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ABSTRACT

This report describes the development of an educational software program to assist youth with disabilities in participating in discourse in regular school settings. The software was designed to manage cooperative groups as students engaged in hands-on science activities and was specifically developed for teaching the subject of batteries and bulbs. Ten classrooms in which special education students were enrolled with regular education students were observed, and the types and quantities of verbal interactions between disabled students and peers were reported. Eight groups of four or five students (each group containing one special education student) were then pulled from these classrooms and the software was tested with these students. Evaluation indicated that the cooperative learning activities and the software provided the structure needed to include students with disabilities and increased communication between disabled students and their peers. Evaluation also indicated non-disabled peers were able to help keep students with disabilities on task and that there was a high level of engagement in the learning activities. Appendices include the texts for sample lessons at different reading levels, a technical specifications document, parent permission forms, sample student workbook pages, and sample teacher manual pages. (Contains 78 references.) (DB)

The Use of Cooperative Group Management Software for Hands-On Science Activities to Improve Communication between Students with Disabilities and their Peers

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Abstract

Learning requires a synthesis of ideas into something new. Contemporary cognitive scientists agree that learning is embodied in the fluid medium of language, and language development can only occur in a rich social environment, where ideas are transformed, reformed, and dynamically changed by the participants in conversation. This report describes educational software which we developed to assist youth with disabilities in participating in discourse within regular school settings. The software managed cooperative groups as the students engaged in hands-on science activities. Ten classrooms in which special education students were enrolled with regular education students ("inclusion" classrooms) were observed, and the types and quantities of verbal interactions between disabled students and peers are reported. Eight groups of four or five students (each group containing one special education student) were then pulled from these classrooms, and the software was tested with these students. We found that the cooperative learning activities provided the structure needed to include these students in learning activities and provided increased opportunities for communication between disabled students and their peers. We also found that the non-disabled peers were able to help keep these students on task, and there was a high level of engagement in the learning activities.

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1 Introduction

In public educational settings the current practice is to integrate students with disabilities into regular classrooms so that they can learn from their non-disabled peers and teachers. Many cognitive scientists and educational researchers today agree that the largest part of learning that takes place in classrooms is due to student communication, with peers, peers acting as tutors, and teachers. This concept and its rationale is well articulated by Jerome Bruner (1985):

> "...[The] world is a symbolic world in the sense that it consists of conceptually organized, rule-bound belief systems about what exists, about how to get to goals, about what is to be valued. There is no way, none, in which a human being could possibly master that world without the aid and assistance of others for, in fact, that world *is* others. The culture stores an extraordinarily rich file of concepts, techniques, and other prosthetic devices that are available... The prosthetic devices require for their use certain fundamental skills, notable among them the *ability to use the language as an instrument of thought* [emphasis mine] – natural language, and eventually such artificial languages as mathematics, ... it is a matter of using whatever one has learned before to get to higher ground next. What is obvious and, perhaps, 'given' in this account is that there must needs be at any given stage of voyaging into the zone of proximal development a support system that helps learners get there." (Bruner, 1985, page 32).

This support system of which Jerome Bruner speaks is most often the rich culture of student peers that interact to learn new concepts. The theory of "proximal development" is derived from the work done by Vygotsky, and rests on the concept that a person learns by interacting with peers or teachers to carry out cognitive processes jointly that are more advanced than could be managed independently. This joint problem solving process serves as a basis for children's subsequent independent efforts. This occurs when students are heterogeneously grouped, with students at a range of developmental levels available to interact with each other.

There is currently a concerted effort being made to mainstream students with disabilities into the regular classroom, providing a rich heterogeneous mix of students. The stated reasons for this push are myriad, and include the attempt to implement federal, state, and local education laws and policies; cost savings through elimination of pull-out programs and special classes; and benefits to students. There is every reason to assume that this trend for integration will continue (Putnam, 1995). In classrooms where the instructor is capable of handling diversity, mainstreaming is beneficial to both the disabled student and his peers. The disabled student has opportunities to develop skills to compensate for his disabilities and capitalize on his abilities, while his peers learn more about working with others in a diverse environment and valuing the contributions of students with capabilities different than their own. Benefits are obtained by both the disabled student as well as his peers, as Nel Noddings (1989) demonstrated in her study showing positive effects on students' learning and behavior when they learned to care for others and themselves.

Fortunately, there are well tested solutions to many of the social problems encountered in the classroom when attempting to integrate disabled students. The use of cooperative learning techniques, in which students are provided explicit social training in cooperating with a diverse group of students, provides a framework in which students with disabilities can be integrated into a regular classroom. Many studies have shown that even students with multiple severe disabilities can acquire certain basic skills at the same rate as their non-disabled peers when the instructor uses cooperative learning activities (see, for example, Hunt 1994).

During cooperative learning activities, the students are assigned specific roles, each with associated rights and responsibilities. Typically, these roles are rotated each lesson so that students have the opportunity to learn new social and academic skills and to learn to value the different roles and skills necessary to meet with success during complex problem solving activities. To be successful, a cooperative learning activity requires that the task be sufficiently complex (not merely an exercise) and that both individuals and the group are held accountable for the outcome of the task.

Unfortunately, many teachers find it difficult to implement cooperative learning in the classroom. Cooperative learning researchers agree that not all teachers are able to implement these methods, and that successful teachers require both a period of time to adjust to using cooperative groups in the classroom and adequate administrative support (Cohen and Lotan, 1988). Successful implementation of cooperative learning in the classroom depends upon the teacher's understanding of how to implement a lesson and provide an environment in which students can learn to interact socially in academically constructive ways.

We have developed computer software designed to overcome many of the most difficult elements of coordinating and managing cooperative learning in the classroom, making it considerably easier for the teacher to implement cooperative learning modules. This software provides the framework and structure for implementing and managing cooperative group activities as the students work together in authentic science problem-solving activities. The software assigns student academic and social goals, rotates roles and handles absences, provides prompts and interaction focusing the group on the activity and guiding them through it, maintains records of group progress, and provides additional support, as needed, for students with disabilities.

This report outlines (a) the research undertaken to provide information needed to design effect software, (b) a description of the interface of the software that we designed, and (c) the classroom based research we engaged in to test the effectiveness of the software.

Background of the Problem

In this section we discuss our research literature search findings in these four areas directly relevant to our software design: (1) current usage of adaptive devices by disabled students in the classroom, (2) development of communication skills by disabled students, (3) effective science education practices, and (4) cooperative learning. In our proposal we had also identified motivational factors for students with disabilities as a topic we would research; however, we found very little research available on this topic, and what we did find is reported in sections two and three, as appropriate.

1.1.1 Current Usage of Adaptive Devices by Disabled Students in the Classroom

Students with disabilities can benefit greatly from being integrated into the regular classroom. More and more schools are following federal guidelines and implementing programs so that all children with disabilities can be included in the regular classroom (DeBan, 1995). Once students with disabilities are integrated into the regular classroom they can become a vital part of the classroom culture. Students with disabilities can offer an alternative way to look at the world. Is it the student who is disabled, or is it the world that disables the students by putting up barriers, especially in the area of technology? According to Sheryl Burgstahler, "standard input and output devices (e.g., keyboards, mice, monitors) present barriers to access for students who cannot see, use their hands, or have one or more other disabilities. However, some companies build in accessibility features into their original designs and commercial adaptive products are also available to help overcome many of these barriers."

In the last five years new technologies have filtered down to the disabled population at a greater rate than ever before. Even the severest disability groups now have access to the computer. Assistive devices, such as a voice input system, allow the disabled to access the computer easily and effectively. According to Joseph Lazzaro, "Adaptive or assistive technology is any device that enables persons with disabilities to work, study, live, or play independently. An example of commonplace adaptive technology is the use of a speech synthesizer to read information to a blind computer user."

Adaptive software devices include any software that allows for some kind of modification on the computer from the normal setup which allows a person with a disability to access that computer. The Technology-Related Assistance for Individuals with Disabilities Act of 1994 (P.L. 103-218) requires that states promote technology related assistance to all persons with disabilities regardless of their race, age, type of disability, ethnicity or gender, also including those from underrepresented and rural populations.

For example, augmented and alternative communication (AAC) devices that employ either synthesized or digitally produced speech have increased the possibilities of communication for children with a variety of disabilities. AAC devices increase communication abilities and allow children with disabilities to participate more substantially in the home and at school. Research has shown that assistive technologies improve functioning and facilitate integration of children with disabilities into community settings (Parette, Hourcade, & VanBiervliet, 1993).

There are many different adaptive devices used by disabled students in the classroom. Each case is unique, and many students have multiple disabilities which require creative use of various devices. The available device list undergoes rapid change as more and more advances in technology make assistance practical and affordable. Table 1 provides descriptions of devices of the devices most commonly found in classrooms, along with the types of disabilities for which the device is appropriate.

Table 1. Adaptive devices commonly in use.

Device:	Description:	Useful for these disabilities:
BAT	The BAT personal keyboard is a compact, ergonomic keyboard that uses ChordEasy software to permit one-handed input. There are only seven keys on the keyboard. Chording can be learned in about an hour.	LD, Arm amputee, Carpal tunnel, ABI, CP, Stroke, MD
Dragon Dictate	Dragon Dictate permits the user to dictate to the computer to activate menus, move around in a document, and enter text and numbers. The "Power Edition" contains a 120,000 word dictionary. The 60,000 most common words are kept in RAM as the "active vocabulary". It works in Windows and DOS.	LD, Quad, Arm amputee, Arthritis, Carpal tunnel, Stroke, MD
Glide-point	The Glidepoint is a trackpad that replaces the system mouse. It is easier for many students to manipulate than a mouse and requires less desk space. It can be used on PC or Macintosh systems. It is especially useful for students with little mobility, as the hand can be stationary while only two fingers need to move.	LD, Quad, Arm amputee, Arthritis, Carpal tunnel, Stroke, DD, MD
Handi-KEY	HandiKEY is an on-screen keyboard emulator for Windows and DOS. It provides alternative methods for accessing keyboard keys. For example, you can set it up to scan the keyboard rows, and then press a switch to choose a row. Next, it will scan the columns, and another press of the switch will choose a key in the column.	LD, Quad, Arm amputee, Arthritis, Carpal tunnel, CP, Stroke, DD, MD
Handi-WORD	HandiWORD is a word prediction program for Windows and DOS. It aids individuals with limited keyboarding and can be used with standard software. HandiWORD is statistically weighted, so that the words that are used most often always appear at the front of the pick list. Users can set up the software with their own dictionaries.	LD, Quad, Arm amputee, Arthritis, Carpal tunnel, ABI, CP, Stroke, DD, MD
MAGic	Magic, which runs under Windows, magnifies the screen from 2 to 20 times. It permits the user to specify foreground and background color. A screen locator lets the user know where they are on the screen.	Visually impaired, LD
Mono-logue	Monologue is a Windows software program that reads text from the clipboard. It can add speech to virtually any application.	LD, ADD
See Beep	See Beep is software which "flashes" the screen whenever a program would normally "beep" for attention.	LD, Deaf, DD
Switch	A switch is an alternate input device, used by students with very little motor control. Different switches are activated by different methods—for example, a mouth switch can be activated by blowing into it or use of the tongue. For students with very limited mobility, these devices may be the only means of controlling a computer.	Quad, Arthritis, Carpal tunnel, CP, Stroke, MD
Trackball	A trackball is an alternative to a mouse. It can be easier for some students to manipulate than a mouse. Cursor movements are easier to control with a trackball than a mouse, and it can be adjusted to require large movements for small distance changes, thus being helpful for students with difficulty in motor control.	LD, Quad, Arm, Amputee, Arthritis, Carpal tunnel, CP, Stroke, DD, MD
Voice-Type	VoiceType is a Windows dictation system. It can convert speech as quickly as 70 to 100 words per minute. The software must be trained to understand a users speech, which takes about two hours per user.	LD, Arm amputee, Arthritis, Carpal tunnel
Jaws	JAWS for Windows is a screen reader. It can be loaded or unloaded at any time. It uses "smart screen" technology, looking at the screen and determining what to speak so unfamiliar applications can be used easily.	Blind, Visually impaired, LD, ADD

Our review of current research on adaptive devices used by students with a variety of disabilities determined how these devices might be used in conjunction with, or integrated into, the software we designed. We found it possible to adapt our software to function with the most widely available and commonly used adaptive devices used with computers to assist students with disabilities. Table 1 lists again the devices included in Table 2, and indicates how the software supports the device or replaces the need for the device.

Table 2. Use of adaptive devices with this software.

Device:	How this works with our software
BAT	Can be used with the software without any additional design changes. Not tested.
Dragon Dictate	Very little typing is required with the software, so this is not really necessary. However, it could be used without any design changes. Not tested.
Glidepoint	Can be used with the software without any additional design changes. Tested with software and one student.
HandiKEY	This could be used with the software, however it is not necessary. Other means of input for students with limited motor control are available, and students with extremely limited control would be assigned the role "assistant" or have an assistant assigned to them. Not tested.
HandiWORD	Very little typing is required with the software, so this is not really necessary. However, it could be used without any design changes. Not tested.
MAGic	A similar feature is built into the software. The reader can request the inputter to enlarge the type (the student in the role of "inputter" operates the mouse while the student in the role of "reader" reads the screens). Double-clicking on the text fields will enlarge the text to 48 point size. The foreground and background colors can be switched from the menu.
Monologue	Although this software could be used with the program, it is not needed as all of the text files have corresponding digital sound files, read by a human. For students unable to vocalize, unable to read, blind, or who need audio prompts, this option can be made available by the teacher.
See Beep	The software does not make use of beeps or other audio prompts, but uses color changes in the screens to indicate "time's up" and other status changes.
Switch	This feature is compatible with the software. However, for students that have very limited mobility, the teacher can also assign them the role of assistant to another student or assign an assistant to them.
Trackball	Can be used with the software without any additional design changes. Tested with software but not with students.
VoiceType	Very little typing is required with the software, so this is not really necessary. Unlikely to be compatible with this software without major revisions.
Jaws	Although this software could be used with the program, it is not needed as all of the text files have corresponding digital sound files, read by a human. The instructor may choose to not have a totally blind student in the role of inputter, or assign an assistant to that student.

1.1.2 Development of Communication Skills by Disabled Students

Our review of current research on development of communication skills by students with disabilities was undertaken to answer the questions: What are the nature of difficulties encountered by students with various disabilities as they attempt to communicate with their teachers and non-disabled peers? What techniques have been shown to effectively assist disabled students as they attempt to communicate with their non-disabled peers and teachers?

1.1.2.1 Communication Between Disabled Students and Their Teachers

Students with behavioral or emotional disabilities may lack understanding of syntax, semantics, and abstract concepts of language (Harrison et. al., 1993.) Teachers who employ the use of figurative speech, and complex verbal directions often find themselves faced with avoidance and disruptive behaviors emanating from these children. The students simply do not understand what is required from their instructor. Specifically, it is proposed that students with EBD and language disorders may react to misunderstood instruction as aversive stimuli (Sidman, 1989). Typically, when students reach the third grade teaching methodology changes from experiential learning to delivering new information through the conveyance of advanced language usage (Nelson, 1989). Children who are behind their peers in understanding language complexities are at a greater loss when this shift occurs.

Teachers have found that certain types of strategies applied when working with students who have emotional/behavioral disabilities will enhance their learning. Most of these methods are not unusual, and are often found in the classrooms of "exemplary" teachers; their importance is enunciated when working with special needs students in a regular education classroom. They include smooth transitions from one subject to the next, with a clear introduction to the new subject. It is advised the instruction be consistent and precise (Englemann & Carnine, 1982). Language indicators which define the order in which material is to be covered provide students with a sense of direction and a feeling of accomplishment of small goals through a larger lesson. Social skills training is also beneficial (Goldstein et. al. 1980). Finally, a statement that summarizes the end to a particular section of instruction is recommended.

The American Speech-Language-Hearing Association (ASHA, 1996) has called for increased research concerning children and youth with communication disorders with regards to inclusive practices in schools. Inclusive practices have been shown to benefit children by exhibiting gains in different areas of competency and social and interactive abilities. The ASHA also noted that cultural issues must be taken into account when assessing needs so as to understand the differences of learning styles and cognitive strategies. Children from culturally diverse backgrounds may demonstrate speech and language disorders while presenting communication style differences. Such children should be viewed through a multi-faceted looking glass as to best access their needs in inclusive programs.

1.1.2.2 Communication Between Disabled Students and Their Peers

Children with handicaps frequently have difficulty in maintaining conversations with peers. For example, according to McDonough (1998), "...emotionally handicapped subjects could not handle the conversational move necessary to maintain coherent, fluent interactions" (page 37.) Varied language difficulties in the area of syntax (correct production of speech following the rules of the language), semantics (such as vocabulary), and pragmatics (the social use of language) have been identified in children exhibiting disruptive behavior (see, for example, Cohen, Davine & Meloche-Kelly, 1989). The inability of students with disabilities to engage in discourse takes many forms, including difficulty in staying on a conversational topic, inappropriate responses, situational inappropriateness, and inappropriate speech style. These language deficits may be perceived by peers as purposefully aberrant, and these students may be avoided by peers.

The transactional relationship between cognition and language may play an important part in explaining why many disabled students have difficulty in language development. Language involves the learning and processing of arbitrary symbols for objects and events. Some children with handicaps are thought to have global problems in symbolic-representational functioning. Delays in such skills as memory or categorization of function, form, and color may predict receptive language ability. This suggests that there is a relationship between cognition and language, and has been the basis of studies in which individual differences in language learning and performance is accounted for by differences in cognitive task performance (Berkson, 1993). On the other hand, in specific groups (such as children with autism), these types of categorizations do not necessarily predict receptive language very well. Thus, although cognition and language development are related, there might not be a causal relationship between these two variables.

For some disabled students, language development is delayed, with language proceeding normally (that is, following the same sequencing of development), but at a slower rate than normal. Research has indicated that this may be the case for visual disorders, hearing impairments, autism, language impairments, or Down syndrome (Berkson, 1993.) However, some aspects of language development, or the relationship of specific aspects of language development to other forms of physical, cognitive, and socioemotional development, may show significant deviations in children with handicaps. For these students, the best practice is to target specific skills and provide assistance to the student in gaining these skills. Often, the assistance of special education teachers, parents, inclusion teachers, and other specialists are needed. In some cases, the teacher may need to learn to change her instructional discourse, and targeted services can assist the instructor in making these shifts (Coufal, 1990).In any case, providing these students with a learning environment that motivates them to gain language skills and provides opportunities for them to practice these skills is very helpful. Cooperative learning provides students with just such an environment.

The ability for students to work effectively in small groups depends upon students being able to interact cooperatively. However, students with low social status find it very difficult to be productive members of a group, as their contributions will not be valued by other students in the group. They might find their suggestions ridiculed or ignored. Unfortunately, disabled children are at high risk for low social status (Bierman & McCauley, 1987.) Older children are more likely to tolerate differences, perhaps because they can see that the cause is outside the intentions of the handicapped child, and girls tend to be more accepting of handicapping conditions than boys (Safran & Safran, 1985.) The type of disability does not predict the social status. However, specific behaviors have been associated with higher and lower status. Competence, sharing, athletic skill, affection, and tactful verbal exchanges are all related positively to social attractiveness. Hyperactivity, externalizing behaviors (such as screaming, hitting, and whining), and internalizing behaviors (such as moodiness, shyness, depression, and social withdrawal) are associated with lower status (Berkson, 1993). Studies of ways to increase the rated acceptance of handicapped students by their peers have zeroed in on the need to increase exposure in order to increase understanding and acceptance of the handicaps. However, this has been shown to be most effective when coupled with training of the non-disabled peers. Attitudes can be made more positive and accepting when taught that the child's negative behaviors are associated with handicaps. This works best in conditions where the handicap causes the child to act in a withdrawn manner rather than aggressively. The best possible means of increasing acceptance has been shown to be through positive personal interaction, such as through peer-tutoring (Acton & Zarbatany, 1988).

Berkson, after reviewing many studies, concluded that "children who are developmentally closer to each other interact more easily. When mental development is homogeneous in groups, interaction increases, although problems in social interaction remain. However, interaction also becomes more positive when mentally retarded children are paired with normal children of the same chronological age, perhaps because the normal children take a more active role in organizing the play activities. This suggests that the problems that exist in heterogeneous groups of handicapped and non-handicapped children be reduced by making the groups more homogeneous with respect to developmental level and by creating special temporary pairing arrangements. These ideas have found application in improving the social interaction rates of disabled children who have been mainstreamed into regular classes." (Berkson, 1993, page 266). He also found, through his review of the literature, that teacher intervention (if at a low level) can bring positive effects, and that tasks that require cooperation tend promote social interaction.

Increasing and improving communication between disabled students and their non-disabled peers, then, requires the teacher to take an active role in instructing the class so that they can accept the disabled child and occasional interventions in learning groups, an active role in reducing social status imbalances, and careful grouping of students, and creating lessons which require students to cooperate in order to succeed.

Table 3 summarizes the key elements of methods which will assist disabled students and their peers and teachers in improving communication.

Table 3. Key elements of methods used to assist students in developing communication skills.

	Key Element	Reference
1.1	Use of direct instruction, either by teacher-student or student-student	Harrison, Janet-Gunter, Philip, et al., 1996
1.2	Instruction should be consistent and precise	Hertz-Lazarowitz & Miller, 1992
1.3	Language indicators should be used to define order in which material is covered	Sidman, 1989; Englemann & Carnine, 1982
1.4	Alternative uses of language to provide redundancy	Goldman & Pellegrino, 1987; Lieber & Semmel, 1985; Panyar, 1984
1.5	Use of adaptive devices is key to facilitating communication with peers and instructor	Parette. & Angelo, 1996
1.6	Use of communication alternatives such as hardware/software devices, communication Board promotes collaboration	Lazzaro, 1996
1.7	Use time delays to ensure that everyone can participate	Hertz-Lazarowitz & Miller, 1995; Lazzaro, 1996
1.8	Provide support for culturally diverse learning styles and cognitive strategies	ASHA, 1996
1.9	Provide social skill training for students to deal with low status issues	Berkson, 1993
1.10	Create temporary pairings of disabled students with non-disabled students	Berkson, 1993
1.11	Provide social skill training for students to assist them in learning to work together and to accept the disabilities of other students	Goldstein et. al. 1980

1.1.3 Effective Science Education Practices

Students in the United States score lower on science achievement tests than students in many other countries (Executive Summary of the National Education Goals Panel, 1991). Studies indicate some root causes for this problem. We know, for example, that our students spend far too little time doing science in school, and learn early to dislike science (Costa, 1992). Because of this learned distaste, few students choose to study science at the higher grade levels. We also know that most schools use a curriculum and teaching methods that emphasize factual learning (Tobin & Fraser, 1989), and that this has been shown to be far less effective than a curriculum that emphasizes hands-on, inquiry based learning (Bredderman, 1983; Shymansky, Hedges, & Woodworth, 1990). Disabled students may face additional problems in learning science because of their disabilities. Good science teaching practices will have beneficial effects on all students in the classroom.

There have been many attempts to improve science education in the United States, and some of these attempts have been quite successful. Unfortunately, despite the great deal of time and money that has been spent on disseminating these new science teaching techniques, a "traditional" science curriculum still persists in most schools. Although little research has been done that illuminates reasons that teachers do not use hands-on science teaching practices, we are convinced that a large part of the reason is related to the time-consuming need for managing materials and the difficulty in getting students to cooperate in small group work.

Students need to learn to model the thinking process used by scientists; this thinking process is part of what understanding science is about. Science learning is most effective when students learn to use the inquiry process, and least effective when students conceptualize science as a series of facts that must be memorized. (Bredderman, 1983).

Students must also learn to like science. "Liking of science" has been shown to be positively linked to student achievement in science (Bredderman, 1983). Although causality cannot be inferred from this correlation, it makes sense that students who do not "like science" will not be motivated to put a great deal effort into learning science. Studies have also shown there is a link between liking science and student choice in further study of the subject in higher grades, where science is an optional subject. Thus, an appropriate goal for science education is to help students gain a liking of science. Students must have the opportunity to "talk" science in the classroom. Through talk, students can learn the vocabulary of science and begin to model scientific thinking (Lemke, 1990). Many students with disabilities gain in social as well as academic skills when given the opportunity to engage in discussions about science.

