Based Laboratory. An MBL is an integrated package that consists of hardware which attaches peripherally to the computer and software for control and design of experiments. Probes or sensors are able to collect data on such phenomena as temperature, light, distance, velocity, acceleration, or pH. The data are graphed in real time on the computer screen, and at the conclusion of the experiment students have opportunities to analyze the data in graphic or tabular forms.

Microcomputer-Based Laboratories first emerged as a tool for science instruction about a decade ago. MBLs were initially used with high school or college students, typically in physics laboratories. Most of the literature dealing with MBLs has suggested that the use of this type of tool can increase students' conceptual understandings in science (Friedler, Nachmias, & Songer, 1989; Thornton, 1985) and can increase students' ability to interpret graphs (Mokros & Tinker, 1987; Adams & Shrum, 1988). Graphing is considered a key symbol system for scientific communication and Mokros and Tinker (1987) suggest that "graphs are an important tool in enabling students to predict relationships between variables and to substantiate the nature of these relationships. They suggest a link between students' graphing skills and their ability to understand scientific relationships" (p. 370). While MBLs may have the potential to promote student acquisition of mature scientific concepts, at this time very little research has been done on its use with young children. Indeed, some concerns have been raised that perhaps with elementary school children MBLs may actually promote misconceptions about science by putting an "extra layer" of equipment between the children and the scientific phenomenon (Alfred Bork, personal communication, 1992).

If science learning in the classroom is really to improve--that is, if students are really to construct robust conceptual models that are consistent with accepted scientific theory--it seems apparent that instruction must be designed to address students' naive scientific conceptions. MBLs may provide conditions under which students can confront and reconstruct these naive theories. Clearly this type of technology allows students to interact with scientific phenomena in ways that have not before been possible. Whether these interactions will promote meaningful conceptual learning is certainly a question worthy of serious consideration.

Gender equity in science education has also been a topic of great concern in recent years. A number of studies have investigated gender effects on student learning when using MBLs. Brasell (1987) noted gender differences in high school students with particular respect to graphing skills involving distance or velocity concepts. She reported that females showed greater gain scores on a posttest of distance graphs, while males scored higher on a posttest of velocity items. Stuessy and Rowland (1989) reported that laboratory activities, including the use of MBLs, result in greater gains in graphing skills for females than males involved in temperature investigations. Chiu (1990), while reporting no significant differences in achievement using MBLs, reported that gender differences did exist between boys and girls prior to instruction in distance and velocity concepts. These findings seem to support the conclusions of Linn and Hyde (1989) that gender differences in cognitive domains are small and that the magnitude of gender differences is a function of context or situation. They suggest focusing on situations that minimize gender differences in order to achieve the goal of gender equity in science education.

Thus, this study sought to investigate the ways in which young children interact with MBLs, and to explore how this influences their conceptions of scientific phenomena. The major questions guiding the research were:

1. What are student understandings about the particular scientific phenomenon being studied (i.e. light) *without* the use of the computer?
2. What are student understandings about the use or function of the probe? (i.e., What kind of a probe is it? What does the probe do? What could you use the probe for besides classroom experiments?)
3. What are student understandings about the graph produced on the computer screen? (i.e., What does the graph show you? What do the numbers/scales mean? What does the graph tell you about the scientific

phenomenon being studied? What are the connections between the probe and the graph?)

4. What are student understandings about the particular scientific phenomenon being studied *with* the use of the computer? Are they the same or different than conceptions without the use of the computer?
5. How do student understandings of MBL compare for boys and girls? (i.e., Is there a difference in how boys and girls conceive of or interact with MBL? If so, what is the nature of the difference?)

CONCEPTUALIZATION

Researchers interested in understanding elementary school students' conceptions of science have sought to classify, categorize, and organize these conceptions using a number of different frameworks. Smith (1984) described what she termed mis-perceptions, stunted conceptions, mis-translations, confused conceptions, lost conceptions, and true misconceptions. The last category in particular utilizes the theory that children construct cohesive mental models of real-world phenomena. Vosniadou (1988) described three types of mental models science-naive individuals may use to interpret everyday experience. These include the phenomenal (highly based on perceptual experience), scientific (consistent with current scientific theory), and assimilatory (which show a combination of the two and usually indicate in-process conceptual change).