Students who collaborate with other students during the science learning process are more likely to meet with success. This is especially true for female students, students with limited English language proficiency, and students who are below average ability (see Jones & Steinbrink, 1989; Roth, 1990; Duran, 1990; Webb, 1984.)

The inquiry methods that scientists engage in are rarely modeled in the classroom by teachers and students. (Doyle, 1983). However, understanding the scientific thinking process is an essential part of the science education curriculum; without this understanding, the broad range of science topics and science applications cannot be appreciated. And without an understanding of the process students cannot design and run experiments that will lead them to construct their own new knowledge. To be effective, teachers must encourage students to model the inquiry process by modeling this process themselves.

Science teachers who use instructional strategies that sustain student engagement and encourage students to participate in learning activities, while maintaining a favorable classroom learning environment, have been shown to be the most effective (Tobin & Fraser, 1989). One instructional technique that has been shown to increase student engagement is the provision of open-ended problems requiring manipulation of science materials. When students have interesting materials to work with and are given the opportunity to discover scientific principles, they enjoy the work. and are eager to participate.

Teachers require training in science in order to model scientific thinking for students. Yet, teachers at the elementary school level rarely have more than a rudimentary understanding of science topics, and many feel uncomfortable about their ability to teach science. Training programs that have been implemented in the past have been shown to be effective in increasing teachers' understanding of science. However, it takes many years of practice in the classroom before teachers are effective in teaching science (Sevilla, 1992).

Our software design attempts to get around some of these difficulties by careful design. With the use of this software, teachers are not required to be science experts. The students themselves become the experts through the computer-guided discovery of scientific principles, while the teacher acts as a faciltator to the learning process. The software also guides the students in managing the materials needed for the lessons themselves, saving the teacher the considerable time it can require to maintain materials, put together kits, and pass out materials to students for each lesson.

Our research findings led us to develop a list of key features (Table 4) that would need to be included in the software to encourage students to learn science.

Table 4. Key elements of effective science education.

	Key Element	Reference
2.1	Provide scientific problems for students to explore in order to encourage students to talk science	Lemke, 1990
2.2	Effectiveness of hands-on learning	Bredderman, 1983
2.3	Support teachers' management so that the learning environment remains "favorable"	Tobin and Fraser, 1990
2.4	Model utilizes collaborative process for support of science learning	Jones & Steinbrink, 1989
2.5	Models inquiry methods used by scientists	Doyle, 1986

1.1.4 Cooperative Learning

In a traditional classroom environment in which the teacher relies heavily on lecture to teach students, there is little opportunity for students to talk — talk is dominated by the teacher. Because of this, students do not often have the opportunity to explore their own understanding of the science topics, and may develop misconceptions that the teacher is unable to detect and correct. Cooperative grouping is one solution to this problem.

Cooperative grouping is a classroom management technique that is often advocated for science education. For example, the California Public Schools Science Framework (1990) suggests ways to "transform the usual classroom setting into one that encourages curiosity and motivates students to learn more science. Classroom tables can be arranged to facilitate small-group work on direct science experiences...Students should have opportunities to work in cooperative groups, perform investigations, manipulate science equipment..." For cooperative learning, teachers are advised to divide students into groups of three to five students. These students are given tasks that require active participation of all group members for success. This arrangement offers many benefits to students over traditional classroom arrangements. Students have the opportunity to "talk science" with each other. If the task is set up carefully, talking science can be made to be essential to the completion of the task. Small group work can increase the amount of time a student has for talk from the usual one minute or less available in traditional science lessons to ten minutes or more.

Cooperative learning groups also help motivate student liking of science. Most often, when given a choice, students prefer to work with other students rather than alone on a task, and they enjoy the work they do more when working with other students (Slavin, 1983). Cooperative group work requires students to work collaboratively with other students. Science taught this way prepares students for later scientific work, as most science research and application is done through the collaborative efforts of many scientists. Learning how to work with others should be one essential goal of science education.

Cooperative learning techniques are especially beneficial to disabled students. Use of cooperative learning has been shown to be a much more effective learning environment for students with disabilities (Armstrong, Johnson & Bakiw, 1981). In addition, cooperative learning's emphasis on development of effective social skills for group interaction can be a very important part of the learning that takes place for disabled students. In general, it is clear that students with disabilities have social skills deficits. Aside from the students whose disabilities are defined in social terms (autism, conduct disorders), other types of handicapping conditions are also associated with social deficits. Hearing handicapped, mentally retarded, and learning disabled students have all been shown to have social skills problems (Berkson, 1993). Training in social skills (using modeling and social rewards) has been shown to have positive effects for these students (Schneider & Byrne, 1987, and Schumaker & Hazel, 1984.)

Training teachers in the concepts of cooperative group management in the classroom is also time consuming, and actual implementation in the classroom takes most teachers a number of years to master. Cooperative group classroom management schemes have many inherent difficulties. A basic problem in using peer collaboration in subjects such as science is the students' lack of subject knowledge. Much "mis-information" can be shared, and students can come to share incorrect scientific understandings based more on social constraints than on scientific reasoning. Also, without social training and directions on how to function as a team, students who are grouped together will often be very unproductive, spending time furthering social goals and avoiding working towards the teacher's academic goals (Salomon & Globerson, 1989). Effecting changes in the students' peer culture in such a way that it incorporates academic goals as well as social goals is not an easy task.

Research has shown that successful teacher implementation of cooperative learning groups requires institutional support (training, release time for observations and professional collaboration, help in collecting materials appropriate for cooperative groups). Yet even in the best situations, some teachers who at first appeared to have successfully adopted cooperative group strategies in their classrooms eventually abandon the practice. Although the reason that teachers discontinue use of cooperative grouping has not been systematically studied in the research literature, I contend that one reason is that it is "just too much work" for many teachers to maintain. Small group work, especially in combination with open-ended science exploration using hands-on materials, can lead to a great diversity of activity within the classroom. Teachers must not only monitor materials (making sure that students have what they need in each group for the lesson), but must settle details about assignment of roles, monitor social interaction and academic progress, keep groups on task and on time, be able to sense what other groups are doing while engaged with one group, and be willing to switch roles from being the sole arbitrator and judge of appropriateness to sharing that role with students. These changes in the classroom, although they can have distinct advantages for students, could well be overwhelming for many teachers.

This project involved creating computer software that takes over many of the management details of cooperative group work and hands-on science lessons and then examining what occurs in the classroom after its introduction. The software design is based upon careful observation and analysis of the tasks that teachers actually perform in a cooperative learning classroom, and observation and analysis of what students do in cooperative work groups. The intent of the software is to facilitate student exploration of science materials, and to increase student communication. To accomplish this goal, the software needs to be open-ended (that is, it cannot be strictly linear, but must allow for student choice in exploration). It is *not* designed to replace hands-on science experimentation with computer simulated science and does *not* drill the students and provide immediate feedback on correct and incorrect responses. Instead, the software is designed to provides *process management*. It offers the framework for the lesson, the resources and reference materials that students might need, and takes care of the management aspects of the task. It accomplishes this by managing the mundane yet time-consuming details of implementing cooperative group work, such as assigning roles, detailing the projects, obtaining and recording student input, requiring students to cooperate to complete the assigned task, reminding students of the social goals that must be met to work successfully as a group, keeping track of time and completeness of the project, providing visual feedback to the teacher on where the students are in the task, assigning enrichment activities for groups who finish ahead of time, providing productivity tools (encyclopedia, dictionary, plotting), and a myriad of the other little details of cooperative group work and hands-on science lessons.

When considering teaching models for the diverse environment found in the mainstreamed classroom, it is intriguing to note that collaboration has been defined as, "an interactive process that enables people with diverse expertise to generate creative solutions to mutually defined problems" (Villa et. al., 1996). Collaboration is also thought of as positive social interdependence. There is overwhelming evidence that group efforts to solve a common problem or reach a common goal produce positive relationships, good mental health and social proficiency. Collaboration allows the needs of diverse students to be met. Students become co-teachers as well as, co-learners bringing into the group or team a unique set of skills, knowledge, and problem solving techniques.

The review of research on cooperative learning led us to develop this list of features (Table 5) to evaluate for inclusion into the software development project:

Table 5. Key elements of effective cooperative learning methods.

	Key Element	Reference
3.1	Shared responsibility for participation and decision making	Villa et al., 1996
3.2	"Careful" grouping to minimize status issues, provide students with opportunities to interact with others with a wide range of personality and cultural differences	Johnson, Johnson & Maruyame, 1983; Cohen, 1986; Noddings, 1989; Lou et. al., 1996
3.3	Individual & group accountability	Male, 1993; Johnson, Johnson & Maruyame, 1983
3.4	Attention to social as well as academic goals	Berkson, 1993
3.5	Include disabled students with their peers	Prochaska, 1996

1.2 Questions Posed

The objective of this research is to develop computer software that assists students with disabilities in their integration into science lessons in regular school settings. The software accomplishes this integration by assisting the students and teacher in implementing cooperative learning lessons in the classroom. A large body of educational research literature has demonstrated that cooperative learning:

- assists students in learning to get along with other students
- provides a strong social incentive for learning to cooperate
- provides a framework for developing student communication skills
- enables students to understand the value of others with different abilities than their own
- increases academic learning

Our previous research has demonstrated that the type of software that we are proposing has benefits for teaching and learning, including:

- assists an instructor new to cooperative group work in successful implementation of this classroom management technique
- creates a structured learning environment for students, providing the social and academic guidelines that will permit them to successfully collaborate on a project
- enables students with different language abilities a better opportunity to communicate (in the previous study, ESL students were grouped with non-ESL students)

Our design goals for the software included the need to:

- provide support for teachers with little previous experience integrating students with disabilities into the regular classroom
- provide direct support of social training essential for students (disabled as well as non-disabled) as they learn to cooperate in the classroom
- facilitate interaction between regular education students and students with a variety of disabilities, including auditory impairment, vision impairment, reading disabilities, physical handicaps, and other types of disabilities (the range of which was determined in this study)

The project proceeded in successive stages. The first level of questions that needed to be answered before development of the software could procede were:

- What are the nature of difficulties encountered by students with learning disabled students as they attempt to communicate with their non-disabled peers and teachers? What techniques and devices have been shown to be effective in fostering communication?
- What is the current state-of-the-art for computer software and adaptive devices used by students with a range of disabilities?
- What characterizes effective group collaboration? What aspects of collaboration are likely to prove difficult for students with disabilities and teachers as they attempt to integrate these students into the classroom?
- What aspects of classroom learning are most and least motivating for students with disabilities? What methods have proven to increase motivation for these students?

These questions were answered by the literature review, and reported in the *Background of the Problem* section of the report. The next level of questions that needed to be answered were:

- What types of classroom interaction between the disabled students and their peers and teachers can be observed?
- What methods are used by the teacher to include disabled students in the classroom activities?
- What difficulties does the teacher encounter when implementing curriculum that makes it difficult to provide support for her disabled students?
- What methods are used by exemplary teachers to include disabled students in classroom activities? What difficulties do teachers encounter?
- What are the major functions that this software will need to perform?

- Under what conditions will the software be used, with what expected outcomes for students and teachers?
- What aspects of collaborative work can be well supported by such software?
- What aspects of integrating students with disabilities can be supported by such software?

The answers to these questions permitted the research team to develop a technical specifications document, and a subsequent beta version of the software which was used during the classroom testing phase of the project. During this final phase, we attempted to answer the questions:

- Does the software work in the expected ways under the conditions that it was designed to operate?
- What unexpected outcomes, if any, arise from the human computer interface?
- What features of the software need additional work in a redesign effort?

The research questions posed, the research methodology used to answer the questions, and the results of the research are summarized in Table 6. The *Results* section provides the detailed explanation of these findings.

Table 6. Summary of research questions and results.

Question Posed	Research Methodology	Results
What types of classroom interaction between the disabled students and their peers and teachers can be observed? What types of collaboration and cooperation are observed?	Ethnographic observations and open-ended questions	The interactions vary widely, depending on student disability and personality. During the beta test of the software, students were observed to be very cooperative.
What methods are used by the teacher to include disabled students in the classroom activities?	Ethnographic observations and open-ended questions	—Minimal curriculum modification —Differential expectations —Pairing disabled with regular education students —Adaptive devices to help students focus
What difficulties in supporting disabled students do teachers encounter when implementing curriculum?	Ethnographic observations and open-ended questions	Teachers find it somewhat more difficult to manage activities when there is a wide range of student abilities
What methods are used by teachers to promote discourse with disabled students?	Ethnographic observations and open-ended questions	Directing questions to the student, redirecting other students to include the student in discussions
What are the major functions that this software will need to perform?	Review of results of previous questions	—Support non-readers and low readers —Provide explicit social goals appropriate for the groups
Under what conditions will the software be used, with what expected outcomes for students and teachers?	Ethnographic observations and open-ended questions	Optimal conditions may not be present in most classrooms, which could have a negative impact on implementation of software
What aspects of integrating students with disabilities were observed during testing?	Ethnographic observations	A much higher than normal interaction between students and peers was observed during the testing in comparison to the regular classroom setting
Did the software work in the expected ways under the conditions that it was designed to operate?	Ethnographic observations	Most aspects of the software worked as hypothesized, with some exceptions
What unexpected outcomes, if any, arose while testing the human computer interface?	Ethnographic observations	—Some students with reading disabilities can recite verbatim a script they have been read —Students without any training in using the interface did as well as students with a 45 minute training session
What features of the software need additional work in a redesign effort?	Review of results of tests	—Text should be broken into smaller chunks —More direct methods for retaining attention of some hyperactive students may be needed —Changes in software for deaf and blind students might be required —Additional academic support might be required for lower functioning students

2 Methods

The research was performed using ethnographic research methodologies. Ethnography of schooling is a well established methodology for coming to understand the interrelationships of participants in a school setting. According to George Spindler, who was a pioneer in this field of study and perhaps the best know ethnographer of schooling, a "good ethnography of schooling" meets these criteria (Spindler, 1982, pages 6 and 7):

- Observations are contextualized. The significance of events is seen in the framework of relationships of the immediate setting being studied but is pursued, as necessary, into contexts beyond.
- The native (any participant in a social setting) view of reality is brought out by inferences from observation and by various forms of ethnographic inquiry: interviews, other eliciting procedures (including some instruments), even, at times and only cautiously, questionnaires.
- Sociocultural knowledge held by social participants makes social behavior and communication sensible to oneself and to others. Therefore, a major part of the ethnographic task is to understand what sociocultural knowledge participants bring to and generate in the social setting being studied.
- Instruments, codes, schedules, questionnaires, agenda for interviews, and so forth, are generated in the field as a result of observation and ethnographic inquiry.
- Since the informant (any person being interviewed) is the one who has the emic, native cultural knowledge (in varying degrees of self-conscious articulation), the ethnographic interviewer must not predetermine responses by the kinds of questions asked. The conversational management of the interview or eliciting interaction must be so carried out as to promote the unfolding of emic cultural knowledge in its most heuristic, "natural" form.
- Any form of technical device that will enable the ethnographer to collect more live data—immediate, natural, detailed behavior—will be used, such as cameras, audio tapes, and video tapes.

Ethnography is a rigorous methodology useful for the study of complex environments. Each finding in an ethnography must be "triangulated", or validated by multiple sources. Our information was triangulated by verifying accuracy of observations with other researchers on the project (through mutual on-site observation of events as well as through review of audio and video tape), special education teachers familiar with the students and teachers in the study, the regular education teachers used in the study, the students themselves, primary data sources (field notes, audio and video tapes, student work), and secondary data sources (transcripts and counts of events).

During the classroom observation phase of the project, two researchers observed in ten inclusion classrooms, visiting each classroom between three and six times for an hour or more in each observation. In addition, some of the students were also observed in the special education classrooms in which they spent part of each day (for students that were not in full inclusion programs.) The researchers took field notes which were later transcribed and filled in with more detail. Some classroom observations were also audio taped, where such permission was obtained by the instructor and the audio taping did not disrupt classroom activities. Counts of various types of occurrences were made (as reported in the *Results* section.) A "count" of an occurrence was registered when an utterance of the type being observed for was heard by the observed students (for example, if a student turned and made a comment to another student while the teacher was lecturing and such talk was not sanctioned by the teacher, this would count as a single "off-task" talking incident.)

A set of survey level interview questions (Spradley, 1980) was developed that included broad questions (see the *Results* section for details). These questions were posed to the classroom teachers and the special education teachers working with these students. These interviews were not recorded, but the researchers took field notes and transcribed these notes after the interviews. Further questions were put to instructors during and after the observation periods.

After the beta version of the software was complete, the researchers obtained permission to test the software with students. Because of the lack of adequate computer facilities at any of the target schools and the difficulties in scheduling, it was decided that one or two groups of students per class would be pulled out to participate in the hands-on science lessons outside of the regular classroom setting. In six of the groups the students used the special education classrooms—these were familiar settings not only to the special education students, who spent part of the day in that setting, but also to the regular education students who were frequent visitors to the room (either to work on projects with special education students, or for remedial help themselves, or to assist with younger students as aides.) In the other case, two tables in the back of the library were made available for the testing.

During the beta-testing phase of the project, eight groups of four to five students were observed as they used the software and interacted. Three lessons, lasting 45 minutes to one hour each, were observed for each group. Each group consisted of one disabled student with three or four students without disabilities. The parents of these students used in the beta tests of the software were required to fill out permission slips permitting the researchers to video and audio tape the group interactions (see *Appendix C* for a copy of the form used.) Audio tapes, video tapes, and ethnographic field notes were obtained during the beta testing.

Because of the bulk of data collected, only selected sections of the audio and video tapes were transcribed. Also, counts of different types of interactions between students were made of the selected tapes in the tape set, as reported in the *Results* section.

2.1 Participants

In this section I will describe the teachers involved as part of our development team, the students observed in the study, the school districts, and classroom environments. A summary of the observations is presented in Figure 1.

Situated Classroom Observations	Beta Testing of Small Groups
10 inclusion classrooms	8 groups of 4 to 5 students
3 to 6 observations of approximately 1 hour each	3 observations of 45 minutes each
1 to 5 inclusion students in each classroom	1 inclusion student in each group
25 to 30 regular education students in each class	3 to 4 regular education students in each group
1 teacher and 0 to 2 special education aides in the classroom	1 to 2 researchers and 0 or 1 special education teacher with student groups

Figure 1. Summary of observational data collected.

2.1.1 Teachers Working with Development Team

We identified three teachers to work with us as part of our development team. Our original proposal called for two teachers, but during the observation phase we discovered that there were three classifications of instructors important in the integration of students with disabilities into the classroom, and wished to have representatives of each of these groups informing the project. The first instructor, Diane Logan, is a special education teacher with her own classroom for deaf and hearing impaired students. She acts as the primary teacher for these students during most hours of the day. The students are integrated into regular classrooms for some hours of each day (the number of hours and times depend on the student's abilities and the availability of a classroom aid.) The second teacher we have identified is a classroom teacher, Linda Thomson, who integrates students with various disabilities into her normal classroom routines. During the testing phase of the project she provided students for one of the beta tests. The third is a special education teacher, Ann Marie Smith, who also works in the regular education classrooms during the day. She assists the students with disabilities in the classroom, doing tasks such as modifying the curriculum, helping students understand instruction, writing out what students say, etc. The participants provided feedback on software design and helped triangulate results of the study.

2.1.2 Students Observed

Students involved in the study were diverse. All students were in the fifth grade. The regular education students were chosen by their classroom teachers, and different teachers used different criteria. The students and their cooperative group partners are identified in Table 7. The student names used throughout this report are not the student's actual names, but were assigned to protect their right to privacy.

Table 7. Students participating in beta tests.

Student(s)/ Setting	Characteristics
Allan/ Lompoc	Allan is hearing impaired. He recently moved to this school district from Las Vegas and is probably capable of full inclusion, but his parents will not approve this. Although his hearing loss is severe, he can often distinguish speech and is quite good at understanding what other students are saying (as long as he can see their faces.) His speech is very clear and understandable. Allan is a very friendly young man, and is well liked by his peers. He was not treated any differently by peers than any other member in the group. Allan's class work is pretty much at grade level. Allan was excited to participate in the project.
Allan's cooperative group/ Lompoc	The four students in Allan's group were chosen by the teacher, Mrs. Davidson, as students who could afford to miss the regular science that was scheduled during that time block. The students did not mind being pulled out from science in their classroom (which they assured the researchers was "boring" because it came from a book and lecture and had lots of new words to learn) but they were required by their instructor to make up the missed work. These students came from a class in which cooperative work was a regular part of the daily structure.
Belinda/ Lompoc	Belinda is almost completely deaf, with very limited ability to hear some sounds. She cannot understand most of the conversation that takes place around her, but can lip read if the student turns directly towards her while speaking. She can use a remote microphone and hearing aide to help her hear one person at a time. Belinda has a social group in which she is comfortable, and she plays with this group during recess and at lunch. However, in the classroom she is not very social and generally prefers to work by herself. She was not interested in being part of this project, and her permission slip came back with "not willing to participate" checked. The teacher called the home and explained that she felt it was important for Belinda to work with other students more, and permission was obtained. Peers tend to ignore her in class as she does not enter into conversations. Belinda's speech can be difficult to understand. Academically she works at or above grade level.
Belinda's cooperative group/ Lompoc	Belinda's group was chosen by their teacher, Mrs. Evans, as "students who should do well". She chose students that were working at or above grade level and who were friends. The students were excited to participate and were not required to make up missed work from the regular class. Their teacher never uses cooperative learning groups, and teaches in a traditional style (lecturing, individualized student work.)
Carrie/ Davis	Carrie has multiple diagnoses, most prominently Learning Disabled (LD). Academically she is below grade level, but teachers indicate a sense that she is capable of more. She was not observed in class conversing with other students. In class she needs assistance with starting and maintaining projects, and with organization. She was excited to be part of the science project. Carrie's reading level is well below grade level.

Table 7. Students participating in beta tests (continued).

Student(s)/ Setting	Characteristics
Carrie's cooperative group/ Davis	Carrie and Doug are both in Mrs. Brannon's fifth grade class. The other members of both of their groups were chosen by the teacher as students who would not be disrupted by the change in routine. They would not be required to make up the work that they missed during the beta testing, which happened to be science. The students are accustomed to hands on work in science and math, and said that they had done cooperative group work before.
Doug/ Davis	Doug is diagnosed as Severely Emotionally Disturbed (SED). Academically he is at or slightly above grade level. Socially, we observed him trying to communicate with other students but the other students did not seem to know how to respond. Doug has a great deal of trouble staying on task, staying in one place, and knowing when to talk. He frequently blurts out inappropriate comments which are difficult to understand. During the science project we observed that although he was thinking hard about the project, he just had so many ideas coming so rapidly to him that he could not communicate the ideas. He appears quite manic. In the regular classroom, the teacher had a one-legged stool built for him to "sit" on. Keeping his balance occupies much of his time and helps him stay focused. He was excited to participate in the project, and came into the project claiming expert knowledge about the topic and science in general.
Doug's cooperative group/ Davis	Doug and Carrie's group were both from the same classroom.
Ellie/ Lompoc	Ellie has multiple diagnoses, including ADD, LD, and Tourette's syndrome. Until recently it was nearly impossible to include Ellie in any regular education activities, as she literally climbed the walls. About a year ago Ellie started a new medicine, and many of the overt mannerisms from her disabilities lessened. Although she frequently blurts out responses or vocalizations and has many facial ticks, she is now capable of working with other students in the classroom. Academically she reads at about a grade four level, and is close to grade level in other subjects. Ellie was excited to be part of the study. She will not be required to make up missed work from the regular classroom.
Ellie's cooperative group/ Lompoc	Ellie and the remaining students in the list are all mainstreamed in the same classroom. The teacher, Linda Thomson, has six special education students that spend most of the day in her class. Linda has a collaborative learning environment for the students. She uses "learning centers" and rotates student groups to these centers. Students are expected to assist each other throughout the day, and talking is encouraged. She assigns a regular education student "helper" to each special education student so that they get the attention they need. Students were selected for the study based on availability (those that were not assigned to other tasks at that hour.)
Frank/ Lompoc	Frank has Landau Kleffner syndrome. This genetic disorder makes it difficult for Frank to speak and understand language. He reads at grade 2.4 and his math skills are at grade 3 to 4. He is not socially active but can interact with other children. He concentrates hard on his work and asks many questions.
Gary/ Lompoc	Gary is Hispanic, and speaks only limited English. He is multiply diagnosed, prominently as LD. His reading is at grade 1 to 2. He speaks extremely slowly, and moves very slowly. We observed that often a student would need to repeat things to him more than once to get a response.
Henry/ Lompoc	Henry has multiple problems. He is SED and has a play specialist assigned to help him. He is suffers from depression and hyperactivity. He has a poor ability to discern auditory input. Because of behavior problems he was mostly isolated during the time of this study, working in a private carrel assigned to him. He participated in the cooperative group only on the third day of the study.

2.1.3 Schools and the School Districts

The research was carried out in two school districts in California: Lompoc and Davis. We chose these districts mainly because of the difference in resources available to the school (Davis has very well-funded schools while Lompoc schools are very poorly funded) and our ease in access (we have used schools in these cities in previous studies and have numerous contacts.)

Davis is a town located in an agricultural valley in North Central California. It has a population of about 50 thousand, and is bordered by agricultural land on all sides. The state capitol is the nearest city, 12 miles to the east. While a fairly small town, Davis has a University of California campus adjacent to downtown. One effect of this juxtaposition is the presence of professionals, academics and working people comprising a fairly small population.

Lompoc is also a farming community, with flower seed production one of the main outputs. The community has a population of about 50 thousand. A large portion of the population is Hispanic, limited-English speaking. Lompoc has the lowest cost housing in the Santa Barbara County, and thus many of the lower income families and welfare families live in the area. Lompoc is also the home of a federal penitentiary, and many of the families of inmates choose to live in the city. And, Lompoc also houses an Air Force military base, Vandenberg AFB. The children of military personnel, however, are mostly enrolled at a school located on the base, which is not the school involved in our study. Because of the low income for the area and the low property values, schools do not receive much money from local resources.

In Davis, teachers find it relatively easy to obtain money for field trips and programs on campus. In Lompoc, most teachers have given up field trips and other "frills" for lack of support. No bond measures for funding for schools have passed in the previous 15 years, whereas in Davis nearly all school bond measures pass. Davis schools have money for music programs, arts programs, science teachers, and large libraries. Lompoc has eliminated all such extras due to lack of funds.

2.1.4 Classroom Environments

The classrooms in which the students were mainstreamed varied considerably. We observed in ten classrooms for three to five days in each. For this study, we report only those classes which we used students from for the beta testing, or six classrooms. In the Davis school studied, "track" scheduling is used. Teachers in each grade level specialize in different subjects and teach only these subjects to three groups of students during the day. The students travel around to the different teacher's rooms.

In Lompoc, the school which we studied used standard tracking. Students stayed with the same teacher all day, except that the special education students spent part of the day in the special education classroom. For the deaf students, only one or two hours per day were spent in the regular classrooms. For the other students, two to three hours were spent inside the regular education classes. Generally, language arts and mathematics were the areas of the curriculum focused on in the special education classroom. Because of the extra help and individualized attention, many of the special education students perform better academically in these subjects than the average regular education students (confirmed by two regular education classroom teachers and two special education teachers.)

We will identify the inclusion classroom teachers (with the exception of the Mrs. Thomson who participated as members of the software development team) and students by pseudonyms to protect privacy.

Teachers Observed:

Mr. Anderson (Davis) has been teaching 30 years, most of which has been practiced at this school. He teaches Communication, which includes spelling and grammar, to 5th grade students. He uses direct instruction methodology with paper and pencil exercises.

Mrs. Brannon (Davis) has been teaching for twenty-five years. She teaches Math and Social Studies. In Social Studies, she uses open and closed questioning techniques, based on text reading; in Math she uses hands-on manipulatives and loosely structured groups, allowing tables to work together.

Mrs. Calle (Davis) has been teaching science at this school for eight years. This year, during school restructuring, she has adjusted to teaching science door-to-door, supplies and desk housed in a former storage room. She maintains a weekly schedule of instruction, review, watching part of a video series, and running an experiment (the class has music with their homeroom teacher each Wednesday.) Concepts are taught through direct instruction, review and prep is through open and closed questioning techniques, and experiments are hands-on small group work.

Mrs. Thomson (Lompoc) has been teaching for five years. In all, Mrs. Thomson, has six special education students that spend most of the day in her class. Also, eight of the "regular education" students in her classroom receive resources outside of the classroom. These eight students perform well below grade level in most subjects, and most exhibit behavior similar to ADD and LD students, but have not been formally diagnosed as special needs students. A few of her students are also ESL. Linda has a collaborative learning environment for the students. The students are grouped with other students for each subject; sometimes these groups are persistent over a unit, and other times she changes the groupings daily, depending on where students are on an assignment. She uses "learning centers" and rotates student groups to these centers. Students are expected to assist each other throughout the day, and talking is encouraged. She assigns a regular education "helper" to each special education student so that they get the attention they need.

Mrs. Davidson (Lompoc) has been teaching for more than 20 years. She frequently uses cooperative grouping in her classroom. She has one disabled student in her classroom.

Mrs. Evans (Lompoc) has been teaching for over 15 years. She uses direct instruction teaching methods. Students are not encouraged to talk in her classroom. She has two students with disabilities in her classroom.

Students Observed:

Ianna: Diagnosed with Attention Deficit Disorder (ADD). African American girl, average in stature. Academically, she is below grade level and works with the Resource Teacher when she is in the room. Socially, she seems to have one close friend, the girl who sits across from her and is the only other African American student in class. Strained relationships with other girls seen in basketball game during PE. In class, she takes frequent circuits around the room when small errands come up, chats regularly with her neighbor, and sustains conversations with her teachers for as long as possible.

Justin: Diagnosed as Severely Emotionally Disturbed (SED). Caucasian boy, small in stature. Academically, his teacher reports that he is on grade level, and generally is caught up with his homework. Socially, he was not observed communicating with other students. In class, he maintains a body posture that is usually drawn close to his desk, head low between his shoulders, hands up by the sides of his head with his elbows on the desk top. He was not observed to volunteer an answer to questions posed by the teacher. He participated on the fringe of the basketball game, mostly running up and down the court alongside the pack of boys.

Kyle: Receives resource services. Caucasian boy, taller than other students his age. Academically, he is considered two grades below level. Socially, he is gregarious and popular; a most valuable player in basketball. In class, he was observed instigating many off task conversations at his table.

Lonnie: Receives resource services. Hispanic boy, average in stature. Academically, he is well below grade level, and is early in developing his reading skills. Socially, he appears to be more of an observer. In class he maintains a steady stream of sound, verbally or by moving objects

Mort: Diagnosed as autistic, referred to as "Full Inclusion." African American boy, considerably larger than other students his age. Academically, he works with early counting games and does not participate in the class curriculum. Socially, he is out of reach of other students during class, but various peers offer to play with him during recess each day. In class, he works with a full time aide who closely monitors his behavior.

Nathan: Diagnosed as Severely Emotionally Disturbed. Caucasian boy, average in stature. Academically, he works with the same materials as the rest of the class, but is expected to complete only a portion of it. Socially, he is apparently volatile and is closely monitored by his full time aide. In class, he generally works at a separate table, but he does participate with success in group work. Other students seem to work with him as a full member of the group.

Carrie, Doug, Ellie, Frank, Gary and **Henry** are listed in Table 7 and were also observed in the classrooms.

2.2 Design

In this section I will discuss the design of the software as well as that of the research project. I begin by discussing general issues about the software design, followed by details about the software and hardware supports that were designed into the software to promote cooperation between students and free the teacher from the responsibility of detailed management of the groups. Finally, a detailed description of the software interface screens is provided, in order to allow the reader of this report to better the understand the results that are presented. Finally, a section on the research design is presented.

2.2.1 General Issues of Software Design

Prior to the beginning of this study the software initial prototype, designed to assist teachers as they begin to implement hands-on science units for cooperative groups of students, was developed through careful review of the cooperative learning and hands-on science research literature with the goal of creating "check lists" of key elements necessary for success. The element lists were then scrutinized for items that could be modeled in a software management tool. Categories of these items included those that were essentially mechanical (such as assigning student roles, rotating cooperative roles and reassigning or combining roles during absences, providing instructions for choosing materials from supply boxes needed for the lesson), interactively instructional (such as assigning and reinforcing the academic and social tasks for the lesson, setting time limits for different aspects of the task, and informing the students of each next step in an experiment), and assessment or feedback related (such as checking to see that groups were progressing through the lesson at an appropriate pace, checking student work for completeness at each stage, providing feedback to students about actions, and collecting student work).

A science unit on the topic of electrical circuits was developed, consistent with curriculums that have been used extensively throughout the schools. The unit was divided into 16 lessons of 45 minutes each. Each lesson was structured so that it was appropriate for cooperative work, requiring all students to work together to accomplish the task. Individual accountability and group accountability were built into the tasks. The science tasks were experimental in nature, requiring students to manipulate batteries, motors, light bulbs, and other materials; computers were used to manage the group activities and record results, not to simulate the science.

The findings from the preliminary tests of the project were very promising. The amount of time that the classroom beta-testing instructors (two classrooms) had to spend taking care of the "mundane" tasks of cooperative group management was very small in comparison to similar observed classrooms. We found that the teacher spent virtually no time managing the student group role rotation, assigning roles or checking that students were acting in accord with the expectation for these roles, and handling the "paperwork" aspects of managing cooperative groups. Our tests showed that even in a classroom in which the teacher was convinced that (a) cooperative work was not a viable means of managing her classroom, and (b) hands-on science was too difficult for her bilingual students, the science unit was successful. In fact, the teacher became so convinced that cooperative learning was beneficial for her students that she organized the other teachers at her school so that they could all teach cooperative lessons.

The software was designed to support different learning modalities; this was accomplished by providing multimedia support for different types of learners and alternative means of accomplishing the same task. Student roles were assigned and managed by the software and students were rotated each lesson so that each student had the opportunity to learn to work with the group in different capacities.

The software also permits different groups of students to proceed at different paces. This feature was included in our design because one of the difficulties that we observed in classrooms was that student groups completed an assignment in differing amounts of time. This difference could be due to one group needing to take more time to come to understand a difficult concept, or because the students needed to work out a social problem, or because they had a slow writer, or for any other number of possible reasons. This differential rate of project completion proved to be difficult for teachers to manage, as they felt uncomfortable when a group had completed the task well ahead of the rest of the class or another group lagged far behind. It presented logistics problems for the teacher, who needed to have students all working on the same lesson in order to be able to manage the materials needed for a lesson. We solved this difficulty by providing only a small core of steps that each group would need to complete in a given lesson, thus ensuring that each group would get through the basics for the lesson. The remainder of the lesson would be spent on extension activities to assist students to come to a deeper understanding of the subject. If a group completed the extension activities for the day's unit, the group could choose between a wide range of enrichment activities related to the same lesson and emphasizing different types of thinking skills (hands-on kinesthetic practice, thinking and writing or discussion activities, or examine research materials to provide a richer background on the topic). Thus, no group could ever exhaust the possible materials for any lesson, and all groups were assured of completing the core material needed for a lesson, providing the instructor with a means of keeping the class working on a schedule without sacrificing the needs of particular groups to work at different paces.

2.2.2 Software and Hardware Support for Various Types of Disabilities

In addition to the general features of cooperative learning groups that are beneficial to students with disabilities, we built into the software specific adaptations for these students. These are summarized in Table 8.

Table 8. Hardware and software support for various types of disabilities.

Disability:	Adaptations:
Blind	• Optional use of computer reading of text* • Braille print out of all text for blind students
Visually impaired	• Large text software toggle for the computer screen • Large text print outs • Optional use of computer reading of text*
Learning disabled students	• Provide text in multiple reading levels (teacher can set reading level for each student) • Optional use of computer reading of text* • Student collaboration on tasks will assist students unable to perform mathematical calculations • Option in software for different color combinations for students with visual/perceptual problems
Quadriplegic (from mild to severe)	• Special role tasks will be assigned to the facilitator in such groups (e.g. "help Marcy get the materials your groups needs") so that student can be as fully integrated as possible • Mouth stick or other device can be used to control computer
Amputees, arthritics, students suffering from carpal tunnel, neck or arm injuries	• No special adaptation required other than support of alternative keypads, trackballs, etc. • Design of software supporting different rates of completion of tasks permits a group with a physically slower student to meet with success
Deaf and hard of hearing students	• Flashing of screens along with beeping will be used as attention getting devices • Any audio media (video or audio clips) to include close captioned text • Special social goals will be assigned to group to assist in integrating student into group
Psychological disorders	• Cooperative work permits these students to obtain more tutoring and assistance than is normally available in a regular classroom though peer help • Constant software prompts help students in group stay on task • Design of software supporting different rates of completion of tasks permits a group with a mentally slower or disruptive student to meet with success
Acquired brain injury	• Software provides constant reminders of what to do next • Software provides a beginning summary of what happened in the previous lesson and the teacher provides the class with wrap-up activities to help students retain information
Cerebral palsy	• Same adaptations as for quadriplegics and/or physical disabilities will apply

*Provide an option in the software for the student in "reader" role to use alternative input device and auditory and visual cues to have computer read text. Reading is thus under the control of the student in the "reader" role (not the student in the "inputter" role), and this most closely provides students unable to read the ability to either (1) listen to the text read through a single ear phone, which they can then repeat or use as an aid in deciphering the text, or (2) broadcast to the group via audio speakers.

Program features:	support of peer collaboration	explicit step-by-step direction-giving to students	higher-level thinking required for success	support for alternative input devices	phrase-by-phrase reading option	use of hands-on science materials	support for multiple learning modes	support of differential completion time for lessons	design of lesson units	multiple reading levels	integration of social goals into lesson	teacher lesson plans	coop. learning lesson structure	role rotation
Devices for increasing student communication:														
Students with behavioral/emotional disabilities benefit from direct instruction, use of clear introduction to academic subject and a summary session		●							●				●	
Students with communication disorders benefit from inclusion practices in schools	●									●				
Instruction should be consistent and precise		●							●				●	●
Alternative uses of language (same meaning in different ways) supports students who have language difficulties	●	●					●			●				
Communication alternatives such as hardware/software devices benefit range of students with communication disabilities	●			●										
Time delays ensure that everyone can participate								●						
Support for diverse learning styles supports a wide range of students			●			●	●							
Direct treatment of social status issues		●									●		●	
Devices for increasing student collaboration:														●
Shared responsibility for participation and decision making	●	●	●						●		●		●	
heterogeneous grouping												●	●	●
Individual and group accountability									●			●	●	
Focus on how the activity is occurring rather than what is occurring (need to word this better)		●	●			●	●	●	●	●	●	●		●
Inclusion of disabled students in authentic activities with peers	●				●						●		●	
														●
Motivational factors:														
Access by all students to the learning environment				●			●						●	
Opportunity to socially interact	●				●				●		●		●	●
Sense of belonging as an active group member	●		●				●	●			●		●	●
Peer collaboration in a non-threatening environment	●	●			●		●		●				●	●
Opportunity to participate as an equal group member	●			●	●			●		●			●	
Stimulating materials that are engaging and within the grasp of learning disabled students		●	●	●		●							●	●

Figure 2. Features of the application that support identified needs of the disabled student population.

2.2.3 Limitations for Disabled Students in Cooperative Learning Roles

Students with disabilities may not be able to fully participate in some of the cooperative learning roles. For students with multiple disabilities that make it impossible to achieve at or near grade level, it may be preferable to assign them to the role of "assistant" to another student, or assign an assistant to help that student. Other adaptations for various disabilities are made within the software, as outlined in Table 9.

Table 9 . Cooperative role definitions and adaptations for disabled students.

Cooperative learning role:	Adaptations needed:
Inputter—student who sits at the keyboard and advances the screens, controls the mouse and keyboard	• For physically impaired must support adaptive devices
Reader—student who reads aloud the instructions for each step from the prompts on the computer screen	• For blind and sight impaired may use large text software toggle, large text print outs, Braille print outs • For ABI and deaf students may provide computer phrase by phrase reading of text • Provide text in multiple reading levels (teacher can set reading level for each student)
Facilitator—student who makes sure that everyone in the group has what they need to meet with success; is the only person in group who may request help from the teacher	• No special adaptations required
Draftsperson—takes notes in the science notebook, sketches the group's work	• Blind students and student with physical impairments may have special needs that require assistance by the group facilitator to complete the tasks
Supplier—is in charge of maintaining supplies, taking out what is needed for the lesson, preventing materials from getting lost or broken and students from injuring themselves	• Students with physical disabilities may need assistance with tasks from the facilitator

2.2.4 Software Design

In the opening (Figure 3) screen, students choose the name of the unit they are studying (currently, Batteries and Bulbs is the only unit in the software.)

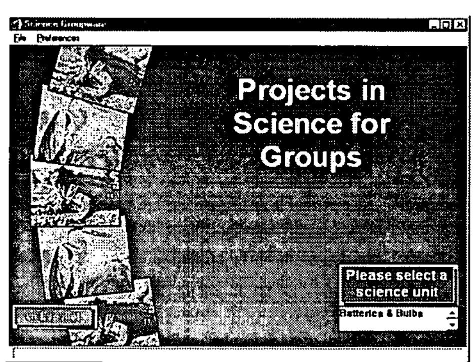

Figure 3. Opening screen.

On the Group / Student Entry page, students first select their group name, then click on the name of each student that is present that day. Next, they click on the "done" button (Figure 4.) Now, they will see the roles for the day. It is at this point that the students situate themselves at the table, giving the inputter the chair next to the keyboard, and the supplier room to spread out supplies, the draftsperson a place to write, and the reader a location convenient to read. In our observations, all groups did this naturally after the first day, as they understood the needs for the various roles.

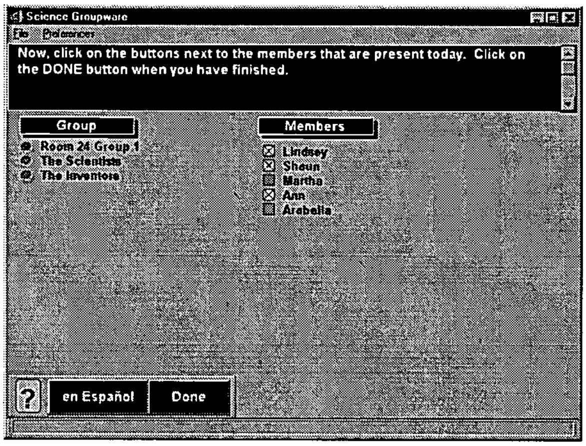

Figure 4. Group and student entry.

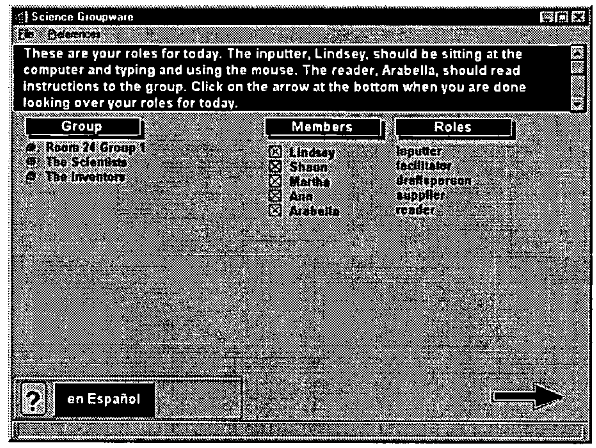

Figure 5. Student roles assigned.

Next, the students would see a list of the different lessons for the unit (not shown). The lesson subsequent to the lesson last completed would be highlighted. If the students choose a lesson out of sequence, the computer prompts them with "Do you have your teacher's permission to change lessons?"

Now, the first screen of the lesson appears. The background of the "core" screens, those screens that all groups in the class are expected to complete during the science lesson, are displayed with a blue background. Later, a similar screen layout will be used with yellow screens, to indicate that the group is working on extension activities. Most groups will complete at least some of the screens in the extension activities; however, these are not essential to understanding the lesson, but provide additional opportunities to increase understanding and reinforce the concepts.

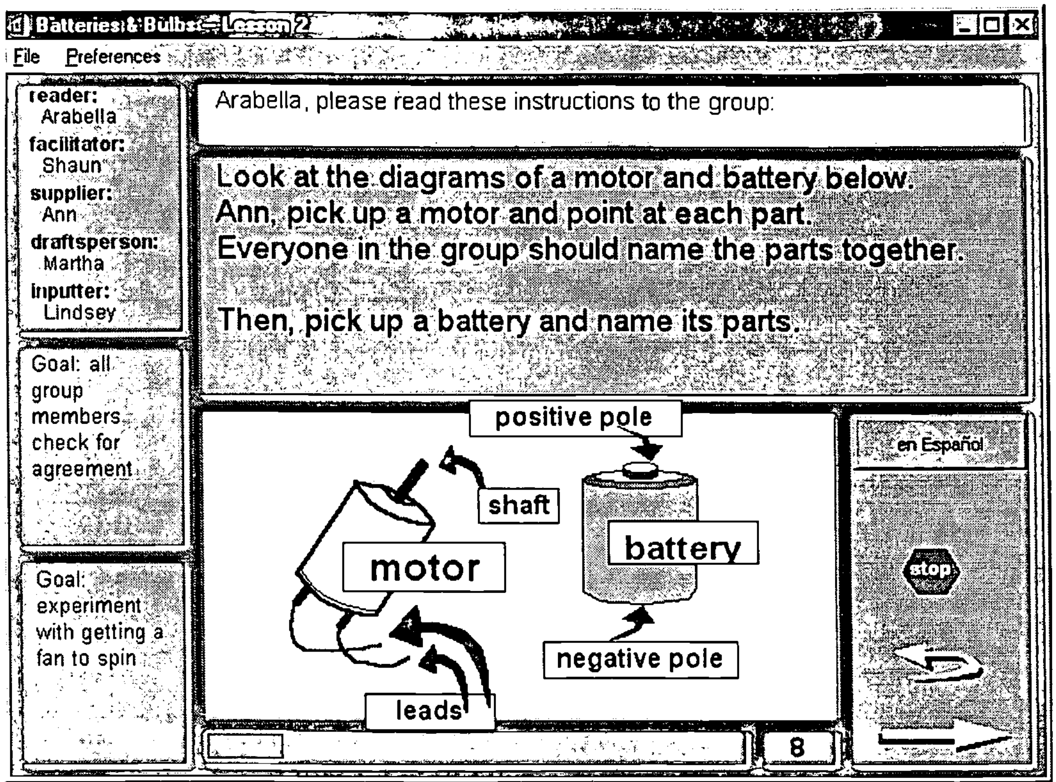

Figure 6. A Sample "Core" screen.

In the top-left screen area, the student names and roles are displayed. This permits the teacher to quickly see which student should be performing which role. It also helps remind students of their roles. If the inputter clicks on a student name, a yellow box appears which tells the group what is expected of that student at this moment (see Figure 7.) At some point early in the lesson, the inputter is instructed to "click on your names to see what jobs I want you to do right now." The draftsperson will be told what his/her task is and what page to turn to in the notebook, the supplier will be told what supplies to use, etc. This helps reinforce the student roles.

The box below the student names contains the social goal for the lesson. This box is filled in only after the goal is explained to the students. The bottom left box contains the academic goal for the lesson, again displayed only after it is explained. The top box virtually never changes, just asking the reader to read aloud. The box below contains the body text. Below that is a space that is used to show pictures, photographs, video clips, etc. In Figure 6, this space contains a diagram of the motor and battery. Underneath the display area is a timer (the number eight in this example) showing the time elapsed since the lesson began. The red bar to the left of this number slides to show the percentage of time used compared to the time available (which is set by the teacher, with 45 minutes recommended, but a range of 20 to 95 minutes workable for most groups.) In other words, when the bar is about half way across its space, then the lesson is about half way over.