Results of these studies indicate that some mental models tend to be more robust than others, and as such tend to be resistant to instruction or change through incidental exposure to new scientific knowledge. Vosniadou (1988) suggests that those conceptions that are based largely on perceptual or contextual features are more salient, and those based on underlying experiential beliefs or theories tend to be stronger and less likely to change. For purposes of this study, children's conceptions will be broadly categorized as "perceptions" and "beliefs/theories".

Driver (1985) has suggested that children's thinking about science has a number of generally identifiable features. As suggested by other authors, she notes that children's thinking is largely *perceptually dominated* and in many cases *limited in focus*. Often children will emphasize salient perceptual features of a problem situation, viewing the situation in concrete rather than abstract or theoretical terms. She notes, too, that children tend to focus on change rather than steady-state situations. For example, children may not conceive of the existence of *force* in the absence of *motion*. Further, she describes children's thinking as tending to follow a linear causal sequence. This may result in children's thinking moving sequentially through a preferred direction and failing to take in account symmetrical interactions within or between systems. Finally, she indicates that children tend to use scientific concepts in an undifferentiated manner (e.g., weight may carry connotations of volume, pressure, and density) and to be highly context-dependent.

In light of these general trends, it is interesting to note a number of misconceptions commonly held by young children specifically regarding light. Driver (1985, p. 30) reports:

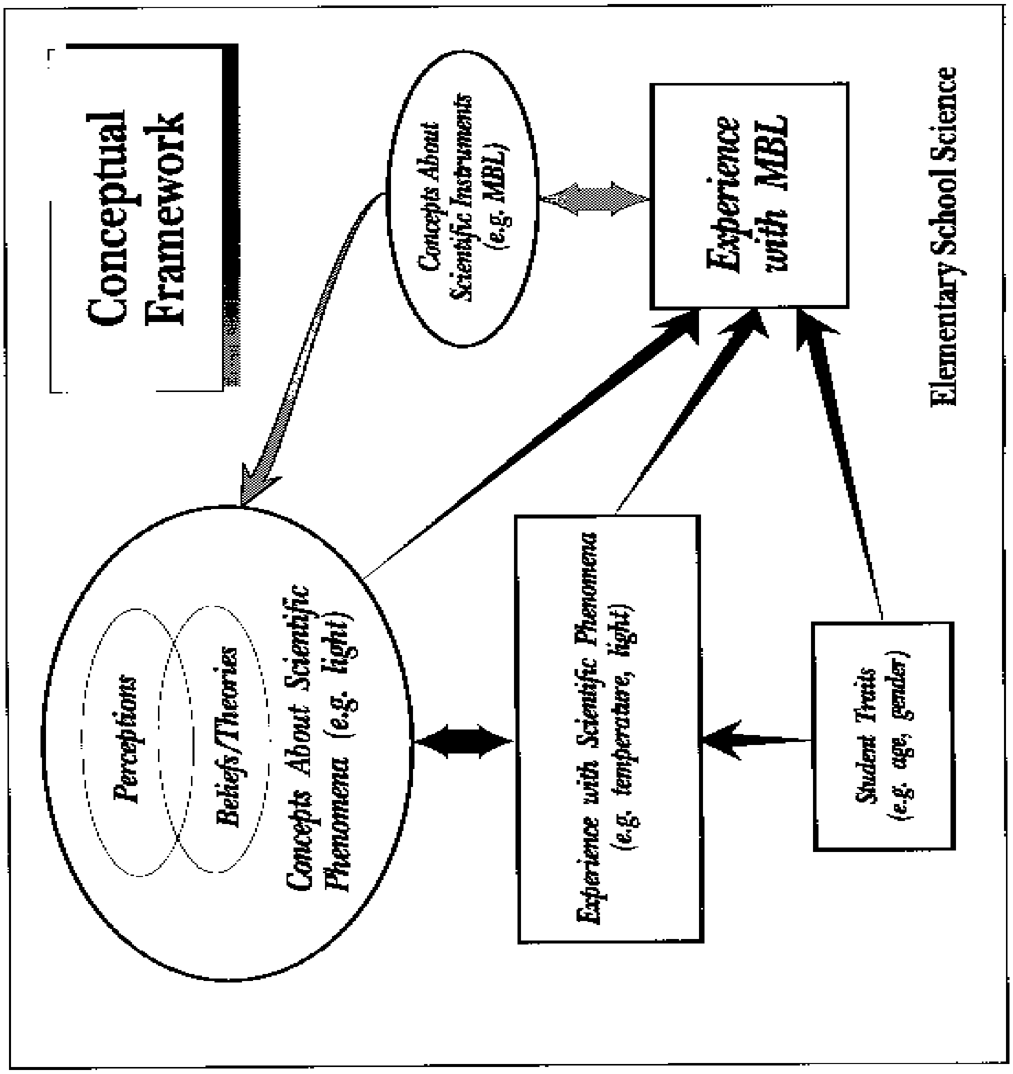
1. the movement of light is not explicitly accepted; children often speak of light as if it were an entity in motion (it leaves, crosses, rebounds, etc.), but refuse to make explicit the propagation time except, sometimes, in the case of great distances.
2. light does not exist for children unless it is intense, intense enough to produce perceptible effects; thus they are led to believe that, unlike the mirror, a piece of paper does not reflect light and that their eyes do not necessarily receive light when they look at an object.
3. light is not necessarily conserved; for many children, it can disappear without any interaction with matter, when it is no longer intense enough to produce perceptible effects; or on the contrary, it can be intensified, when passing through a magnifying glass.

Feher and Meyer (1992) confirm these results, and further suggest that often children believe: 1) light from a luminous source travels in a preferential direction toward the element that matters in the problem at hand, 2) light rays are redirected through interaction with an object (a result of this being the belief that an object can have only one shadow, and 3) a luminous source does not emit light rays in all directions.

Children's conceptions of scientific phenomena may be shaped by many factors. First, the particular traits or characteristics of the child (such as age, gender, ethnicity, interest in science, IQ, or motivation) may effect his or her ability to interact with and understand particular science concepts. How the student has experienced science in both formal and informal settings may also influence his or her conceptions of science. In turn, the students' conceptions of science may also affect how he or she continues to perceive of and experience scientific phenomena. Thus both "nature" and "nurture" may contribute to a child's current understanding of science.

Unlike conceptions of scientific phenomena which have been studied extensively, young children's conceptions of scientific instruments such as MBL are not well documented in the existing literature. Figure 1 presents a conceptual framework showing possible relationships between student traits, experience with MBL, conceptions of MBL, and conceptions of scientific phenomena in the context of an elementary school science program. The current study attempted to illuminate young children's conceptions of MBL (their understanding of its structure and function), and the ways in which their experience and conceptions of MBL shape their conceptions of the particular scientific phenomena being investigated through use of a computerized laboratory tool.

FIGURE 1. CONCEPTUAL FRAMEWORK



RESEARCH DESIGN AND METHODS

Setting and Participants

The research was conducted at a large suburban elementary school in Lacey, Washington. The school (which serves a population of approximately 650 students Grades Pre K-6) opened in the fall of 1990 with a "restructured" instructional model, and was awarded a 21st Century Grant by the Governor's Task Force on Education. The school's program is heavily infused with technology in grades 1-6 and teachers have received extensive training in the use of instructional technologies. While the school was not designed to provide a magnet-type program (it was designed to draw the typical neighborhood enrollment) there are approximately 50 students attending the school on waivers from outside the attendance area. The teaching staff was recruited specifically to be involved in a significant restructuring process, and the group is largely comprised of high achievers, risk-takers, and innovators. So, while the student population served by the school could probably be considered "typical", the staff and the overall instructional program in the building are not.