The en Español button can be clicked to instantly change the text everywhere on the screen to Spanish (other languages can be added.) At that point, the caption of the button changes to "in English" so that it can be clicked at any time to switch back to English. There is a space below this used for a video button, that can be pressed to view again a video clip used in the lesson. It only appears after the video clip is shown the first time. The back-curving arrow allows the inputter to move back through the lesson to a previous screen, while the front-pointing arrow moves to the next screen.

In half the groups we didn't explain any of the buttons or screens to students, yet we never saw any group have trouble navigating through the software. Perhaps this is because students are so comfortable with computers that they are now able to figure them out quickly. Virtually all of the students had used computers, and nearly half of them had computers at home.

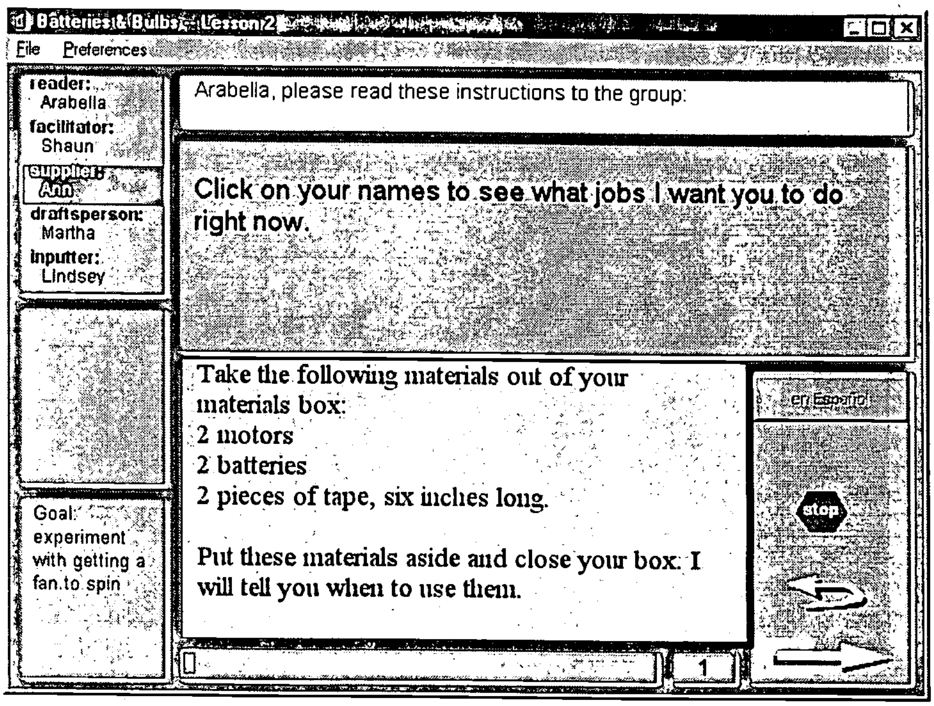

Figure 7. Clicking and holding the mouse cursor on a student name displays what the student should be doing at that very moment.

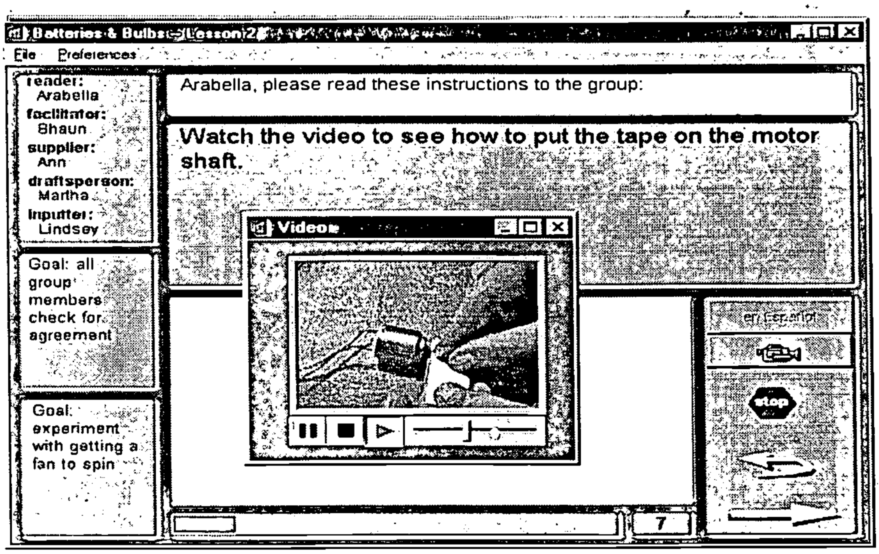

Figure 8. The video window appears when there is a concept that can be best explained by a video or animation clip.

Various types of media are available to assist students, when needed. In our design we chose to include only multimedia aides wherever these were necessary or extremely helpful, but never where it might be distracting. In the case of lesson two (the first lesson students completed) it was helpful for students to see exactly how to put tape on the shaft of the motor to make a fan. A few of the groups watched the video many times in order to figure out how to perform this task (see Figure 8.)

As students get to the experimentation stage of the lesson, the software calculates how much time they have to complete the experiment. Minimum and maximum amounts of time have been predetermined, and the software determines how much time to allow the students based on how much time remains in the session and these minimum and maximum values. When the time is over, a "beep" is used, and the screen changes to the next screen.

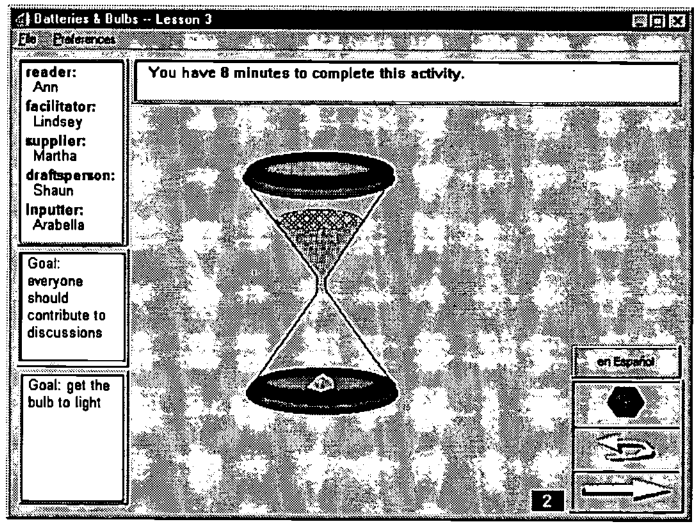

Figure 9. The "timer" screen, with an animated hour glass, provides a visual indication to students about how much time they have remaining for an experiment.

To permit the instructor to see, at a glance, how far into the lesson students have progressed, screens are color coded. The "core" material (material that all students must get through in the lesson to be exposed to the basic concepts of the lesson), is displayed with a blue background. The "extension" materials (material that extends the learning) are displayed with a yellow background. Groups may or may not complete the yellow screens, depending upon how much time the teacher has set aside for the lesson, how fast the group completes the experiments, and how long it takes students to negotiate answers to questions. The "expansion" screens have a purple background (see Figure 11.)

The extension activities always include some kind of question that assists students in articulating what they discovered during the hands-on portion of the lesson. There are also questions that help to reinforce the social goal for the lesson (see Figure 10.) In our observations, students sometimes use these questions to help them bring out ways that they think the group could work together better. We know that this technique of introducing and reinforcing social goals is effective, because we have numerous examples of students in groups insisting on being treated in certain ways, based on the exact wording used for social goals of previous lessons. Thus, these social goals are used as referents by students for insisting on other students taking responsibility for their actions.

The expansion activities (Figure 11), which may or may not be used by groups depending on how much time they spent on other parts of the lesson, always contain three types of activities: research opportunities ("find out more"), additional kinesthetic experiences though experimentation with materials ("experiments to try"), and creative thinking and writing activities related to the day's lesson ("thinking and writing activities".)

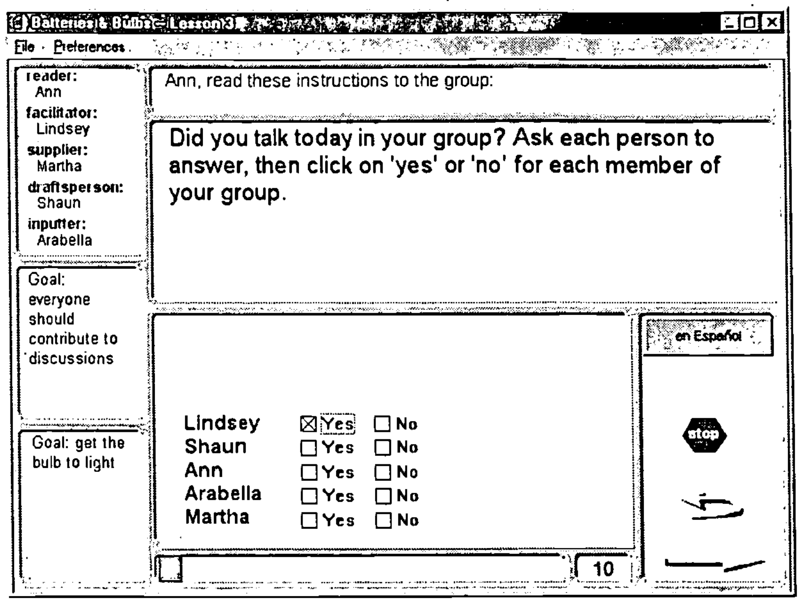

Figure 10. This extension screen reinforces the social goal provided earlier in the lesson.

Expansion activities provide students with opportunities to reinforce their learning in a variety of ways. They were designed to appeal to students with different learning modalities, and to bring out the creativity in students. Also, the use of these activities ensures that no matter how much time the teacher has allocated to the day's science activity, there will be enough material that all groups will continue to be occupied in a productive learning activity. Because there can be such a great variation in how much time different groups require to complete the lesson, the expansion activaties ensure that all groups will start at the beginning of the next lesson the next time they use the software. This design prevents teachers from requiring students to come in during lunch or recess to complete work, or assigning the work to be completed at home. Instead, it is impossible for any group to ever complete all of the possible "work" for a lesson, and in our tests all groups finished the core materials on every lesson. If, for some reason, a group did not complete the core screens, the next time they start up the software they would be given the option to complete the activity, and the software would start on the last screen that they used. Thus, if the science lesson gets interrupted (say, by a fire drill), students can pick up where they left off the next time they use the program.

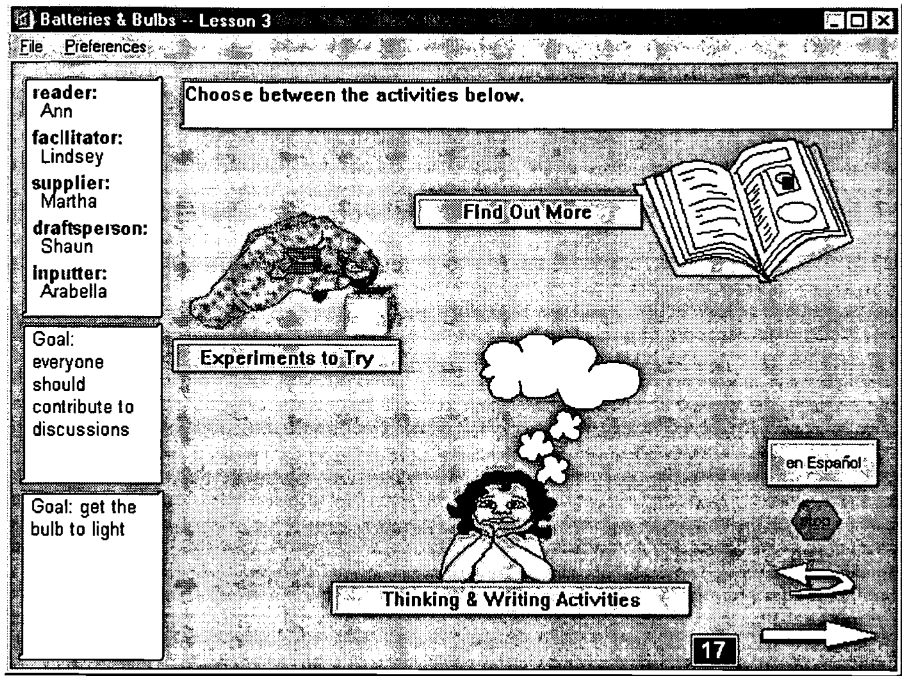

Figure 11. The expansion activities always include three types of activities.

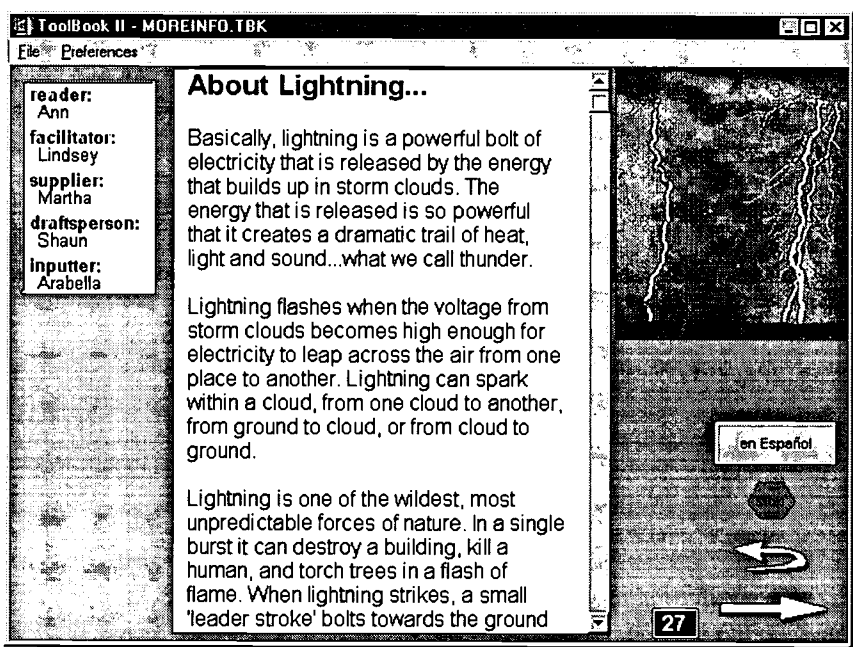

Figure 12. The "find out more" option provides students with topics related to electricity that are interesting to students of this age.

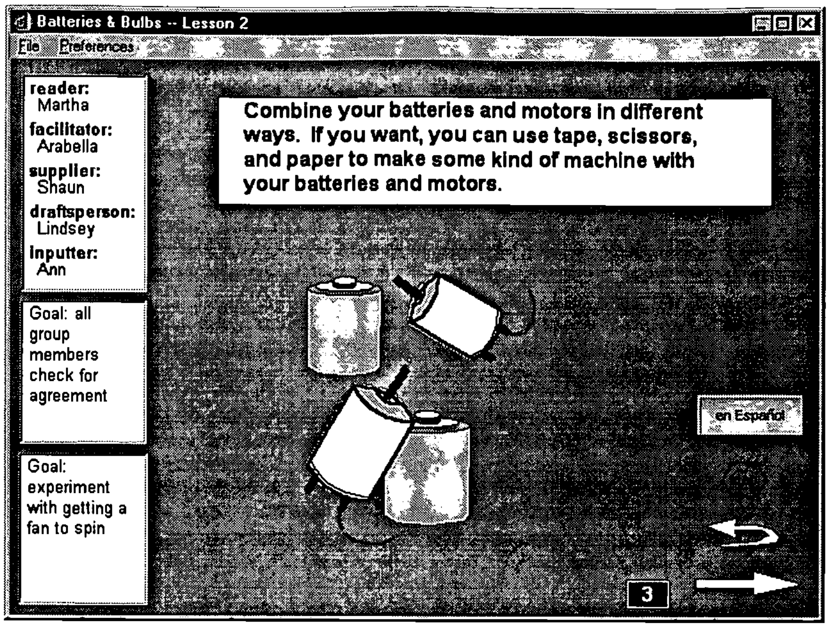

Figure 13. "Experiments to try" provides an experiment that is related to the lesson for the day.

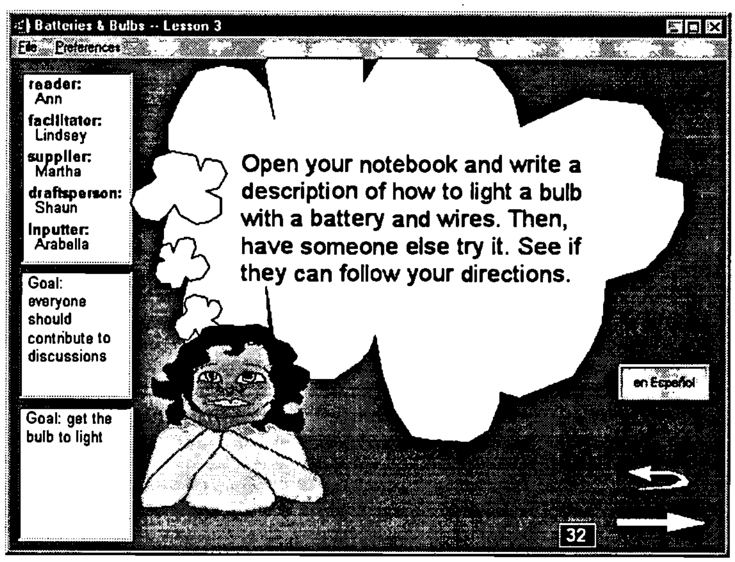

Figure 14. "Thinking and writing" activities provide students with opportunites to do additional thinking, discussing, and writing.

Student workbooks are designed to go along with the lessons, with spaces for students to write in the responses to questions and to draw sketches or keep notes. The pages of the notebook that were used for this study are included in *Appendix D.*

It is possible for a student who needs reading assistance to gain this help by clicking on the top left key of a serial keypad. These devices are readily available, cost between $20 and $50, and are simple to install. The student clicks the key, and either hears the sound through ear phones (as did Carrie,

Figure 15) or listens, with the group, to the sound through speakers for the group to hear (as with Gary.) This feature is enabled or disabled by the teacher when she enters information for each student. Thus, a student who does not need this assistance could not accidentally activate this feature. We also defined the keyboard ESCAPE key to perform the same function, for classes in which no keypad can be provided. As this key is at the top left of the keyboard and thus out of the way for the inputter, it is unlikely to cause keyboard control problems (although we didn't test this assumption.)

Figure 15. Carrie, a non-reader, uses the keypad to have the computer read aloud to her; she then repeats what she has heard to the other students.

Visually impaired students can have the screen that they are reading enlarged by the inputter. The inputter just needs to double-click the text that needs to be enlarged, and the text field will take over the entire screen, with the letters presented in 40 point font. The background and foreground colors can also be changed for students that have trouble seeing white on black or black on white. A single click on the enlarged field brings it back to normal size. For the final release version we also plan to have the screen text typeset in Braille. We have not tested the software yet with blind or visually impaired students.

The teacher has a complete manual designed to be used with the lessons (see *Appendix E* for the pages for the lessons used in the beta test.) This manual provides them with ideas to use during the introduction and wrap up for the lesson, lists the academic and social goals, and provides a materials list for supplies for the lesson (although the lessons are designed so that each group can keep a kit with the supplies needed for all the lessons, taking out only those supplies needed for the day's lesson.)

To set up the groups in the software, the teacher chooses "Add a group" from the teacher support menu and types in the name of the group. She will be presented the screen shown in Figure 16, where she can enter information including name, disabilities (if any), and special selections (computer reads test, student is an assistant, student is assigned another to assist him or her.)

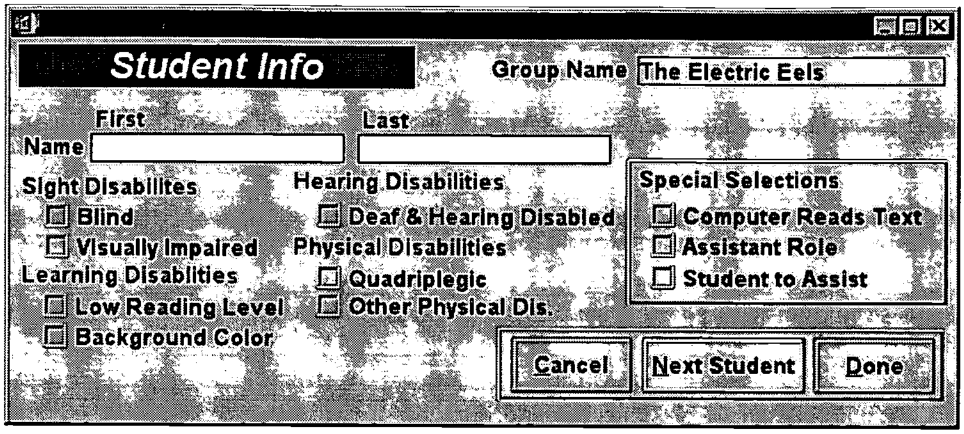

Figure 16. Teacher menu for setting up student information.

Settings for an individual student or a group can be changed at any time. Another screen permits the teacher to make changes at the group level. A "drag and drop" feature makes it easy for the teacher to move a student from one group to another (Figure 17) simply by clicking on the name, dragging it to another group, and dropping it. The software keeps track of group information in a database, and the teacher can set groups up on one computer and then copy this setup file onto a floppy disk and move it easily to other computers. If the classroom has a network, the setup file can stay on the file server for all the groups to access. If one computer is used by more than one group, the teacher enters the information for the groups, and the students select their group from the list of groups (see Figure 4.) Another set up option (Figure 18) permits the teacher to use a drag and drop interface to set up the initial role that each student will fill, and to determine the order of rotation. This ensures that the teacher can avoid bad combinations (such as a poor reader in the reader role and a poor writer in the draftsperson role on the same rotation.)

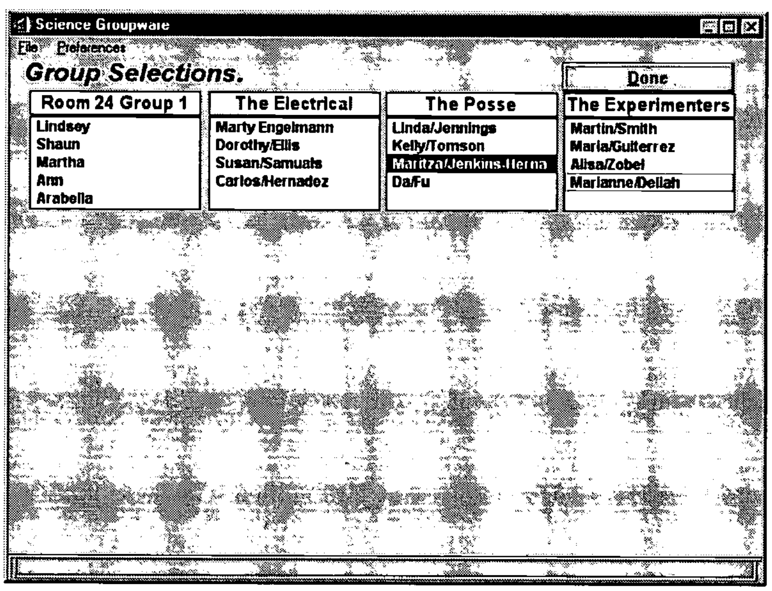

Figure 17. A drag and drop interface makes it easy for the teacher to move students from group to group.