This does provide some advantages, however. The teachers are willing to test and evaluate new materials. They are flexible and willing to participate in research studies (even if it means a little extra work). There have been over 1,300 visitors to the site over the past three years from national and international locations. As a result, both teachers and students are used to being observed, videotaped, and questioned by a variety of people. Computer equipment is available and accessible. So, while the school is not a typical neighborhood school in the strictest sense, it provides access to students and computers without significant or unusual disruptions.

The student participants in the study were 4 children selected from the existing third grade classrooms. Because of the focus on gender, boys and girls were equally represented. The students were all above-average in achievement and had stable, supportive family environments. This allowed for the students to miss several class periods of regular instruction to take part in the interview sessions without substantial impact on their school performance. Since it was necessary to spend a considerable amount of time with individual students to probe their deep understandings of MBL, a deliberately small sample size was utilized. At the time the students were interviewed they had all had approximately 6 weeks of classroom exposure to MBL and physical science concepts related to light.

Data Collection Strategy and Procedures

Data were collected through a series of three individual student interviews. These interviews attempted to focus on the topics outlined in the first four research questions: 1) conceptions of science content *without* computer 2) conceptions of computer *(probe and graph)* 3) conceptions of science content *with* computer.

Lowman (1985) and Suchman & Jordan (1992) have described important considerations for conducting clinical interviews. They suggest that a too-rigidly structured interview may have negative effects on the interviewee--namely, through their inability to answer inappropriately framed questions or the loss of interest in an interview that seems uninterested in their perceptual schemes or point of view. They suggest that it is necessary to provide for flexible interview situations which will promote collaborative construction of meaning and present valid data that truly measure what the researcher intends to measure. Thus the student interviews were semi-structured so as to simultaneously focus on the intended conceptual framework of the study, while at the same time providing opportunities for the interviewees to shape the course of the interaction.

Interview #1

This interview was designed to establish a baseline of student conceptions about light. It was an open-ended interview, and included a variety of hands-on science items such as a lamp, flashlight, mirror, candle, etc. The students were able to select and use the items to explain or elaborate their understandings. The questions were consistent with the topics described by Driver (1985) and topics covered in the school's third grade MBL curriculum.

Feher and Meyer (1992) have indicated that one of the most fruitful types of questions for illuminating children's mental models are those that ask "What if?" questions requiring students to make predictions. These predictions, followed by students being required to provide explanations of observed phenomena, may serve to "unmask" thinking processes which most truly reflect underlying beliefs. During the course of the interviews, as children interacted with various materials, they were asked to make predictions in this fashion. In addition, students were asked to make drawings on several occasions to visually represent and more clearly communicate their ideas about light.

Interview #2

This interview was designed to determine student understandings about the function of the probe itself (the input of data into the computer) and student conceptions of the graphs produced on the computer screen or printer (the output of data from the computer). Again, during the interview concrete items such as flashlights, lamps, mirrors, etc., were accessible to students. In addition, during this interview students were introduced to the temperature probe and asked to use it for the first time.

A number of MBL studies (Clement, Mokros, & Schultz, 1986; Barclay, 1986; Mokros & Tinker, 1987; Nachmias & Linn, 1987; Adams & Shrum, 1988) have described student conceptions/misconceptions about graphs produced by MBL. These include the conception that the graph is a *picture* rather than a *symbolic representation* of a particular phenomenon and slope/height confusion in line graphs. Items used to explore student understandings of the data output were various graphs on the computer screen which students were asked to describe. In addition to this, various printouts of computer graphs (i.e., 2 graphs with like data displayed in GrowBar versus Line Graph format, 2 graphs of like data displayed in GrowBar format with different scales) were presented to students for interpretation or explanation.

Interview #3

The third interview focused primarily on the students' conceptions of light when using the computer probeware. Questions similar to those of Interview 1 were utilized, except that the questions were framed specifically with reference to the light probe and computer. Since students had been introduced to the temperature probe in the last interview, they were also asked several questions about heat/temperature and use of the temperature probe and computer in this interview. All of the interviews were tape recorded (to allow for transcription of verbal data). Field notes were taken which described student responses and noted materials used to illustrate student conceptions. Students were asked to make drawings to clarify concepts where appropriate. In addition to this, classroom curriculum materials in student work journals were examined. Using a variety of data sources provided a basis for determining the reliability of the students' direct verbal reports.

Data Analysis Strategies

The first step in data reduction occurred as soon as possible after each interview was completed. This consisted of listening to the tape recording of the interview, and summarizing the responses by major question or topic. In addition to this, some initial impressions about the session were noted, as well as miscellaneous responses that were not associated with the major categories.

Next, the complete text of each interview was transcribed verbatim. The transcripts were used first to create a representation of each individual student's conceptual model of light and MBL. This was done by sorting and arranging segments of the student's verbal reports from Interview #1 into categories (e.g., reflection, shadows, seeing, colors, computer) and displaying them along with their drawings on large sheets of color-coded posterboard. Similar displays were created for Interviews #2 and #3 for each student. This provided a means for assessing individual student conceptions on a single interview, or comparing individual student conceptions across the three interviews. These data were compared with the students' written work completed during their classroom science unit on light, and the initial interview summaries. Consistent results were noted for all students.

From the individual student data displays, descriptive assertions were developed. These assertions paraphrased and reduced the transcript quotations to a series of descriptive statements. The statements (approximately 45 per student) described the individual's conceptions of light across the three interviews. To be sure that these assertions closely reflected the transcript data, a content check was devised. A coding scheme was developed based on the physicist's view of light outlined by Driver (1983). Eleven elements of this view were identified, and each instance in an interview where a student elucidated a concept about light was coded as an agreement (1A, 2A, etc.) or disagreement (1D, 2D, etc.) with the corresponding element of the physicist's view of light. Frequencies were recorded for each element.

After the transcripts were coded using the elements of the physicist's view of light, the descriptive assertions were coded using the same scheme. Unexpectedly, the patterns were not comparable in several areas (notably where students disagreed with the physicist's views) and several additional assertions were added to more closely reflect the pattern revealed by the original transcript data. Table 1 shows samples of descriptive assertions from interviews #1-3 (DA1= Interview 1, DA2=Interview 2, DA3=Interview 3).

TABLE 1. SAMPLE DESCRIPTIVE ASSERTIONS

Descriptive Assertions from Interviews #1-3
DA1. Light comes from the sun.
DA1. The amount of light from the sun is greater than the amount of light from a light bulb.
DA1. Light brightens things so you can see them.
DA2. The probe takes light in, and the light goes through the wires to the blue box, where the light is actually measured.
DA2. You have to point the probe towards the light you want to measure.
DA2. The light goes away but the bar stays on the screen (you can save or discard the measure).
DA3. You can compare your estimate and the actual measure using the computer.
DA3. The probe measures how much light there is in different colors.
DA3. Both the probe and your eye take in light.

The students all appeared to have what Vosniadou (1988) calls an "assimilatory" concept of light since they showed some agreement with the scientist's views, but some areas of disagreement as well. The students showed consistency in their understanding that light propagates from a source, that light interacts with objects and produces perceptible effects, and that a shadow is somehow associated with a light source. They consistently disagreed with the physicists' view that light is conserved as long as it does not interact with an absorbing medium, that vision results from the reception of light by the eye, and the color is a property of light rather than objects. There was inconsistency with respect to the speed of light, and whether or not light propagates in a straight line.

After the descriptive assertions had been checked for content they were sorted into categories where students *used* the computer and those where they *did not use* the computer. Because the probeware itself focuses on quantification of scientific phenomena, the statements were then further sorted into those that dealt with qualitative issues, and those that dealt with quantification of light. Examples of student statements from interview transcripts reflecting qualitative versus quantitative thinking (from which descriptive assertions were drawn) are displayed in Table 2.