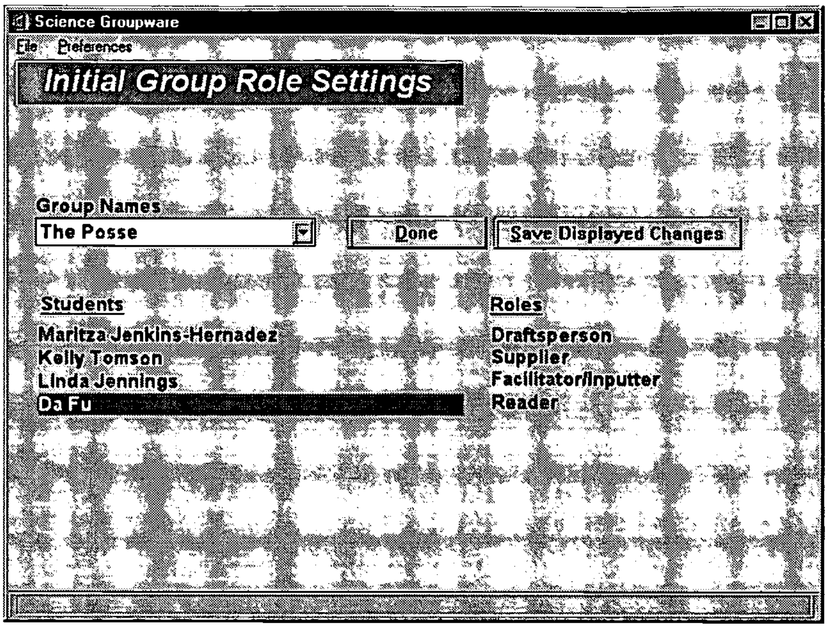

Figure 18. A drag and drop interface permits the teacher to set up order of rotation and initial roles for students in a group.

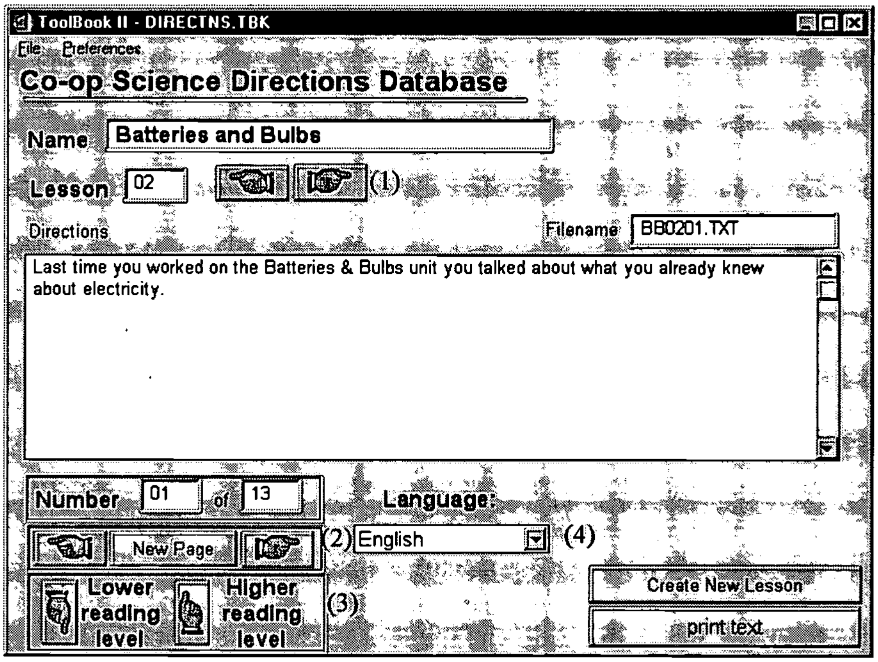

Figure 19. The input screens for text entry make it easy to modify text or add reading levels or languages.

The data entry program for the text of the lessons permits the instructor to modify text for a lesson. The instructor can flip through the lessons (1), and through the steps (or pages) in the lessons (2). Higher and lower reading levels are accessed using buttons (3) and the language of the body text can be entered in the "language" drop down box (4). Currently the software is configured to support two reading levels and two languages, although this can be easily modified in subsequent versions if it becomes desirable.

2.2.5 Research Design

The research process used was essentially a formative evaluation process. Software was designed using a multi-stage, iterative process using intensive research techniques to determine the needs of a particular group. This process of research and software design is a key innovation of our software development company. As part of the process, we study the environments under which the software will be used, paying close attention to the social interactions in the environment. All of our software is developed by applying theory to the application. It is our goal to create software with these characteristics: it provides an environment which enhances the effectiveness and efficiency of the user; it is easy to use; it is open-ended, allowing the user to modify or make changes as needed; it is based on research into the needs and constraints of use particular to the end-users. This method of development, although time consuming, has allowed us to develop truly innovative software applications that are both powerful and easy to use. Software developed through study of the environment it will be used in leads to a software design that is natural and familiar to the end-user. The stages in our design process are:

Analysis: develop a clear understanding of the constraints under which the end-users will utilize the software and their particular needs and goals

Design and Develop: work with a design team to develop interfaces that meet the needs of these end-users, utilizing rapid prototyping techniques

Formatively Evaluate: the interface and support materials (manuals, on-line references, help files)

Re-design and Develop: until evaluation shows product meets the needs of the end-users

Summatively Evaluate: release beta version and gauge public response

During the Phase I of this project we completed the first three stages of the process. In the first stage (analysis) we developed a clear understanding of the needs of the end-users. This stage culminated in the creation of a technical specifications document. The second stage (design) consisted of developing the interface design specification and a prototype of the interface features. The third stage (formative evaluation) involved testing the beta version with end-users that typify those that would use the finished product. The final stages will be included in Phase II of the project.

The analysis stage of the project used two means of determining the features that should be supported in the software: (1) interviews of exemplary teachers that already facilitate communication between disabled students and their peers, finding out what types of technology, media and techniques have proven useful in assisting students develop communication skills, and (2) a thorough review of relevant research literature. The literature review was reported in previous sections of the report, and assisted us as we developed a technical specifications document and prototype design for software effective within the constraints imposed by the environment under which it would be run.

Analysis Stage

During the Analysis stage we developed a list of the key elements essential for effective cooperative efforts between students with disabilities with their non-disabled peers. This list, Table 5, guided the software development, providing constraints and material for the concepts. The list was obtained from a thorough review of the related research literature, which suggested key areas of concern for the interface development and through observations of exemplary teachers. This software must provide support for a wide variety of learners, as well as support the needs of instructors new to cooperative learning or working with students with disabilities. The list of design features was determined using these research methodologies:

Review current research on adaptive devices used by students with a variety of disabilities to determine how these devices might be used in conjunction with, or integrated into, the proposed software.

To answer these research questions:

- What is the current state-of-the-art for computer software used by students with a range of disabilities?
- What is the current state-of-the-art for adaptive devices used by students with a range of disabilities?

Using these analysis methodologies:

- Library research and literature review

Analysis provided:

- A list of adaptive devices to be evaluated for support inclusion into the software program (Table 2)

Review current research on development of communication skills by students with disabilities

To answer these research questions:

- What are the nature of difficulties encountered by students with various disabilities as they attempt to communicate with their non-disabled peers and teachers?
- What techniques and adaptive devices have been shown to effectively assist disabled students as they attempt to communicate with their non-disabled peers and teachers?

Using these analysis methodologies:

- Library research and literature review

Analysis provided:

- A list of key elements to consider during the interface design phase of the project (see Table 3)

Review current research on group learning (collaborative group work and cooperative learning)

To answer these research questions:

- What characterizes effective collaboration?
- What aspects of group collaboration are likely to prove to be difficult for students with disabilities?
- What aspects of group collaboration are likely to prove to be difficult for teachers to implement as they attempt to integrate students with disabilities in with other students in learning groups?

Using these analysis methodologies:

- Library research and literature review

Analysis provided:

- A list of features to evaluate for inclusion into the software development project (see Table 5).

Observe in exemplary classrooms where teachers have successfully implemented classroom management techniques and technologies that foster communication between students with disabilities and their non-disabled peers

To answer these research questions:

- What types of classroom interaction between the disabled students and their peers and teachers can be observed?
- What methods are used by the teacher to include disabled students in the classroom activities?
- What difficulties does the teacher encounter when implementing curriculum that makes it difficult to provide support for her disabled students?

Using these analysis methodologies:

- Ethnographic field study techniques combined with ethnographic in-depth interviewing techniques

Analysis provided:

- Examples of problems that exemplary teachers experienced when attempting to integrate disabled students into the classroom

- Suggestions from classroom teachers for software features that would be beneficial to the setting
- Lists of actions that the teacher performs that could be better handled by a computer, freeing the teacher up for more interaction with students
- Lists of actions that students perform that prevent clear communication between peers, that could be better handled by a computer

Results of this research are presented in the *Results* section of this report.

Write a preliminary technical specifications document that lists the necessary conditions and constraints of use as determined from the research in steps one through five above.

To answer these research questions:

- What are the major functions that this software will need to perform?
- Under what conditions will the software be used, with what expected outcomes for students and teachers?
- What aspects of collaborative work can be well supported by such software?
- What aspects of integrating students with disabilities can be supported by such software?

Using these analysis methodologies:

- Review of the outcome from steps above and meetings with the software design team.

Analysis provided:

- A technical specification document with feasibility questions to be addressed by the software design team (see *Appendix B*).

Design Stage

During the design stage we developed a design that met the needs of students and teachers in the classroom. This stage culminated in a software interface design, ready to be tested in the classroom (for the results, see the *Software Design* section of this report). The design evolved as the design team met weekly to discuss ideas and review the current prototype. Design sessions each began with a review of the previous session and then all participants examined the current prototype on the computer. Next, brainstorming activities, coordinated by the P.I., helped focus the group on the key issues from the technical specification document. Different ideas were discussed, and group participants voiced opinions and developed new sketches. Then the programmers divided up the new interface ideas and worked at the computer developing prototypes of the new screens. These prototypes were then viewed at the beginning of the next meeting. The design team consisted of programmers, subject matter specialists, interface design specialists, learning specialists, classroom teachers that have faced the difficulties of integrating disabled students into the mainstream, and a graphic artist.

The tasks were:

Identify members to act as beta test site participants.

Task description:

- Based on the profile of the "typical" end-user, identify between four and ten end-users willing to participate in a beta test of the software.

Using these technical tools and methods:

- Contact school personnel including teachers, principals, and administrators to identify twelve potential participants for the beta testing
- Identify "typical" end-users for testing the prototype. These users should include exemplary, experienced teachers as well as teachers new to cooperative learning, new to computers, and new to the concepts of integrating students with learning disabilities into the classroom
- Request permission to seek assistance from these teachers
- Contact the selected teachers and determine their schedules, willingness to participate, and current classroom conditions

Results:

Because of the difficulties in scheduling, and the problems in finding enough computers in the classroom in order to complete the beta tests within the time of Phase I of this project, we chose to pull out students from the classes and individual groups in a setting other than the classroom. In all but two of the cases, the special education teachers were available to interact with the students. In the other two cases (in Davis) one researcher took on the role of authority figure for the students. In no cases were the classroom teachers available to run the sessions. However, we do not feel this was a severe limitation on the study, as even in a classroom setting teachers typically spend little time with any particular cooperative group. In essence, rather than testing the teachers' ability to manage these groups, we tested the students' ability to manage themselves. Results of the analysis of student interactions are reported in the *Results* section of this report.

Create a list of the features that must be included in the software and develop the software prototype

Task description:

- Using the technical specifications document written during the Analysis Stage above, the design team will brainstorm and create a list of the features that must be included in the software design.
- The design group will generate rapid prototypes of the software designs as they are developed.

Using these technical tools and methods:

- A rapid prototyping will be performed on the IBM PC Windows platform using Asymetrix ToolBook as a programming environment. This permits nearly real-time visualization of the function and structure of the resulting application.
- The prototypes will be shared with others, including those identified as beta team members, for review.

Results:

This task was completed successfully, and the prototype was developed.

Design the beta version of the software, using the prototypes developed during the rapid prototyping stage.

Task description:

- Develop a beta version of the software

Using these technical tools and methods:

- Using a lower level programming language (C++, Visual Basic, or Java) or cleaning up and optimizing the routines developed in the higher level programming language used during the prototype phase, design a working beta version of the application, programming each of the subroutines that have been identified for inclusion in the first beta
- Focus first on the "core" routines, leaving other routines for later development.

Results:

This task was completed successfully, and the beta test was then conducted. Many of the core routines were created and will be used in subsequent versions of the software.

Formative Evaluation Stage

During the formative evaluation stage, we made use of beta reviewers to test the software. During this phase we closely observed the actual usage of the interfaces by potential end-users of the product in the classroom setting to see how well it met their needs and performed to expectations. We examined ease of use issues and looked for programming problems (bugs). Steps involved were:

From a list of potential end-users of the product and possibly those used in step one of the design phase, review the current beta software by testing it in real world conditions.

To answer these research questions:

- Does the software work in the expected ways under the conditions that it was designed to operate?
- What unexpected outcomes, if any, arise from the human computer interface?
- What features of the software need additional work in a redesign effort?

Using these analysis methodologies:

- Situated observations at the sites of use, analyzed using ethnographic research methodologies including conversational analysis
- Computer interaction collected automatically by the software for testing purposes and subjected to a statistical analysis

- Interviews with the beta test participants, including students and teachers, analyzed using ethnographic research methodologies

Analysis provided:

- A list of features that need to be re-evaluated
- A list of bugs in the software that need to be fixed
- A list of desired changes and enhancements from the participating beta test users

2.3 Procedures

First, the administers in the two school districts used in the study were contacted by the researchers. In the Lompoc district, the Superintendent was met with. The meeting took one month to arrange, due to her busy schedule. She was told about the general goals of the project and the type of interventions that would be used. The Superintendent then identified the schools with inclusion programs, and directed the researcher to the administrator in charge of Special Education. A meeting with the Special Education director was subsequently scheduled, and he was given a copy of the research proposal for review (by the researcher) prior to the meeting. It required a two week delay in order to fit the meeting into his schedule. At the meeting he admitted to not having had time to read the proposal, and so the researcher provided an overview of the project. He then identified a school with students appropriate for the study, and promised to contact the principal of the school. This required another month, as the principal was also involved in organizing some district level events and did not have much available time. Eventually the teachers were contacted, and asked if they were willing to participate. Four special education teachers and eight classroom teachers were identified, and observation dates and times were arranged. Eventually, times for interviews were scheduled, and then, finally, the students and facilities for the beta test were negotiated.

The process was similar for the Davis school district; however, the superintendent was not met with. Difficulties in obtaining a meeting with the administrator at the school level in charge of special education almost necessitated eliminating the district as a testing site; however, at the last minute the arrangements were finalized, and the teachers and students became available for observation. Fortunately we had started the process of obtaining entry at the very beginning of the project, or we would have never been able to complete the process within six months. As it was, we were forced to change the schedule of beta testing to dates a month later than originally planned, as illnesses (with our staff, students, and teachers) made it impossible to complete the tests on time. Also, the Christmas season caused the classroom schedules to become so chaotic that the teachers and researchers agreed that postponement until late in January would be preferable.

Student groups were identified as participants for the study, as discussed in the *Participants* sections of this report. In Lompoc, two special education classroom were made available as sites for running the beta tests. In both cases, the tables used were part of the regular furniture of the classroom. In the deaf and hard of hearing classroom, a back corner of the room was utilized; the noise of the groups was not a problem for the other students, whose desks faced in the other direction, as they could not hear it anyway. For the other groups, a time was found when the room was not used for other purposes. In Davis, the computer lab had been designated as the site for the study, but when we came to set up we discovered (1) the computers in the lab were not compatible with the beta version of the software (which is currently PC Windows only), and (2) the computers were so close together that there was no way for students to interacte and use hands-on materials. We quickly looked for another site, but as this study took place the same year that class size reduction measures began in California, classroom space was at a premium. By far, the largest "open" space on campus was in the library. We discussed our situation with the librarian, who agreed to allow us to use a table in there during the first day of the beta test. We set up, and then asked it might be possible to spread out to two tables; she agreed. On the second day, we had still not located another suitable site, and although the librarian had many other things going on at the same time, she permitted us to once again use the tables. By the third (and final) day of the study she had become resigned to our presence, and we were permitted to set up our equipment.

In all cases we attempted to minimize our impact on the environment as much as possible. All equipment was carted in, set up, and then carted out of each classroom between sessions, leaving no trace of our intervention. We were careful to provide easy access to cabinets, counters, etc. that the teachers might need access to while we were there in order to minimize impact. A minimum of one half hour was required to set up the equipment each day, because we had two computers (with monitors, keyboards, headphones, keypads, speakers, mouse, and the large bundle of cables necessary to connect all of these devices.) In addition, we had recording equipment (stereo tape recorders with lapel microphones, video cameras, etc.) that needed to be set up, requiring more cables, tapes, and tripods. Power cables were taped to the carpet as a safety precaution.

We attempted to obtain tape recordings of the talk of the disabled student in the group using a lapel microphone, so that we could easily separate out the voice of this students from the others. We also obtained a recording of the group as a whole, and a video tape (with a sound track) of the group interacting. In all, our goal was to obtain seven different records of the student interactions in each group: two audio recordings, one audio-video recording, one set of field notes, student notebooks, and a set of computer traces (which kept track of student input as well as what screen the students were on, and for how long). In reality, the redundancy was not always possible. In one case, the disabled student was so distracted by the recording device that we could not use it with him. In two other cases, students fiddled with equipment when the researcher was not watching, turning off microphones and thus eliminating the data source. In four other cases equipment or researcher problems caused some potential data to be lost (no video tape brought for one session, tape ran out without being replaced in three cases.) Although the desired redundancy was not available in all cases, some recording for every session was achieved. Redundancy allows the researcher to be certain what was said (as if it can not be heard from one audio source, it can be from another) and who it was said by (a video recording assists greatly, but often the video is blocked by a student, or a student has his or her back to the recorder, etc.)

These tapes were listened to, and counts of different types of interactions were created to obtain statistical data. Also, portions of the tapes were transcribed to provide examples of the different types of interactions being observed for during the beta tests.

Prior to the beta test, many of the students used in the tests were observed in the classrooms as they interacted with peers and the teacher. The results of these interactions are also reported in the *Results* section. Field notes were taken during the observation periods, and counts of specific behaviors were made. In a few cases, audio tape recordings of the classroom were made, but these were not necessarily useful for counting.

The classroom teachers and special education teachers were met with throughout the study to triangulate the data. For example, the researcher might say "When I was in the classroom today, I noticed that Kathy seems to keep to herself most of the time." and the teacher would reply "Yes, but out on the playground she talks up a storm!" or whatever. This type of triangulation assists in getting to know the range of student interactions and the particulars about each student. In the case of students in Lompoc, the special education teachers have long histories of knowledge about the students, as they frequently have worked with them for many years. In the case of the deaf students, the teacher has had many of her students from the time they were three or four years old.

3 Results

I walked down the elementary school hall with Mr. Smith, a fifth grade teacher, discussing the software we were developing. "Well, what I don't understand", he finally blurted out, "is why bother? I mean, hands-on science is probably fun for students, but it just takes so long. It is so much easier to just *tell* them something than to wait for them to *discover* the same thing. We will never cover the curriculum if we do science hands-on!"

This conversation reminded me of how far we still have to go in providing teachers with opportunities to understand the purposes of science education. As a researcher who has not had to shoulder the responsibility of day-to-day teaching in many years, it is easy for me to forget the pressures that teachers face in "covering curriculum". At the elementary school level, science education is just not valued as much as language arts, social studies, and mathematics. Mr. Smith was expressing a genuine puzzlement over basic purposes in changing teaching methods. His question boils down to: Why bother?

Veteran teachers love to talk about "educational fads" amongst themselves. Basically, an attitude of "pretend to adopt the new methods while continuing to use the old methods until the pendulum shifts back this direction" is employed by many teachers. Why? Because this method of managing the ever-shifting tide of educational theory is a useful means of surviving. Witness the recent set of changes in reading teaching. For a number of years the phonics methods were dropped in favor of whole-language literature. Currently there is a national move back towards the use of phonics teaching methods for language arts.

Really what it comes down to is that any given teaching method is likely to be optimum for some students while not for others. Thus, the gains experienced by shifting from one teaching method to another can be felt by a subset of the students in the class, while at the same time some of the students in the class will do less well. Unfortunately, the effects of a major shift in teaching methods (such as from phonics to whole-language approach) can take years to appreciate.

If we are going to require teachers to make a shift from a comfortable, known method of teaching a subject to a "new", more time-consuming method, we, as researchers, should be absolutely certain that this shift is actually beneficial. Too often in educational research we confuse statistically significant results with educationally significant results. If there is only a 5% gain in learning by switching to a different method, yet the new method requires lots of time, new materials, and rearrangement of the classroom by the teacher, then is the new method worthwhile? Probably not.

Unlike many other "improvements" in educational content, hands-on science has been shown to be beneficial for all students. Meta-analyses, as reported in the *Problem* section of this report, have shown overwhelmingly positive differences between academic gains in science made with hands-on science curriculums over traditional learning. And, meta-analyses on cooperative learning student management methods, as reported in the *Results* section of this report, have also shown students have great improvement in academic gains over "traditional" methods of teaching. Most importantly, the gain in academic scores average 30% across studies, and gains have been shown for *all* students, with the most notable gains for those students normally are the least successful in school (minority students, students with disabilities, girls in science education.)

In the case of this software, which can create a new environment for the students and teacher, we are making more than one methodological switch simultaneously. "Traditional" teachers, such as Mr. Smith, generally teach science using lecture methods. With this software we are promoting splitting students into cooperative learning groups and using hands-on discovery methods in science. In order to promote these changes in classroom, we must provide a high level of support to the students, which, in turn, provides the support necessary for the teacher to make these teaching method shifts. In this section I report the findings from this study, answering the questions posed (for a summary, see Table 6, page 21.)

3.1 What Types of Classroom Interaction Between the Disabled Students and Their Peers and Teachers Can Be Observed?

In this section I report the types of interactions observed between the disabled students and their peers and teachers within their inclusion classrooms (in which they spent all or part of the day) and also within the cooperative group setting provided during the beta test of the software. The observations in the classroom were made at the invitation of the teacher, and may or may not be indicative of the types of interactions experienced throughout the day or the year by the students observed. No inferences can be made from the statistical count data presented in this section, as the data does not satisfy the assumptions for statistical tests (random group assignment, control groups, large enough sample size); also, the total number of observations and length of time spent in the classroom does not provide a large enough set of information gathered over a long enough time to do a complete ethnographic study. Thus, the data presented here is provided to assist the reader in gaining a better understanding of the settings in which students were observed and in seeing potential trends in the differences between the regular classroom environment and an environment in which students work cooperatively.

3.1.1 Students Observed Within Their Inclusion Classrooms

In the Lompoc school district, the students involved in the study were mainstreamed into the classroom for part of the day. In the Davis district, the students are mainstreamed for most or all of the day. In the classroom, we observed to obtain information about the students and their interactions between peers and teachers. For each student observed, we counted the number of utterances of different types, as reported in

Type 1 (T-S): Student to teacher, initiated by teacher (includes directives and correcting)
Type 2 (S-T): Student to teacher, initiated by student. (includes callouts, approaching, raising hand when no teacher question is raised.)
Type 3 (S-S): Student to student, sanctioned by teacher (group work, partnered work, etc.)
Type 4 (OT): Student to student, not sanctioned by teacher (off task talking).

3.1.1.1 Mr. Anderson's Classroom

Table 10 presents the results of five days of observation of four target students (Ianna, Justin, Kyle, and Lonnie) in Mr. Anderson's classroom. The teaching method in most used during observation was direct instruction with the teacher asking questions and evaluating student responses, and paper and pencil individualized exercises.

Table 10. Count of student utterances in Mr. Anderson's classroom by opportunity type.

Day:	Type 1	Type 2	Type 3	Type 4
1	2	4	0	6
2	10	4	0	8
3	11	5	0	30+
4	0	2	0	Talking permitted
5	4	2	0	13
Total:	27	15	0	61+

Day:	8:30	8:40	8:50	9:00	9:10	9:20	9:30
1	Hm Rm	Silent Reading	Guest Speaker from Davis Waste and Recycling				
2	Hm Rm	Handwriting		HW Ck	Lesson Review	Drill and Practice	
3	Hm Rm	Silent Reading	HW Ck	Spelling Test	Pop Quiz	Review	
4	Hm Rm	Silent Rdg.	Lecture	Physical Education			
5	Hm Rm	Library Visit		Silent Reading			

Figure 20 . Class schedule during observations in Mr. Anderson's classroom.