TABLE 2. QUALITATIVE VS. QUANTITATIVE STATEMENTS

Type of Statement	Not Using Computer	Using Computer
Qualitative	Uh, rainbows are, um... are sun and water mixed together. When the sun shines through the, um... through it makes like a rainbow. Well, light and electricity are pretty much the same, because light is electricity. Most light is electricity. One difference is, like, the sun. The sun is not electricity. If it's like winter and you go outside at nighttime when it's pitch black, turn on a flashlight and then you blow over the light, you can see the waves running through the light.	It has a lens right here and the light travels through the lens, but only when you want it to, that's when you press the GO button. You havta keep it holding in one direction, you can't switch directions... I had to remember to, wait until the time was up and not put it down before then or else, before then or else the um... time would change. [the computer] tells you that red is a dark color... green is a dark color but not as dark as a dark, single color.
Quantitative	Well, in the Earth... well, the mass of light is much smaller than that comes from the sun, because the sun is bigger than the Earth, and you couldn't get anything bigger than the sun on the Earth or things that equal up to the sun... [Light travels] very fast! Maybe like microseconds. Um, it would travel over, uh, I think, I'm not sure... over a hundred miles an hour.	...ooh, I have a temperature. I think it's about 26 grams. ...and sunglasses like this, it, um... I tried this, and you pick up the sunglasses and you measure the light and see how much light gets through the sunglasses. It tells me that the, um... flashlight is about 81... well, I don't know how high, but over 80.

These data provided the basis for both comparisons across students, and comparisons across gender. However, no gender specific patterns were identified.

RESULTS

Individual Differences

It became clear after only one interview, that these children approached the computer, the light probe, and the scientific investigations of light with distinct individual differences. Jason, for example, believed that a person can only have one shadow, but that the shadow can take on many forms depending on the person's stance. Erin, on the other hand, believed that the number of shadows a person has is influenced by the number of lights shining on the person. Adam viewed the computer as a fast, efficient tool that would challenge him and allow him to learn more than would completing an experiment on his own. Jaci viewed the computer as a tool that, while fast and accurate, constrained her ability to control the experimental situation to some extent. Though these students approached the tasks set before them with a charming degree of individuality, some striking commonalities also emerged. These common features, as reported below, have implications for the use of MBL tools for instruction in elementary school science.

Using MBL as a Tool for Scientific Investigation

How did the students conceive of MBL? Did they understand its purpose and function? For these four students the answer is a resounding "Yes!". The students were able to clearly articulate that the probe sensed and measured light, and the measure was represented both on the computer screen and in print. None of the students were able to give a clear explanation of the inner workings of the computer or the probe (although they proposed a number of interesting hypotheses). But they were able to set up a simple experiment, run the experiment, and discuss the results. Consistent with results of MBL studies dealing with older students (Thornton, 1986), these young children seemed as adept at operating computerized scientific instruments as they were at dialing a telephone.

Moreover, they seemed to understand the limits of what the probeware could do for them. When asked what the probe could tell them about color, seeing, reflection, shadows, or what light "is", they either replied that they didn't know anything the probe tells you about that aspect of light, or that it tells you *how much light there is*. They did not attribute functions to the probe that it was not actually able to perform.

New Ways of Thinking About Light

Qualitative vs. Quantitative

Over the course of the three interviews, Adam, Erin, Jaci, and Jason had many opportunities to interact with MBL. The ways in which they talked (and thought) about light took on somewhat different characteristics when the students were engaged with the probeware. The function of the probe is to quickly and accurately measure physical phenomena. Not surprisingly, when using the tool children seem to focus more on aspects of measurement than qualities of light itself.

This increased focus on measurement was documented by analysis of the assertions stating children's views about light. When not interacting with the computer, the assertions reflected quantitative thinking 12-47% of the time. This was usually in response to a question specifically asking the student "how much" or "how fast" and the answers were sometimes quite arbitrary in nature (e.g., "Light travels 100 miles per hour"). In contrast, when interacting with the computer the assertions reflected quantitative thinking approximately 67-80% of the time. Often in response to much more open-ended questions ("What does this tell you about light?") the answers were more focused and specific (e.g., "It tells me how much light is in the shadow"). In addition, the students were able to focus on the scientific concepts in concrete terms within the context of their immediate environment.

The students described both the process and the products of measuring physical phenomena, and used the measurements both to describe and to make comparisons. Table 3 illustrates the increase in quantitative statements associated with use of MBL.

TABLE 3. INCREASE IN QUANTITATIVE STATEMENTS ABOUT LIGHT

Student	Not Using Computer	Using Computer
Adam	47%	70%
Jason	12%	67%
Erin	20%	80%
Jaci	17%	67%

Graphical Representations

Another shift occurred when the students began investigating light through the use of MBL. In addition to observing the beam of a flashlight itself, they began observing a graphical representation of the amount of light propagating from the flashlight. During the interviews, students demonstrated an understanding of the graphs produced by MBL for activities similar to those in which they had participated in their classrooms. They were able to explain what the bars of a "GrowBar" bar graph represented on the computer screen. In addition, they were able to reconstruct a plausible experimental set-up to account for the results displayed on a printed "GrowBar" graph. The students clearly understood these static graphical representations.

In contrast, when dynamic situations were introduced, the students were no longer accurate in their interpretations of MBL graphs. The first of these situations dealt with the "rescale" feature. Once data have been collected and graphed on the computer screen, it is possible to change the scale to either "shrink" or "enlarge" the data set for optimal viewing. When small scale changes were introduced *and the students observed the changes* on the screen, in most cases they suggested that the information had stayed the same and it had been given a new "way of numbering". But when large scale changes were introduced, even when observing the changes, the students did not always believe that the data were the same they had collected. This was particularly notable when Jason watched as a scale change transformed his smooth line graph of temperature to one that was jagged and peaked. When asked if he was absolutely certain that this was the same information he had collected, Jason replied that it was not because "mine wasn't so rigged".

Similarly, when the students were asked to compare printed MBL graphs of the same data displayed using different scales, three of the four students agreed that the information was different when the bars or lines *appeared* to be different sizes. This was the case even when they were specifically asked to attend to the differences in scale on the printed pages. These results seem to be consistent with Driver (1985) and Vosniadou (1988) suggesting that young children's thinking about science is largely perceptually dominated and sometimes limited in focus to the most salient features.

A second instance of dynamic graphing causing confusion occurred during the second interview, when the students were introduced to a line graph plotting one variable (light or temperature) against time. The students were not clear about how the features of the software controlled the duration of the experiment. Nor were they clear about the meaning of the line graph in comparison to the more familiar "GrowBar" format. However, much of this confusion may be attributed to the novelty of the situation.

Confronting Misconceptions

As indicated by Feher (1986) prediction followed by hypothesis testing provides opportunities for young children to confront their sometimes implausible scientific ideas. She suggests that, for the child, prediction amounts to making a bet on the outcome--and confrontation with a dramatic outcome acts as a powerful motivator for the student to become intellectually engaged with a problem. This type of opportunity certainly presented itself during the interviews with young children using MBL.

Two distinctly different types of situations arose during the interview sessions. First, were the formal prediction sequences where students used the prediction function built into the MBL software. This function allowed the students to position a shaded GrowBar to the size they anticipated would match an actual data measurement. The subsequent test would give students feedback about the accuracy of their predictions. Second, informal prediction sequences occurred. In these instances, students simply verbalized their prediction ("This time there will be less light..."), resulting in a somewhat less focused analysis. Prediction and testing were not limited to situations posed in the interview, they sometimes (but not consistently) occurred spontaneously as well.