Discussion of type 1 (T-S) interactions: Mr. Anderson circulates between desks to check homework completion. This provides a one-on-one interaction with the teacher. Also, during lessons this teacher maintains a control over questions and answers, calling on students randomly to maintain attention. Students such as Justin, Kyle and Lonnie an opportunity to participate, as they would probably not volunteer answers.

Discussion of type 2 (S-T) interactions: During Home Room, Mr. Anderson welcomes students to approach him with questions. Ianna readily utilizes this time, but as she will keep an exchange going as long as she can the teacher redirects her after a few sentences. Justin and Kyle rarely initiated an exchange with the teacher, though Lonnie would cross the room to approach the teacher to ask permission to leave the room, or for a repeat of information.

Discussion of type 3 (S-S) interactions: Mr. Anderson did not use small group or paired work at any time during my observation. During the 30 minute PE period, conversation was not discouraged.

Discussion of type 4 (OT) interactions: Student to student initiated conversation is frequent in this classroom. Ianna converses regularly with her neighbor. While Justin was not seen chatting with others, Kyle and Lonnie sit at the same table with three other boys, and are regularly conversing. Note: One day with about 30-35 minutes given to silent reading, these two took about 20 minutes to settle down to it, but they both did eventually and sustained silent reading for 10-15 minutes.

3.1.1.2 Mrs. Brannon's Classroom

Table 11 presents the results of counts of speech uttered by the studied students in Mrs. Brannon's classroom. The primary mode of instruction was individualized reading for information, group hands-on math, and whole-class discussion and multiple-answer questions in social studies.

Table 11 . Count of student utterances in Mrs. Brannon's classroom by opportunity type.

Day:	Type 1	Type 2	Type 3	Type 4
1	0	0	0	1
2	0	5	0	1
3	2	2	0	4
4	1	3	0	1
5	2	6	0	1
Total:	5	16	0	8

Day: 8:30 8:40 8:50 9:00 9:10 9:20 9:30

Day				
1	Social Studies	Music	Dance	
2	Social Studies	Lecture	Math	
3	Math Test	Assembly		
4	Social Studies	Silent Reading	Math Test	
5	Silent Reading	Social Studies	Review	Math Test

Figure 21 . Class schedule during observations in Mrs. Brannon's classroom.

Discussion of type 1 (T-S) interactions: During Social Studies, this teacher initiated several whole-class discussions, using open and closed questioning techniques. While she makes these opportunities available, it appears that the special needs students in her class are not inclined toward participating in this format. The teacher stated in interview that she does not believe in putting children "on the spot," so she does not call on students if they do not have their hands raised.

Discussion of type 2 (S-T) interactions: This teacher circulates during seat activities, as math lessons generally are. In this way, she is accessible for student-initiated interactions. Doug takes these opportunities often, sometimes crossing the room with a question, rather than raising his hand and asking from his seat. Carrie, however, does not instigate interactions with the teacher.

Discussion of type 3 (S-S) interactions: During this week's math exercises, the teacher was experimenting with inviting tables to work together as a group. While most students chose to work in the group format, Doug chose to work alone, and was firmly focused throughout the series of activities. Carrie also worked alone, though she would occasionally look on without speaking as her other two tablemates worked together.

Discussion of type 4 (OT) interactions: Off-task interactions in this classroom are relatively low in general. This teacher was observed to have a discipline system that is swift and sure. Most off-task comments occur during transitions between subjects; the trickiest times for these particular special needs students, as observed by the teacher. The comments for Carrie and Doug are usually to each other, as they sit side by side. The teacher pointed out that she found that each is the only student that will tolerate the other.

3.1.1.3 Mrs. Calle's Classroom

Table 12 presents the results of counts of speech uttered by the studied students in Mrs. Calle's classroom. The pimary modes of instruction were direct instruction, multiple-answer questioning, paper and pencil exercises and small group hands on experiments.

Table 12. Count of student utterances in Mrs. Calle's classroom by opportunity type.

Day:	Type 1	Type 2	Type 3	Type 4
1	2	0	0	0
2	3	2	Continual	4
3	6	4	0	4
4	2	9	0	2
Total:	13	15	0 + 1 day	10

Day:	9:30	9:40	9:50	10:00	10:10	10:15
1	HW Rev.	Video			Activity	
2	Set up	Review	Experiment			
3	Review	HW Rev.	Discussion	Story		
4	HW Rev.	Video			HW catch-up	

Figure 22. Class schedule during observations in Mrs. Calle's classroom.

Discussion of type 1 (T-S) interactions: This teacher has a question and answer review of homework and recent lessons regularly. Questions usually have several possible answers or are paragraphs in the student's own words. Carrie only occasionally offers input, and sometimes is called on without raising her hand, a technique the teacher uses with most students. Doug pursues these opportunities to respond.

Discussion of type 2 (S-T) interactions: This teacher is accessible and responds to call outs and approaches. During the video series that she shows weekly, she encourages students to visit her to review work. Carrie asks for information repeats occasionally; Doug often crosses the room with a question, instead of raising his hand and asking from his seat. He will also stand near to chat with her on during the video, which she will redirect after three or four of his comments.

Discussion of type 3 (S-S) interactions: One day of this teacher's four-day schedule as a small group experiment period. Students work together on a problem with their table groups. Doug and Carrie sit side-by-side, and work together with two other table mates. They share continual discussion and negotiation, regarding both the experiment and the interpersonal aspects of carrying it out. Nathan was also completely engaged, and included in his table's work, with his aide at same table to support him.

Discussion of type 4 (OT) interactions: In this classroom, off task discussion is at a minimum, possibly stemming from the active environment and the random questioning technique used by the teacher. Also, students generally appear engaged in subject matter.

3.1.1.4 Mrs. Thomson's Classroom

Table 13 presents the results of one day of observation of three of the target students (Ellie, Frank, and Gary) in Mrs. Thomson's classroom. The teaching method most used in the classroom is learning centers. Students are grouped with other students working on the same problem (or, are assigned to assist students working on an assignment.) Students have individualized work assignments to which they are held accountable, but are encouraged to discuss work with other students in the classroom and to request assistance. Students have been taught to avoid "giving" answers, but to give "clues" or "hints" instead. Mrs. Thomson models this behavior for students. Students that have completed all of their work assignments may be given extra work to complete. All students are expected to complete math "mind bender" puzzles.

Table 13. Count of student utterances in Mrs. Thomson's classroom by opportunity type.

Day:	Type 1	Type 2	Type 3	Type 4
1	0	4	continual	0

Discussion of type 1 (T-S) interactions: Mrs. Thomson works with small groups of students, sometimes at front of the classroom using the overhead projector, explaining how to complete an assignment (such as explaining the process of long division to a group of students having difficulty.) She keeps a close eye on the other groups, occasionally calling out comments such as "Maria, are you done? Do you need help? No? Then why not see if you can help Juan finish." She keeps a fluid motion of student groups moving from one learning center to another throughout the day. The groups themselves change frequently as she reassesses student needs. A section of the blackboard contains the names of students, grouped and with a title informing them what they need to accomplish. The groupings may be persistent, lasting for weeks, or may change during a lesson period. Even during a certain subject period, such as mathematics, some groups may be completing work from another subject, such as social studies. None of the target students were in the groups working with Mrs. Thomson during the day that the count was made.

Discussion of type 2 (S-T) interactions: Frank had many questions for the teacher, but little opportunity to ask them. All of the other target students were engaged in learning activities that involved at least one other student and did not have much interaction with Mrs. Thomson during the observed period.

Discussion of type 3 (S-S) interactions: Students in Mrs. Thomson's class are encouraged to discuss their work with other students. Elle was observed working with math manipulatives for over an hour with another (regular ed) student. During that time they engaged in constant talk, discussing which manipulatives to use, negotiating turn taking, etc. Frank was primarily working on his own, finishing a social studies report. He had many questions and asked anyone who might answer, preferring to talk to adults (he approached the researcher frequently, even though she told him she could not answer his questions). He approached the teacher four times; each time she redirected him to find the answers on the map or in his book. Gary worked with a group of other students. The other students did not pay much attention to him, and he mostly sat and smiled, occasionally adding comments to the conversation about math that they were having.

Discussion of type 4 (OT) interactions: Students are encouraged to talk in the classroom, and virtually all conversation observed was on the subject that the students were studying.

3.1.1.5 Mrs. Davidson's Classroom

Mrs. Davidson uses cooperative learning in her classroom on a regular basis. Her classrooms was one of the first we observed in, and we visited her classroom for three days. We did not perform a count of the number of interactions of the different types, and had only one student being observed (Allan). Allan seemed to interact with other students regularly, and his handicap was not readily apparent. The methods of teaching we observed with Mrs. Davidson were direct instruction (science) and cooperative groups (social studies).

Discussion of type 1 (T-S) interactions: During direct instruction, Mrs. Davidson called on students whose hands were raised. Allan did not volunteer to answer any question during the observed periods.

Discussion of type 2 (S-T) interactions: During none of the observed periods did Allan initiate interactions with the teacher. However, other students were observed to do so.

Discussion of type 3 (S-S) interactions: While engaged in cooperative group work students spent a great deal of time talking to each other about the topics being explored. Allan was observed to be engaged in these activities. Students were not assigned roles as they were in our beta test, but were assigned to produce a group product (group accountability).

Discussion of type 4 (OT) interactions: Very little off-task talking was observed in this classroom, except during transitions between lessons. However, Allan was more engaged in gathering materials needed to go back to the special education classroom to work on his mathematics, and was not seen to engage in this talk.

3.1.1.6 Mrs. Evan's Classroom

Mrs. Evan uses direct instruction methods as her primary mode of teaching. Her classrooms was one of the first we observed in, and we visited her classroom for three days (illness of the teacher prevented us from completing a longer observation period). We did not perform a count of the number of interactions of the different types, and had only one student being observed (Belinda). Belinda did not interact with other students during our observations. The methods of teaching we observed with Mrs. Evan were primarily direct instruction across subjects and individualized desk work.

Discussion of type 1 (T-S) interactions: During direct instruction, Mrs. Evan alternated between calling on students whose hands were raised and calling on students who did not volunteer to respond. Belinda was called on once, and the teacher repeated the question directly to her. She responded very shortly, and the teacher did not redirect back to her to elaborate.

Discussion of type 2 (S-T) interactions: During none of the observed periods did Belinda initiate interactions with the teacher. However, other students were observed to do so.

Discussion of type 3 (S-S) interactions: There was no sanctioned time for students to talk to each other during our observation periods.

Discussion of type 4 (OT) interactions: Very little off-task talking was observed in this classroom. Students seemed very intent on completing their desk work.

3.1.2 Students Observed During the Beta Test of the Software

In addition to the talk of types 1 though 4 observed for in the classrooms, we broke down type 1 interactions (teacher to student) and type 3 (student to student) into subtypes which we observed for during beta testing. This breaking down is difficult to do during classroom observations, but can be coded from transcripts and video and audio recordings. The categories are:

Type 1a (OQ): Teacher asks student or student group and open-ended question (such as "what do you think will happen if switch the red and blue wires?")
Type 1b (CR): Teacher corrects a student or student group behavior (such as "Michael, are you helping your group right now?")
Type 1c (T-S): All other teacher to student questions or interactions
Type 3a (RH): Student requests help from another student
Type 3b (OH): Student offers help to another student (either responding to a request or unsolicited help offered)
Type 3c (RA): Student redirects attention of another student (such as requesting them to do their job or telling them to stop doing someone else's job)
Type 3d (HYP): Student offers a hypothesis or theory about the science concept they are working with

We chose these particular subcategories based on the literature on cooperative learning, which shows a correlation between asking for and offering help (Webb, 1991), the literature on learning disabilities which shows the importance on assisting students in focusing on the task at hand (Berkson, 1993), the impact of teacher facilitation (Cohen, 1996), and the literature on hands-on science learning that demonstrates the importance of student generation of theories (Tobin & Fraser, 1990). We coded the second or third session for each cooperative group (depending on which recordings were best for each group), coding all verbal interactions in the group.

Table 14. Type of verbal interaction students had with group members.

	Type 1A T-S	Type 1B CR	Type 1C OQ	Type 2 S-T		Type 3 S-S Other		Type 3A RH		Type 3B OH		Type 3C RA		Type 3D HYP		Type 4 OT		Total
Allan	3	0	0	4	3%	22	18%	0	0%	2	2%	0	0%	5	4%	2	2%	29%
Avg Gp	0	0	0	1		17.3		0		0		0.5		1.25		1.5		N=5
Belinda	3	0	0	1	2%	3	7%	0	0%	0	0%	0	0%	0	0%	0	0%	10%
Avg Gp	0	0.25	0	3		5.5		0		0		0.25		0.75		0		N=5
Carrie	1	0	0	4	4%	13	12%	1	1%	2	2%	1	1%	8	8%	0	0%	28%
Avg Gp	0	.33	0	3		11		3		2		0		6.3		0		N=4
Doug	0	2	0	0	0%	15	8%	0	0%	4	2%	0	0%	5	3%	18	10%	24%
Avg Gp	0	0.67	0	0.7		17		4.7		3		8.3		10.3		1		N=4
Ellie	0	3	0	3	3%	7	8%	1	1%	1	1%	0	0%	1	1%	2	2%	17%
Avg Gp	0	2	0	5.3		10		2.3		2		2.3		1.7		0.3		N=4
Frank	0	4	0	5	6%	10	11%	2	2%	4	5%	0	0%	1	1%	0	0%	25%
Avg Gp	0	1.67	0	4.7		9		2		1		1.3		1.7		1		N=4
Gary	0	1	5	6	5%	8	7%	2	2%	2	2%	3	3%	4	4%	10	9%	33%
Avg Gp	0	0	0	3		9.67		1		6		3.7		2		0		N=5
Henry	0	2	0	6	7%	13	15%	2	2%	2	2%	4	5%	2	2%	1	1%	34%
Avg Gp	0	2.3	0	4.3		8		2		1.7		1		1.3		0.7		N=4

Table 14 provides some insight about the kinds of verbal interactions that the disabled students had with peers. The data was taken over one of the 45 minute cooperative learning lesson (usually the last of the three lessons). The "teacher wrap up" portion of the lesson (usually the last three to five minutes of the lesson, performed in the beta tests by a researcher) were not included in the data. The counts represent the number of times that the student talked (thus, Carrie's count of 2 for "type 3B OH" means that during the coded session, Carrie offered help to others in her group twice during the session). The percentages following the count report what percentage of all group utterances this number represents. For example, Doug's off-task talk represents 10% of all of the utterances in the group for that session.

The "Avg Gp" row presents the average count for the group for the coded type of talk. Thus, you can compare the number of times that Gary offered a hypothesis (four times) to the average number offered by other members of the group (two.) The final column shows the total percentage of counts of speech acts that were made by the student. Thus, of all the talk in his group, Allan made 29% of the utterances. His group size, five, is shown in the next row down. The data in this table provides a triangulation of the observations of the researchers during the lessons.

3.1.2.1 Student Attention to the Task at Hand is Assisted by Group Members

The first three columns represent interactions between the teacher and students, initiated by the teacher (or researcher, acting as teacher). What is notable here is that very few correctives took place by the teacher. The students in the groups were actually able to handle the correctives themselves. Of the eight disabled students in the study, half had disabilities that made them difficult management cases. These were Doug and Ellie, who constantly talked and become easily distracted; Gary, who vocalized loudly, moving and talking very slowly, and appeared to have difficulty understanding what is going on around him; and Henry, who became quickly upset and unhappy, and constantly complained about things (but was largely ignored by his peers.) These students were often drawn back into the group work through peer redirection; Table 15 summarized how many times the students were corrected by other students (e.g. "Gary, you need to be reading now.") Despite the corrections, these students still exhibited some off task behavior.

Table 15. Peers of some of the disabled students had to work to maintain attention in the activity.

	Corrected by other students	Off task talk
Allan	0	2
Belinda	0	0
Carrie	0	0
Doug	25	18
Ellie	5	2
Frank	0	0
Gary	11	10
Henry	0	1
Avg. all other students	0.4	0.1

Despite these differences in counts between the disabled students and their peers, it is clear that the task at hand and the students were able to keep the attention of the disabled students to a large extent. This finding was triangulated with the special education teachers who participated in the beta tests, who felt that the cooperative group structure assisted greatly in maintaining the attention of the disabled students. Examples of the types of verbal exchanges that were coded for in this table follow (see Transcript 1, Transcript 2, and Transcript 4).

Not only are students able to keep each other on task, but the software also aided students by modeling language that was neutral and appropriate to the task at hand. The emphasis on attaining a social goal as well as an academic goal was taken seriously by the students, and the language they used in obtaining another student's attention sometimes reflected the language they had seen in the software or decided, together, as a group, to use to obtain compliance with the social goal (see, for example, Transcript 13, page 64.)

Note: transcripts represent verbatim transcriptions of the conversations. All exchanges by students in the group are included, but voices outside the group are not included. Overlaps and latching on of speech is indicated using the left square brace "[" (for example, in Transcript 1, Doug begins saying "oh yeah" when S2 says "back", and then S2 latches on at the end of Doug's talk.) Ellipses, "...", are used to represent a short pause. An em-dash "—" indicates cut off speech. Loud talk is in all capitals. S1, S2 and S3 are used to indicate students in the group, and names are used to represent the disabled students or peers referred to by name in the talk. "R" or "Researcher" refers to a researcher (Dottie Natal or Corrin Rausenberger).

The targeted student with learning disabilities in one group, Doug, requires a great deal of attention from other members of the group to keep him on task. He talked constantly (33% of the talk in his group, by count, came from him, and even a larger percentage of the talk if you count by seconds rather than speech acts.) His talk was mostly on task, but was at times somewhat annoying to other students as he didn't talk in turn, and didn't always provide others an opportunity to respond. The students constantly keep reminding him to stay on task, as in this exchange (Transcript 1) where Doug is changing the subject, is brought up shortly by another student, and quickly responds by agreeing to stay on the subject (the final "uh, okay" quickly interjected into the objection, which was subsequently followed by attention to the conversation at hand.)

S3: "You stole that, you have to give it [back"
Doug: "[oh yeah? You stole it from my brother["
S2: "[Doug, stop playing with that."
S1: "Doug, just leave it al[lone."
Doug: "[oh-okayyyy. My brother's obsessed with turkey, chicken, [po—"
S1: "[Doug, do we really need to [know this."
Doug: "[uh, okay."

Transcript 1. Doug's group maintains his attention.

Another example of how the students in Doug's group keep him focused in found in Transcript 2, where students are setting for the bulb lighting experiment on the second day of the lessons. Doug has decided that they need to have a holder for the light bulb, which he calls a "socket". The kit contained a bulb holder during the previous lesson, but the researcher removed it as it was not intended to be used until later lessons. The goal of the lesson for the day was to use two wires, a battery, and a bulb, and see if they could get the bulb to light.

S1 (reading from screen): One battery, on[e bulb, and two pieces of wire, any color."
Doug: "[I think um I think um."
Doug: "You-I thin-You-I thin-you-You can't get it to light without the metal on it["
S3: "[yes you can."
Doug: "cause I know IT'S LIKE TRYING to get a LIGHT BULB LIT WITHOUT A LAMP."

Doug: "Wah-don-don-don we need something to hook up the wires, something to put the bulb in?"
Talking while S1 is reading aloud, slowly "...one bulb, one battery, two pieces of wire—two pieces of wire"
Doug: "We need a socket, a socket for the bulb."
S1: "That's all it says to get out, Doug. That's all it says to get out."
Doug: "Yeah, yeah, yeah. Hey, we need a socket for the bulb!" (loudly, while looking in the direction of the researcher).
S1: "Doug."
Doug: "Yeah, yeah, yeah. Let's go forward."

Later in the same lesson, he goes back to the same theme:
Doug: "Tha-tha-tha-thas uh that's impossible. You couldn, you-you-you need a, you need a ... I think, I thinka, I thinka, I think, you need, I think you bet, I think you can't get it to light without the metal on it."
S3: "Yes you can["

Doug: "[no, cause I know, I know, it's like trying to get a light bulb lit without a lamp."

He was ignored by the other students. One of the researcher walks up, points at the screen. "What's the next instr—what's the instruction that's right here?"
S1: reads screen "You will use your battery, bulb, and wires to try to make the bulb light up. The supplier, Annie, will be the first to try."

Later, in same lesson, Doug (who is not the supplier) gets his hands on the supply box (which the other students had kept out of his reach earlier) and keeps looking for a "socket", does not stop until an interaction with researcher when she explained, "No, we're not using those today."

Transcript 2. Another example of Doug's group helping him stay focused.

Many times, students will refer to the software to claim the rights for a role or to force another student to take the responsibilities of a role. For example, in Transcript 3, Henry attempts to get another turn at trying the experiment, but S1 reaffirms that the software ("it") tells them that everyone should get a turn to try the experiment:

Maria: "Okay, you tell me so I can put it together."
S2 (to Henry, who is trying to pull the materials towards himself): "No, let her try it."
Henry (in a whiney voice): "No, let me try it, I haven't tried it yet."
S2: "Oh-huh, you haven't tried it yet."
S1: "Maria, it says when you try it let everybody in the group try it."

Transcript 3. Students refer to directions given by the computer when turn-taking is an issue.

Sometimes, open-ended experimenting with the hardware was difficult for students with attention problems, as they could become easily distracted by the components. In the next transcript example (Transcript 4), the students are discussing the answers they will write in the notebook. They had decided to test air to see if it would conduct electricity. Doug still thinks they could get this experiment to work if they would only add more cells to the circuit. However, he has either not expressed this idea in a way that the other students can understand, or else the other students just want to finish writing in the notebook. In any case, he can't make the experiment work without assistance from other group members, and no one else in the group will assist him.

Doug: "So we've got MORE CELLS! Do-do-dah-do-ta-dah!"
S1: [talking to the draftsperson who is making notes on what conducts electricity, and what does not]: "Okay, so you can circle air but it didn't work."
Doug: "I need, uh, um, I need need someone to do this, I need someone, I need, I need someone to hold this [cell [Here Martha hold these cells"
S2 (reading): "[you should test at least [three items from
S2: "It doesn't matter if it worked or not, you [tested it"
Doug: "[uh, Martha"
Doug, while other students are discussing their answers: "Martha, PLEASE, Martha."
S1: "NO, Doug, we are not doing experiments right now, we are discussing[
Doug: "[no, on air, maybe if we add more, we can..."
Martha: "No, we are discussing stuff right now."
Doug: "But if we add more!"
Martha: "Discussing stuff right now."
Doug pays attention to group.

Transcript 4. Doug's group was persistent in maintaining his focus.

In Table 14 and this write up I have discussed only those interactions that were verbal in nature. A close scrutiny of the video tapes of the sessions demonstrate that there are actually many more examples of ways in which students exert a controlling influence over other students in their group using body language or touching. For example, a few groups had students that had difficulty in keeping their hands off the materials box (Doug, Ellie, and Gary were the most compulsive in this regard, although other students also exhibited this tendency from time to time.) Students in the group most often controlled this problem by removing the materials from the reach of the student. Typically the supplier, whose job it is to maintain the materials, would close the box and keep pushing it out of the reach of the student. Sometimes a student would gently pull the materials away or out of the hands of the offending member. Many examples were seen where this was accomplished by two or more students acting in concert; the student next to the errant student would pull the materials out of the way, and then the second student would push them aside so they were physically impossible to reach.

Direct stares were also used to obtain compliance, as were silences (which are difficult to count or transcribe.) For example, if the reader's attention was wandering and it was time to read the next screen, the other group members might stare, expectantly, at the reader, waiting silently for him or her to begin.

Yet another technique seen was touching. A student might gently tap another student on the arm, or scoot the child's chair closer, or put an arm around the student whose attention was wandering, bringing the attention back to the group. Leaning close to, gently nudging, bending down to look directly in the face, and wiggling an object in the face of another students were also attention-getting devices, usually successful.

3.1.2.2 Student Hypotheses Generation

Students learn during hands-on science by posing questions or hypotheses, by listening to other students pose hypotheses, through testing hypotheses, and through the act of trying to articulate their questions and theories. The groups varied widely in the number of hypotheses they articulated during their experiments. During the lessons counted in Table 14, group averages ranged from 3 (Belinda's group) to 36 (Doug's group). It seemed to me that the groups that had students that were most experienced working in cooperative groups were more likely to generate and articulate hypotheses while the groups that were composed of students from "traditional" teachers were less likely to engage in this activity; however, the size of this study was not sufficient to test this observation, and it is offered only as a suggestion for future study.

The subjects on which students expressed hypotheses were diverse. Sometimes students would interject their idea into a conversation, only providing a partial explanation of what their idea was, as in Henry's interjection (Transcript 5).

Henry, testing crayon to see if conducts electricity, has a concept that you must peel back the paper to test the wax part of the crayon. (All four in the group had hypothesized that a crayon would conduct electricity): "Oh, no no no no. You've got to get the crayon part."

Transcript 5. Henry uses a combination of words and actions to convince students of his hypothesis.

In other cases, students were very explicit about what they thought would happen, and why. In Carrie's group, S1 had the concept that electricity will flow through the air better than through other items, and that it could pass down the center of the pencil, in the same channel as the lead (Transcript 6). The students had to spend some time figuring out how to test this hypothesis (which they eventually disproved.)

S1: "Because it has a little air space and the electricity will pass through.
S3: "Because there's lead in it[
S1: "[because if I broke this pencil, and it has lead in it, but the lead has teeny bits of fluff, and also in between the lead and the wood parts, and[
S3: "[and then it comes out right here."
S1: "and because it doesn't fit exact."

When the researcher came by and asked to see their notebook, she pointed out that they hadn't answered the question about how they would test to see if the electricity traveled through an object.

R: "But how will you test to see if electricity passes through an object? How will test to see if the electricity travels through the pencil?"

They explained how they were going to wrap the wire <u>around</u> the pencil.
R: "But does everybody agree this will test to see if electricity will travel through the pencil?"
Group: "yes"
R: "But does everybody agree that will make electricity go through the pencil?"

S2: "yes."
S3: "I don't know, because that tests if goes on the outside."
R: "Well, show me how you could make electricity go into the pencil, itself."
S2: "It could go inside the [unintelligible], go inside the [unintelligible]."
Carrie: "I don't know, you'd have to break it, probably."
R: "I think you could test it without breaking it."
Carrie: "You could put a hole in it."
R: "But how could you test it without doing that."
Carrie: "You could put wire through it."
R: "But would that test the pencil, or the wire?"
Carrie: "Oh."
S3: "I know! I know! You could kind of stick it on top like this, and then connect it here["
S2: "[an put this here."
S3: "uh huh. And put this here."

Transcript 6. Carrie's group decides that electricity can travel up a pencil, next to the lead.

Some hypotheses were presented clearly and succinctly by students, as in Transcript 7 where one student states his hypothesis "anything metal will work" and another student offers an explanation why that hypothesis is correct (in essence, the logic is "all wire is metal, all wire conducts electricity, therefore all metal conducts electricity"—faulty logic, but typical for this level of cognitive development.)

S3: "I think anything metal will work."
Researcher: "Oh, so she thinks anything metal will conduct electricity."
Allan: "She's right. Cause all wires are made of metal."

Transcript 7. A concise hypothesis.

Often, students in a group would begin an experiment, and as it progressed generate a series of hypotheses to test, offering explanations about why they think something will or will not work, and then revising them as the experiment proceeds. In Transcript 10, we see how students begin with an idea of a test (they had just tried using two batteries and one bulb, and now suggest using two bulbs and one battery). They first discuss what the outcome will be (a dimmer light). But, they had difficulty in conducting the experiment, as they were still not clear about how to create a circuit.

Doug: "You guys, instead of, instead of, hey, can I have a battery for a sec?"
S2: "yeah."
S3: "Instead of, you know how we had two batteries, let's have two light bulbs."
Doug: "uhhh"
S2: "and one battery."
Doug: "Yeah, it's going to be less powerful, cause it's only one battery."
S2: "It will be a dimmer light."
Doug: "Yyyyup. You're right."

Transcript 8. A long verbal exchange in which students test out successive hypotheses.

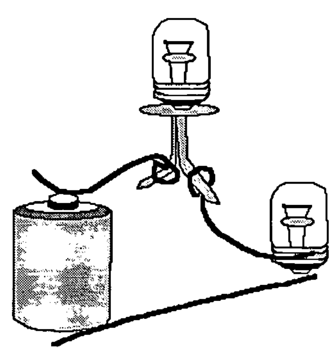

Figure 23. Students' first attempt to light two bulbs.

When the students could not get the two light bulbs to light up, they discussed why:

S1: "remember yesterday, how we tried, remember we tried, how we had the two wires and they went to the motor, and they [unintelligible]"
S2: "Maybe we connected the two wires together."
S1: "Maybe, yeah, maybe we can't connect the two wires together, because uh because the power..."
S3: "maybe it's the brass. Maybe the brass is [sucking the energy."
S1: "[yeah"
S3: "Maybe the brass, maybe is, connect the two wires, then uh, connect both the wires, and then, like, um, maybe since you put them on both ends, when you connect them, then maybe like all the energy is like going through one wire."
S2: "Maybe, if you put them[?"
S2: "[OH YEAH, [if you put the wires through..."
Doug: "Confidential aside, buddies, yeah if you["
(Continue experimenting)
S1: "Someone try connecting to one wire, like, just like putting both on, cause I think most of the energy will go through one wire, instead of like both of them, if you connect them in the middle."
Doug: "Nope, it didn't work."

Transcript 9. A long verbal exchange in which students test out successive hypotheses (Continued.)

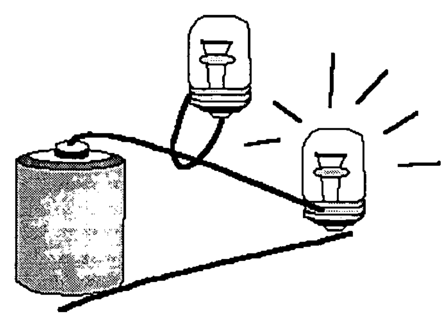

Figure 24. Students' next attempt to get two bulbs to light.

Researcher "What are you experimenting?"
S1: "We're trying to use two wires but only connected to one because if you connect them to one it will burn a little, I think that all of the energy will go through one wire."
Researcher: "If you connect them here in the middle?"

Transcript 10. A long verbal exchange in which students test out successive hypotheses (Concluded.)

Many hypotheses are offered in a tentative form, as in this example from Carrie:

"Woah! Three batteries? That's going to light up VERY bright. Hopefully. Probably."

Transcript 11. An example of a hypothesis tentatively offered.

In addition to the verbal hypotheses generated during the lesson, students often tested ideas without articulating them. For example, a student in Gary's group says "I think I got it!", and then excitedly picked the materials and said, "Okay, Maria, you hold this here" and so on, directing the students about what to hold and where to hold it. This, then, is an internal hypothesis that the student is testing, and it becomes clear to the other students what the implied hypothesis is as the experiment unfolds. In this case, the girl's implied hypothesis was "if we connect a wire to the negative pole of the battery, and another to the positive pole of the battery, and connect the other ends of the wire to the side contact of the bulb, it will light" (which was tested by the students and found to not work.) Implicit hypotheses were not counted in Table 14.

3.1.2.3 Student's Use of the Social Goal for the Lesson

The software introduces a social goal for the lesson, asks the students questions in order to focus them on the social goal, and then at least once in the lesson brings the social goal back into discussion. At the end of the first lesson the researcher questioned students in two of the groups about the social goal for the lesson. Although they were able to generate ideas for appropriate social goals, they had trouble remembering the goal for that lesson (Transcript 12).

R: "Who can tell me, what was the social goal for today."
S1: "Put into words ideas of your group, and like take other people's suggestions."
R: "Those are good social goals, but those weren't the ones in today's lesson."
S2: "I know, I know"
R: "Yes?"
S2: "Trying to get a light bulb to light, using a battery["
R: "[that was the academic goal, and that's right, that was the academic goal, but what was the social goal?"
S3: "Um, try to get the other kids, to um be in the experiment, and to do an experiment."
R: "Okay, and that's a general social goal, but that wasn't the specific goal for today, what was the specific goal, who can tell me what the specific goal for today was?"
S4: "Oh! I know, I know!"
R: "okay"
S4: "Contribute to discussions."
R: "Right, contribute to discussions, and how many of you contributed to discussions today in your group?"

Transcript 12. Students sometimes had difficulty in knowing what the social goal for the lesson was.

During cooperative sessions, however, the social goals of that lesson and pervious lessons were at times clearly in the minds of the students, as the discussions they had engaged in earlier were echoed in their talk. In Transcript 13, students use the same wording that they had used earlier in the lesson when responding to the prompt "what could you say to another student to encourage them to talk?" The repetition of the phrase "good idea" (used almost as a code phrase by this group) shows that they understand that this was the same phrase they had generated earlier.

S1: "Annie, would you mind helping me out, please?"
S2: "yes"
S1: "hold that wire there"
S2: "What do you want me to do."
S1: "just hold that wire there, and put that on top of it."
S3: "put them together?"
S3: "Good idea."
S1: "thank you."
S3: "Good idea."
S4: "Good idea."

Transcript 13. Students, without prompting, practice the social goal for the lesson.

At times, students had to negotiate the meaning of the social goal as they tried to understand how to implement it. In Transcript 14 students negotiate the meaning of the social goal and try to figure out ways to implement it.

Reader (reading): "Today your social goal is to be sure everyone in your group contributes to discussions. This means that every time there is a discussion, every person should say something. In the yellow pad below write three things you could say to members in your group to encourage them to talk. Use kind, helpful words. So write, um, please be quiet, or["
Carrie: "[to ENCOURAGE them to talk."
Reader: "Yeah, Carrie, it's already there, just write one, dot."
S2: "We don't know what to write. Not 'please be quiet' cause we're trying to encourage them to talk." [giggling]

Carrie (to supplier who is beginning to fiddle with equipment): "Hey, I haven't told you to use them yet"
S1 turning to researcher as she walks up to the group: "We don't know what to put."
S2: "How about 'it's your turn'"
Researcher: "If I said that to you, if I said 'it's your turn' would you be encouraged to talk?"
S1: "no"
Carrie: "You know what, they said 'be quiet' and that wouldn't encourage me to talk."
Researcher: "no, I wouldn't think so."
S1: "how about um can we talk now."
S2: "Or even 'it's your turn. Could you listen and say something.' Or 'quit fooling around' if they're not listening"

Transcript 14. Students negotiate the meaning of the social goal for the lesson.

The group with Belinda as a member had an especially difficult time in getting her to contribute to group discussions. Part of the problem was certainly her deafness, as this made it difficult to tell what she had "heard" and what she had missed in a conversation. An added difficulty was that the two other girls in the group were good friends in the regular classroom, and attempted to exclude others from their talk. These students came from a class in which cooperation was not expected, and they had not had much previous experience working on open-ended projects. And Belinda had decided before the testing even began that she would not like to participate (according to the special education teacher and her father.) During the sessions she engaged in many different methods of avoiding interaction with other students in the group, such as shrugging her shoulders when asked a question or leaving the table to go to the bathroom and taking an inordinate amount of time to return.. At one point, I (as researcher) attempted to get Belinda to talk about the experiment she wanted to try, by attempting to get the students to focus on meeting the social goal for the lesson (Transcript 15.) Review of the video tape showed me that little of what I was saying was accessible to Belinda, as she was looking at her experiment and thus could not lip read what the students or I said to her.

R: "Ask Belinda. Remember, our social goal for today is to get everyone to talk. Ask Belinda."
S2 (putting her face close to Belinda, who is looking at her experiment): "What are you doing, Belinda? Do you want some help?"
(no response from Belinda)
R: "Are you doing a secret, Belinda? (laugh)"
S2 takes batteries and wires from Belinda.
R: "No, let Belinda do it. Belinda, to get some help you're going to have to tell people what you're trying."
Belinda looks at researcher.
R: "Do you want both wires on the top?"
Belinda nods, looks at work.
R: "Okay, you want both wires on the top." (probably not heard by Belinda)
S2 helps while Belinda watches.
R: "Or, do you want one wire on the top and one on the bottom." (Belinda is not looking at Researcher, probably doesn't hear)
S2 takes the materials and begins to pass them to next student.
R: "Now, wait. Belinda hasn't finished her turn."
S2 passes them back. Belinda points at bottom of battery and says "put one on the bottom."
R: "She wants one on the bottom. Good talking there. Okay, can you hold one on the bottom and one on the top for her and she'll do the bulb?"

Transcript 15. It was very difficult to get Belinda to engage in conversation.

At times, the social goal is brought out by a student who will correct another student for speaking inapproppropriately or acting rude, as in Transcript 16. Students are generating hypotheses and testing them. The goal is for everybody to contribute, and this is reflected by S2's talk when she insists that S1 switch from saying "I did" to "we did".

S1: "Look, this part needs to be sideways or it doesn't go."
Researcher intervenes, gets them to use more sets of hands to hold the components, leaves.
S1: "See, nothing's happening."
They get it to light
S1: "Let's see your pupils get smaller."

S1: "See, I told you it would work."
Researcher, coming up to group.
R: "Did you get something to work? I wasn't watching. What was it?"
Carrie: "This one's a lot warmer, from use."
S1: "I put two batteries, I put["
S2: "[We did that, we did that"
Carrie: "We put two batteries, we did this["
S1: "[No, we didn't"
Carrie: "Yes, we did."
S1: "That's connecting["
S2: "[NO, that's["
S1: "[I did this"
S2: "Not YOU, WE did this. EVERYbody."
S1: "You want us to do it again?"
S3: "Yeah."
They connect two batteries to one bulb.
R: "There it goes!"
S1: "That's bright!"
S2: "It's a lot brighter than we got it before."
R: "How is it different than before?"
S1: "It was very very very very light."
R: "And what else is different than before?"
S2: "We used two batteries."

Transcript 16. Students working together.

3.1.2.4 Student Requests for and Offerings of Help

Student requests for assistance most usually consisted of one student asking another student to assist in holding equipment for an experiment Other common requests for help were for spelling, requests for clarification when writing or drawing in the science notebook, and sometimes for help in understanding or exploring a concept. This final category of requested assistance was usually oblique; a student would ask a leading question, attempting to draw other students into the experiment they wanted to try, as in Transcript 17 and Transcript 18.

Carrie: "What if we try to hook up one wire to a battery and still make the light bulb work?"

Transcript 17. An example of a question requesting ideas.

S2: "How fast can this thing spin?"
S1: "I don't know. Do you want to find out?"
S2: "Yes."

Transcript 18. Another example of a question requesting ideas.

Occasionally, a student would offer advice or help to another student that was not wanted. This type of assistance could be perceived as friendly and helpful if it was offered as a suggestion but could also be perceived as bossy or intrusive if the student offered it as a command, as in Transcript 19.

Doug, to a girl in the group doing an experiment: "Wrap the exposed metal, around the top, and wrap that around the end."
Other girl: "She can do it."

Transcript 19. Offer of unsolicited, unwanted advice.

In contrast to Transcript 19, the offer of a suggestion in Transcript 20 demonstrates the offer of advice that is well received by the student.

S1 to S2: "Maybe because it's not, not a circle. Maybe you want to put it up like this." Indicates another way to do it (which also is not a circuit.)
S2: "Hmmm."

Transcript 20. Unsolicited well-recieved advice.

Probably the most common form of unsolicited help that we observed being offered was in reading. These were not coded and included in Table 14 because of the frequency with which they occurred. Almost all students had some difficulty reading one or more words on the screen. Students are quick to offer help when a reader stumbles, most likely because this is a commonly modeled behavior by teachers in almost any classroom in which we have observed. An extreme case of this was seen when Gary, who reads at a very low grade level and with extreme difficulty, attempted to read; each time, he was assisted by one or more of the other students in his group (see Transcript 21.)

Gary tells the computer "your turn" and presses the button to make the computer read aloud the text of a screen. On the next screen he says, "my turn" and tries to read the line 'Your group is good at this skill.'

Maria:	**"Your["**
Gary:	**" [your.. your?"**
Maria:	**"Your"**
Gary:	**"No? Still?" Points at the word "group"**
Maria:	**"no."**
Gary:	**"Your is good?"**
Maria & S2, together:	**"No, here, here" pointing at word "group" on screen.**
Gary:	**"Helps?"**
Maria:	**"no."**
Gary:	**"Helps?"**
Maria:	**"no."**
Gary:	**"Helps?"**
Maria:	**"no. Group."**
Gary:	**"group is help"**
Maria:	**"good"**
Gary:	**"That ... is ... licks."**
Maria:	**"skill"**
Gary:	**"Skill. Okay."**

Transcript 21. Gary is greatly assisted by group members when reading aloud.

A more typical example of the assistance offered during reading is shown in Transcript 22, where Ellie is reading the sentence 'Some things, like wire, let electricity pass easily. We call such things "conductors."' Even though Ellie makes many small mistakes in the reading (missing plurals, making electricity into two words, electric city) the only correction offered on the reading was for the replacement of one word with another that was incorrect (constructors for conductors).

Ellie: "Something, like wire, let electric city pass easily, we call, such thing, constructors."
S2: "Conductors"
Ellie: "Conductors."

Transcript 22. Ellie, while reading, gets some assistance from another student.

What was interesting is that student requests and offers of help were not typically verbal, but were more often physical. These non-verbal requests and offers of assistance were not coded for in Table 14. If a student needed more assistance in an experiment, generally the student or students sitting next to the experimenter would offer assistance by reaching out to help. Rarely was help rebuffed by the receiver of the assistance. Many of the experiments that students wanted to complete required (by design of the unit) lots of hands to complete (see Figure 25).

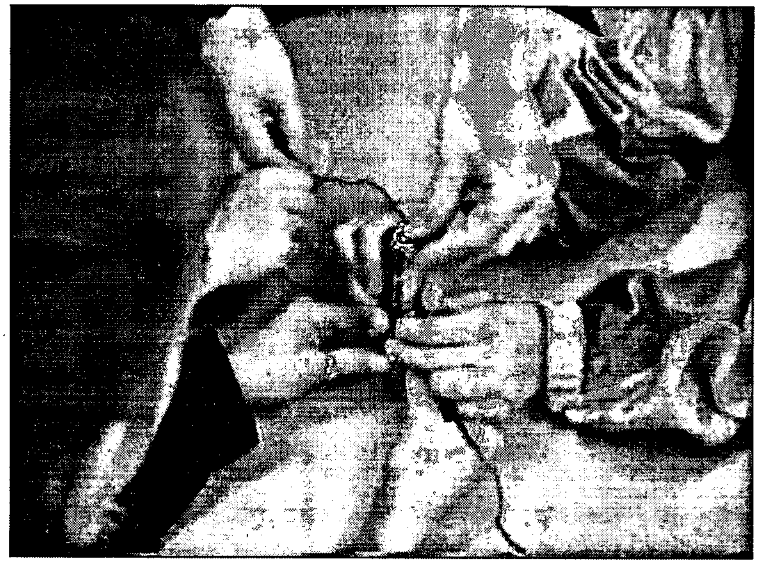

Figure 25. Some experiments required all of the students in the group to contribute simultaneously.

3.2 What methods are used by the teacher to include disabled students in classroom activities?

We asked the classroom teachers to answer some open-ended questions about how they include disabled students in the class. The teacher responses were triangulated with the observations of the special education teachers and our own observations in the classrooms.

Mr. Anderson doesn't treat disabled kids differently from others in class. Everyone gets the same approach with him. He does have different expectations for special needs students. This includes using a different spelling book and giving only parts of whole activities to them. He hopes to support special needs students by encouraging their peers to assist them.

Mrs. Brannon allows Doug to use an exercise ball behind his chair, and to replace his chair with a specially constructed one legged stool. These physical occupations appear to involve him enough to stay focused and keeps his temper. The collaborative testing option was an experiment to support Carrie and Doug, but neither opted to work with others. Mrs. Brannon circulates constantly during activities to be accessible. She tries to pad the schedule to provide catch up time for homework, so kids could work at their own pace. She asks personal experience questions during discussion where all answers are correct to give special needs students an opportunity to engage in class discussions.

Mrs. Calle gives multiple-answer opportunities where some aspects are a matter of interpretation., and responses are encouraged. She supports Doug by providing the adult attention he seeks, within limits. She plans carefully to find engaging activities for group work. The choice of hands-on experiments gives everyone something to do. Also, she invites visits during the weekly video for one-on-one time. She includes Carrie in the role of aide with the science cart.

Mrs. Davidson does not modify her curriculum for the disabled students in her classroom. As the only student with a disability in her classroom was Allan, whose hearing disability did not cause him to need a modified curriculum for content but only for delivery, she did not find any need to change her methods. However, having a hearing impaired student in her classroom had made her pay more attention to how she teaches, and to concentrate on presenting materials in more than one way.

Mrs. Evans has does not make changes in the curriculum for her disabled students. Her teaching methodology is primarily "traditional" (that is, lecture, calling on students to answer questions, and individual seat work.) Belinda has some trouble understanding what is expected of her in class, but is a very good reader and can figure out most of the seat work from the written directions. She is not called on in the classroom. Mrs. Evans does not see any need to modify the way that she teaches or her expectations for student output. In an evaluation of herself she feels that she treats her students with disabilities just the same as any other student in her classroom.

Mrs. Thomson assigns a regular education student as an assistant to each special needs student in her classroom. This helper is the primary resource for the special needs student when a problem or question comes up. Also, there is a special education teacher assigned to assist students part of the day in the classroom. She finds that most activities can be completed by special education students, but perhaps not as completely or in as much detail. Math and language arts skills are studied in the special education classroom, so she does not need to support the disabled students in these subjects.

3.3 *What difficulties in supporting disabled students do teachers encounter when implementing curriculum?*

The aspects of difficulties in supporting students with disabilities in the regular classroom varied. Most of the responses we obtained from our teachers focused on the diversity of ability levels and the difficult in finding means of supporting a wide range of learners. Some teachers, like Mrs. Thomson, handle this issue by using individualized learning plans. Although this means she must keep track of the progress of 28 different students with different learning goals, she finds this the best way to provide learning opportunities for all students. Other teachers pretty much expect the same level of learning for all students, but modify the expectations in the completeness of assignments and the quality of the work, based on the disability. The special education teachers stressed that sometimes the teachers will "over facilitate", providing the disabled student with too much additional assistance. This is especially true for students with a physical disability (such as a speech or hearing impairment) that does not impair a students' academic ability, but makes it difficult for others to perceive their strengths. However, inclusion programs are relatively new in California, and the special education teachers explained that the regular education teachers are quickly learning to raise their expectations.

Both the special education and regular education teachers were more interested in talking about the benefits in including special needs students in the classroom than the difficulties this entails. They pointed out that they found the inclusion program very beneficial for the special needs students. It provides an environment for these students to practice communication skills with peers, thus obtaining valuable life-long skills. But also, it was pointed out by the regular education teachers, the other students in the classroom benefit. Not only are they learning valuable social skills (learning to get along with all types of other people), they also gain academically as they explain concepts and teach others. In addition, inclusion of special needs students creates a more cooperative environment; students learn to pay more attention to other students' needs, and these skills are carried beyond the interactions with the disabled students to all different student interactions in the classroom.