CONCLUSION AND IMPLICATIONS

Did the young man described at the beginning of this paper really develop mature theoretical understandings of complex scientific phenomena by utilizing MBL to engage in scientific inquiry? Perhaps not. It was not unusual for the participants in this study to display misconceptions about light and, to some extent, heat and temperature. For example, Jaci drew a picture of the solar system with its nine planets in a neat and tidy row, and proceeded to explain that Pluto was very cold and dark because Jupiter was so big it blocked all the light. This concept seems to have grown out of Jaci's recent classroom activities using MBL to study "blocking light" and previous classroom units on the solar system. Unfortunately, she seems to have generalized her new knowledge of light blocking into an existing conceptual model of the solar system that is static and substantially inconsistent with the scientist's view.

In light of these types of misconceptions, should the use of MBL be promoted in elementary school settings? The answer may be a *qualified* yes. The students involved in the study were able to effectively use the tool to collect and display light measurement data. Both clearly understood bar graphs that they created using MBL, and could understand and interpret graphs created by others. This suggests that MBL might be an effective tool for teaching graphing skills to elementary school children.

The use of MBL certainly provided opportunities for children to think in quantitative terms about light. None of the participants had much "intuitive" sense about the measurement of light when they began the study. They didn't really understand how the probe might be used outside a school setting, because they had never had exposure to a situation where light was measured. However, they had all had experience with the measurement of temperature. They knew that they could measure the temperature of their own bodies, or of the air or water outside. Their lack of intuition about quantification of light was, at first, disturbing. However, it soon became apparent that MBL could provide students with a first opportunity to experience the quantification of light, and to allow them to acquire the same type of intuitive sense that they already possessed with regards to temperature.

The use of MBL also provided students with opportunities to confront their existing conceptions of scientific phenomena, and to investigate them further. The word **opportunities** must be stressed here, because children may be hesitant to take the risk of exposing their ideas to such scrutiny. Though Jason was well read in scientific matters and was quite confident about the theories and ideas he proposed, he was extremely reluctant to make predictions about the outcome of an experiment. Both his classroom teacher and his mother confirmed that he is very uncomfortable in situations where he may be proven "wrong". Erin, on the other hand, delighted in having the opportunity to try and re-try an experiment until she could "get it right". If her estimate did not match the actual measure of light in an experiment, she spontaneously suggested changes and was motivated to run the experiment repeatedly until she had a satisfying explanation for the results. This seems to suggest that the classroom environment would need to be very flexible and supportive for young students to fully engage in MBL investigations capable of promoting conceptual change.

The participants in the study used the evidence that they had gathered from their MBL investigations to support their ideas about physical phenomena where it was appropriate. Jason predicted that trying to use the light probe in a shadow would be a fruitless pursuit because "the probe measures light, not shadows". Referring to three temperature measurements on the computer screen taken from different parts of her body (hand, forehead, and elbow) Jaci stated that her hand was the warmest part "because you use it the most". Lewis & Becker (1991) have suggested that 7-9 year old children will relate their causal reasoning judgments to specified evidence when there is sufficient evidence, but may also extend their judgments to conditions where evidence is insufficient if necessary. However, children are also likely to change their reasoning when sufficient evidence for causal inferences becomes available. This view also seems consistent with the views of Vosniadou (1988) and Driver (1985) suggesting that some student conceptions may be perceptually based and subject to change.

From results of the current study, it is not at all clear whether or not the use of MBL promotes mature student conceptions of scientific phenomena at the elementary level. These four students appeared to operate the equipment with ease, and understand bar graphs produced on the computer screen or in print. For better or worse, they appeared to assimilate their new knowledge into existing mental models of scientific phenomena at least to some extent. However, further research is necessary to understand the extent to which these results might generalize to other elementary school children, and to provide greater insight into: (1) the durability of conceptions and evidence-based reasoning grounded in young children's MBL experiences, and (2) the specific classroom conditions necessary for successful use of MBL as a tool for scientific investigation with young children.

The elementary school Personal Science Laboratory (MBL) hardware, software, and curriculum materials utilized in this study were provided by IBM through EduQuest.

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