3.4 *What methods are used by exemplary teachers to promote discourse with disabled students?*

When we designed the study, we intended to interview and study exemplary teachers as they included special needs students in classroom discourse. However, we stumbled almost immediately in this task. First, we attempted to define "exemplary"—is an exemplary teacher one who is recognized by other teachers as an excellent teacher? Or one that administrators recommend? Or should we rely upon parent and student reports? In any case, we found that gaining entry into the inclusion classrooms was very difficult, and even if we could define and then locate "exemplary" teachers within the two districts, we might not be able to negotiate entry into these classrooms. The research literature was also relatively mute on this question. We settled, instead, for studying any teacher who had an inclusion program in the two schools we obtained permission to use in the study, and converted the research question to "what methods are used by the observed teachers to promote discourse with disabled students?"

The classroom teachers we observed used a range of techniques for promoting discourse in classroom. Teachers could be put on a continuum from "highly stresses communication skills in the classroom" to "provides no opportunity for student discourse during class time." Some teachers in the study were "traditional" teachers; that is, they primarily used lecture as the mode of providing students with information, and used an individualized learning structure in the classroom. In these classrooms, students were expected to listen carefully to the teacher as he or she instructed the class and explained a subject, and then complete mostly pencil and paper tasks at their own desks without interacting with other students. These teachers typically used questioning techniques in which they would ask a question, students would raise their hands and volunteer answers, the teacher would choose which student should respond, the student would respond, and the then the teacher would evaluate the response (e.g. "Right! Exactly what I was looking for!" or "Well, maybe, but that's not exactly what I was looking for. Anyone else?") In this type of classroom, very little opportunity for discourse is available to students.

These traditional teachers varied in how much they attempted to promote discourse with the disabled students. Some teachers believed that calling on students who did not raise his hands was unfair to the student and potentially embarrassing; in these classrooms, if the disabled student did not raise his or her hand, they did not talk much or at all during the time they were in class.

At the other end of the spectrum, some teachers had very collaborative classrooms. In these classrooms the teachers used learning centers and/or cooperative groups. Students were expected to rely on each other as resources for assistance, and were expected to engage in talk for much of the class period. Sometimes we observed these teachers interacting with the students doing group work, encouraging the students to talk.

The activities that we observed that provided the greatest opportunities for disabled students to talk with other students were learning dyads (where a disabled student was paired with a regular education students for an assignment); cooperative groups; small group work at learning stations; and seat work in classes where students were permitted to talk while completing assignments. Our observations are summarized in Figure 26, illustrating the range of opportunities we observed for disabled students to engage in discourse in the class.

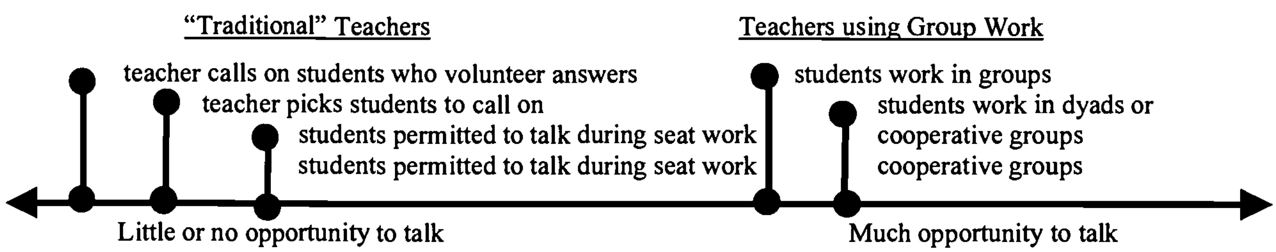

Figure 26. Observed range of opportunities for students to speak in class.

3.5 Under what conditions will the software be used, and with what expected outcomes for students and teachers?

If the classrooms in which we observed are representative of classrooms across the United States (and our literature research leads us to believe this to be true), we expect to find a similarly large range of teaching methods used in classrooms, ranging from "traditional" teaching methods to more open-ended, collaborative environments. This software was designed to provide the highest possible level of assistance to teachers who are new to cooperative learning, new to hands-on science, and new to including students with disabilities in using a cooperative learning teaching method. The software accomplishes this by performing the myriad tasks associated with cooperative learning (rotating student roles, assigning tasks, keeping track of roles when a student is absent, providing the proper level of reading material for students with different reading abilities), providing direct support for group collaboration (providing prompts to help students focus on appropriate role activities, assigning a social goal for the lesson and checking to see if students are applying this skill throughout the lesson, providing just the right amount of work and just the right amount of support), and providing direct support for the academic task (working through the concepts step-by-step, providing multimedia examples where this will provide assistance to students with different learning styles, assigning materials to be used during experiments in such a way that there is just enough material for the size of the group that is present during that lesson so as to require students to collaborate to accomplish the task at hand).

Expected outcomes, based on the results of our observations, for classrooms that implement this software include:

- Increased collaboration between all students
- Increased levels of discourse for special needs students
- Ability for teachers with no previous experience to implement cooperative learning groups
- Ability for teachers with no previous experience using hands-on science units to implement this type of curriculum

The main difficulty we expect in implementation of this software in the classroom is a logistics problem. Although many schools now have multimedia computers, these computers are frequently located in a computer lab. These labs are normally run by a computer teacher. In many schools, teachers bring their class to the lab to "learn about computers", and the teacher absents herself from the location or moves into a corner and grades papers while the computer teacher takes over the lesson. We have found in our previous studies that in schools in which this is the mode of access to computers, it is rare that the computers are actually integrated into the curriculum to any large extent. If the computer is conceptualized as a subject to be learned in school, rather than a tool to be used in all subjects, it is difficult to preempt the "computer instruction" time to use the computers for "science instruction" time. It is unlikely that a teacher who is accustomed to having time off while the students do "computer" will want to change that time to active learning time. And, computer labs are generally set up with a floorplan reflecting a concept of "one student per computer". This software requires student to have one computer per four or five students, and requires the entire group to have access to viewing the screen, as well as to table space to work with the hands-on science materials. Figure 27 shows a group of students working at the computer. The computer is placed on a table, well back from the end, so that five students can gather at the end of the table and have room to work.

Figure 27. Students gathered around computer, with the screen visible to all and enough desk space to do hands-on science.

Computers are becoming increasingly available for classroom use. However, few classrooms are large enough to accommodate one computer per four or five students with enough desk space to work at the computer. For our initial, long-term study, we did transform a classroom into an environment able to accommodate seven computers and one printer, so that students would have constant access to the equipment throughout the day without blocking the view of the students by the teacher or students' view of each other. This room is shown in Figure 28.

Figure 28. A classroom designed to accommodate seven cooperative groups using computers.

One means of getting around this problem is for the teacher to set up one or two computer learning centers in the classroom that have enough room for a cooperative group. Then, science can be taught as a learning center activity, and students can rotate to the science center two or three times per week (which is typically the largest amount of time spent on science learning at the elementary school level.)

Unfortunately, a shift from traditional teaching to using learning centers in the classroom is a very difficult shift for many teachers to make. The use of this software would facilitate a cooperative group working at the computer, but that requires that the instructor be able to coordinate and work with all of the other groups in the classroom, a complex task beyond the capabilities of many teachers.

Regardless of these problems, it is clear that the use of this software can provide great benefits to students and instructors. The advent of lower cost, easily viewed liquid crystal displays (LCD) and gas plasma displays could have a very beneficial effect on this problem. If LCDs and plasma displays could be used in placed of the current vacuum tube displays then many of the problems with setting up computer stations and using them in the classroom would be alleviated. A panel display could be propped up on any convenient working table, and an inexpensive laptop computer could be hooked up to the display. A portable computer lab of this sort could be stored on one shelf of a closet (or loaded on a cart to be checked out from the media center of the school) and could be set up in minutes. As the cost of a laptop computer continues to drop and schools begin to allocate more money towards technology, the idea of creating portable labs of this sort should catch on quickly. The biggest current drawback to this scenario is the bulk of traditional monitors and the cost of flat panel display technology.

3.6 What aspects of integrating students with disabilities were observed during testing?

In the classroom, as explained earlier, teachers varied in their methods of integrating students with disabilities in classroom activities. During the testing of the software the special needs students were given the same rights and responsibilities as any of the other student in the cooperative group. With the exception of the modifications of the software that were made in order to accommodate the special needs of these students, they were expected to participate at the same level as the other students.

Academically, some special needs students are not likely to be able to participate at a level even close to that of the regular education students. However, even these students are accommodated for in the lesson structure. Students that lack the cognitive ability to be fully functioning group members can:

- assist with other students' experiments
- contribute to the general conversation
- act as reader, sometimes by using the lower reading level option in the software (as did Frank), sometimes by listening to the voice over for the screen and then repeating it (as did Carrie), and sometimes by permitting the computer to provide the reading, and augmenting it by reading whatever they can (as did Gary)
- act as draftsperson, even if their writing or drawings are not well constructed
- act as inputter, clicking when instructed by the other students (even if their communication skills are severely limited, this is a task that carries prestige and is within nearly every student's ability)
- act as supplier, getting out supplies and assisting in constructing experiments
- act as facilitator, making sure that the other students complete the tasks

The students in the study all performed each role assigned to an extent that was acceptable to the other students in the group. Even the hyperactive students and students with attention problems were able, for the most part, to be active group members. The only students that were observed to be off-task or not on-task to any large extent were: Gary, who had trouble paying attention for that long of a period of time and occasionally sat and vocalized to himself; Belinda, who may not have been able to follow much of what was discussed in her group, and could not both "listen" and work with the materials at the same time, as both tasks required her visual attention; and Doug, who could not control his impulses. All of the other students were actively involved in the lessons for nearly every moment during the lesson.

In the classroom, the teachers sometimes facilitated inclusion of students into group tasks. During the beta test of the software, the special education teacher (when present) or a researcher performed the role of teacher. Usually the interventions were short and to the point (see Transcript 23 and Transcript 24); rarely, the exchange was more extended (see Transcript 15).

Teacher: "Wait a minute. Okay, now who's the supplier here?"
Mark: "I am"
Teacher: "Mark is."
[students are talking about what to get out and Mark is getting out equipment]
Henry grabs at the supplies.
Teacher: "Ohhh! You're pulling a card. You don't grab equipment like that!"

Transcript 23. Teacher disciplines a special needs student.

In the example shown in Transcript 23, the teacher assists the students getting started during the third lesson. Henry was only permitted to join the science group during the final day of the beta tests because he had been refusing to do his other classwork, and the science project was being held out as a reward for him to complete other work. The school uses a "card pulling" assertive discipline technique. Each student in every class has five cards of different colors in a chart with pockets at the front of the room. If they are disruptive or disobedient, they are told to "pull a card." This means they pull the card in the front of their pocket and place it at the back of the pocket. This exposes the card of the next color. If a yellow card is showing, no cards have been pulled that day. If the green card is showing, the student has had a warning. If the orange card shows, they must stay in at recess. If the blue card is showing, the student must attend detention (at lunch or after school) and the parents are sent a note. If the red card is showing, the student goes to the principal's office and the parent is called immediately. In this example, the teacher is using an understood shorthand for that student, and is really saying "you will be asked to pull a card if you don't stop that behavior this very instant."

S1: "I'm first captain on this."
Henry: "No."
Researcher: "Captain! We're not doing captains. We all have to give ideas."
S1: "I know."
Henry [in a whiney voice]: "We're all captains."
Researcher: "That's right, we're all captains."
Henry: "And we don't be pushy to each other."
Researcher: [pause] "That's right["
Henry: "[and mean."
S1: "I'm not mean!"
Henry: "You were!"
Researcher: "Okay. Okay, everybody give ideas. Who has an idea?"

Transcript 24. A researcher gets involved in a discussion and redirects the students' attention.

In Transcript 24, a case where the researcher got involved in a short argument that two students were having is shown. It seemed clear from their demeanors that these students were normally at odds with each other, and that this discussion was a continuation of previous, similar encounters (this observation by the researcher was later confirmed by the special education teacher when they discussed it after the session.) After the researcher had validated what Henry said, she found herself inadvertently pulled in as an ally to Henry's side of the argument. It took her a moment to extradite herself from the discussion, and she accomplished this by choosing to redirect the students' attention to the direct task at hand ("give ideas," a social goal, for how to make a tester for conductivity, an academic goal.)

Most of the integration of students with disabilities into the group was a direct result of the design and implementation of the learning unit, and a consequence of the cooperative learning structure of the group work.

3.7 Did the software work in the expected ways under the conditions it was designed to operate?

The software functioned mostly without programming errors (bugs) during the testing. There was one typographical error found on one of the screens, which none of the students noticed (or at least, none of the students commented on the error.) There was one case when the hardware malfunctioned, and the computer did not read aloud (but, in fact this was due to the researcher accidentally plugging the speaker cable into the microphone port of the computer.) This was remedied by the researcher switching student roles for the day, and then switching them back the next day, so that the student who needed the sound could access it when they were in the role of reader. And, in one of the screens which queried the students to find out if they had contributed to discussions, there was a programming error that made one student name repeat twice in groups of less than five students. None of the problems caused any particular difficulties for students.

During the design process for the software we focused on key elements that the literature review indicated were important for effective hands-on science education using inclusion practices in cooperative groups. These key elements were listed in Table 3, page 14, Table 4, page 16, and Table 5, page 18. The results are summarized in Table 16.

Table 16. Key elements and how they were observed to be supported by the software during beta testing.

	Key Element	How observed to be supported by software
1.1	Use of direct instruction, either by teacher-student or student-student	Computer software took over in the "teacher" role, supplying step-by-step instructions on an as-needed basis; students read instructions from screen, supplying motivation to stay on task
1.2	Instruction should be consistent and precise	Language in software was consistent and precise, and students were able to obtain directions specific to their group for any given point in time, eliminating the need for the instructor to give vague, multi-step instructions
1.3	Language indicators should be used to define order in which material is covered	Software provided order for directions
1.4	Alternative uses of language to provide redundancy	Software used explicit language and rephrased complex concepts in different ways
1.5	Use of adaptive devices is key to facilitating communication with peers and instructor	Adaptive device support was built into software and used as anticipated by students during the beta tests
1.6	Use of communication alternatives such as hardware/software devices, communication board promotes collaboration	Software devices (specially, the computer ability to "read" for the reader) was used by students and assisted students unable otherwise to perform the role
1.7	Use time delays to ensure that everyone can participate	Software provides ample time for students who work at different paces to have the processing delay time needed

Table 16. Key elements and how they were observed to be supported by the software during beta testing (continued).

	Key Element	How observed to be supported by software
1.8	Provide support for culturally diverse learning styles and cognitive strategies	Software has multi-language ability (used in the beta tests by only one group of students, and then only briefly); language and images used in software are biased towards a "culture of science"; multimedia and hands-on materials support a variety of cognitive strategies
1.9	Provide social skill training for students to deal with low status issues	Specific social skills are introduced in each lesson
1.10	Create temporary pairings of disabled students with non-disabled students	Software was designed to permit pairing of an "assistant" or "to-be-assisted" regular education and disabled students
1.11	Provide social skill training for students to assist them in learning to work together and to accept the disabilities of other students	Specific social skills related to the particular needs of the disabled student can be introduced into the lesson by the teacher; the "default" social skills are also applicable
2.1	Provide scientific problems for students to explore in order to encourage students to talk science	Software presents genuine problems for students to solve that are very engaging and challenging to the students
2.2	Effectiveness of hands-on learning	Hands-on components are part of every lesson
2.3	Support teachers' management so that the learning environment remains "favorable"	Teachers are supported by elimination of the need to handle group rotation logistics, material management, and other "headaches" of hands-on science and cooperative learning
2.4	Model utilizes collaborative process for support of science learning	Software accounts for how many students are present and assigns tasks so that they require full participation of all group members; authentic problems ensure that students collaborate to solve them
2.5	Models inquiry methods used by scientists	The software (informally) introduces students to the hypothesis making and testing model used by scientists
3.1	Shared responsibility for participation and decision making	Cooperative learning structure of lesson provides students with the opportunity to share in decision-making; social goals enforce the need to share responsibility
3.2	"Careful" grouping to minimize status issues, provide students with opportunities to interact with others with a wide range of personality and cultural differences	Grouping is done by the teachers; as long as a teacher groups disabled students with non-disabled peers, many of the beneficial effects should ensue
3.3	Individual and group accountability	Accountability is built into the tasks as much as possible; role assignments and rotations require students to be accountable for certain tasks; the teacher must require group accountability by testing or other means (what ever the teacher usually uses with the class)
3.4	Attention to social as well as academic goals	Social and academic goals are built into the software
3.5	Include disabled students with their peers	Special adaptations in the software support disabled students as they work with non-disabled peers

3.8 What unexpected outcomes arose while testing the human-computer interface? What features of the software need additional work in a redesign effort?

We found that most of the adaptations worked pretty much as designed for these students. However, there were a few things that occurred that we hadn't considered when we designed the unit.

3.8.1 Problems in the Draftsperson Role

Some of the students with disabilities, who were able to actively function as part of the group in most roles with the adaptations provided, had a great deal of difficulty when acting as the draftsperson. For example, you can see a large difference between the drawing produced by Frank (Figure 29) and by a regular education student for the same lesson (Figure 30). The task was to sketch the way that the students had connected a battery, bulb, and wires to try to get a bulb to light, and to indicate whether the bulb lit or not.

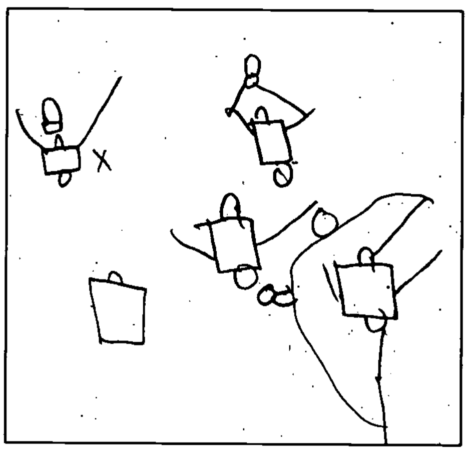

Figure 29. Frank's drawing.

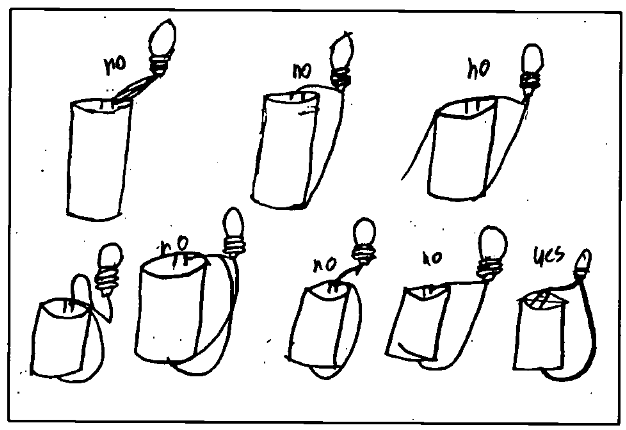

Figure 30. Another student's drawing.

The drawings produced by Frank did not present an accurate picture of the group's experimental attempts. Even in the best of groups it is difficult for the draftsperson to accurately draw all of the student attempts; this is not really expected of the students. However, a teacher who reviews the notebook and can not make sense of any of the drawings is likely to lower that group's score.

In a case such as Frank's, it is not desirable to assign the student to an assistant (or to-be-assisted) role, as he is capable of functioning at a higher level for most aspects of the lesson. On the other hand, he is incapable of performing the draftsperson task. A potential solution we discussed was using "drag and drop" drawing capabilities on the computer, although our research does not necessarily lead us to believe that a student with these types of problems is any more capable of performing this activity on the computer than with a pencil and paper (most likely, this is not a fine-motor coordination problem, but rather a mix-up in the brain.) Although we could have explored this option further, the main reason for abandoning this potential solution is that it requires students to switch roles to some extent—the draftsperson would, of necessity, have to become the inputter to have access to the keyboard and mouse. And this, we feel, would lead to other difficulties.

It is quite possible that this type of problem would resolve itself quite simply in the classroom setting. During our limited beta testing students knew that they would be held accountable for their behavior, but there was no accountability for the academic success of the groups. In the classroom setting, the accountability for actually understanding the subject and communicating the understanding in the notebook would probably lead students in a group to assist the draftsperson in completing the task. Or, the teacher may choose to be more lenient on grading the group on the written product based on the person filling the role.

An option that we should consider adding in the final version that would alleviate this problem is to add to the facilitator's job description: "Make sure that the draftsperson completes the drawings and writing, and assist the draftsperson with their work when needed." This could be reinforced through the social goals for the lesson, for example focusing on when facilitation is good for the student and when it prevents the student from learning new skills.

3.8.2 No Training on Computer and Software Use Required

Because there was so little time available to run the beta tests, we decided not to spend a session training the students on how to use the computer interface. Students were merely shown, incidentally, what button on the mouse to click and where to click to move to the next screen. Many of the students had computers at home (about half) and each of the schools had computer labs. Thus, students were familiar with how to use a computer and a mouse. Although it wasn't shown to them, in the cases where students wanted to go back to review a previous screen, they naturally used the "back" arrow to navigate to the desired screen (Transcript 25.) In this case, S4 couldn't remember what a conductor was, and when no one in the group could define it she asked the inputter to "go back", which she did.

S2:(reading from screen) "Do you think that a crayon is a good conductor of electricity?"
Carrie & S4 "No!"
S4: "Wait, what's a conductor again?"
S2: (mumbling) "electrical current["
S4: "[go back"
S4 used the back arrow to move back to the screen where conductors were introduced.

Transcript 25. Students figured out how to navigate back to a previous screen.

3.8.3 Text Chunks Too Large

In some cases, the chunks of text that were displayed on a screen were too large for the reader to keep track of. For students that have certain types of disabilities involving visual discrimination, the larger text blocks may cause some problems. Also, for students using the sound feature to listen to the text before reading it or repeating it, the longer chunks were too big to hold in auditory memory. An example of this problem can be seen in Transcript 26 of Carrie "reading" the screen from auditory memory. The text on the screen is: "Arabella should sketch in the notebook all the ways the group connected the batteries and motors that made the fan spin. Also, draw pictures of the ways that the group connected them that did NOT make the fan spin. (see the example of a notebook, below)" while the voice over says: "The draftsperson should sketch in the notebook all the ways the group connected the batteries and motors that made the fan spin. Also, draw pictures of the ways that the group connected them that did NOT make the fan spin. (see the example of a notebook, below)." This passage was too long for Carrie to memorize. What she repeated was:

Carrie: "The draftsperson should sketch in the notebook all the way, your group hmm mmm hmm made the fan spin. Also, draw pictures ah mm hmmm mmm mmmm dah umm dah mmmm mm mmmm dah umm in the notebook below."

Transcript 26. Carrie, trying to repeat what she heard from the computer.

The pauses and approximate length of the mumbles matched the speech she had heard, but lacked the necessary content. Carrie looked intently at the screen while "reading" this passage. Another student complained to her: "I can't hear what you're saying!"

For students for whom reading is difficult, the larger text chunks may have been discouraging. There is no design reason why the text could not be broken into smaller sections, and in our next version of the software we will do this.

3.8.4 Direct Method for Retaining Attention of Hyperactive Students May Be Required

For ADD and other hyperactive students, maintaining a focus on the task at hand was a problem. For the most part, this problem was solved by the students themselves, as the peers attempted to retain and redirect the attention of the student, sometimes requiring them to use many corrections each minute (for examples, see Transcript 1, Transcript 2, and Transcript 4.) Doug provides a good example of this type of student. His body was in constant motion, and his visual attention was frequently focused outside of his group.

Figure 31. Doug's body was constantly in motion, and his attention was often focused outside of his group.

We gave some thought to using an automated behavior modification system. For example, at random intervals the software screen could flash red and pop up an appropriate question such as: "Is Bobby working with the group on the experiment right now?" or "Is Bobbie reading the screen aloud for the group right now?" or whatever the appropriate behavior for the student is at that moment. The teacher could turn this feature off and on as needed and determine the average delay between questions. The teacher would obtain the final count and use the reward system that is normally used for that student, e.g. "Bobby, if you can score six 'yeses' today in science, you will get an extra ticket towards the ten you need to earn ice cream on Friday."

It is also possible that a feature such as this could be counter-productive, causing the student to feel singled out unfairly, or cause other students to resent this student. It is also possible that if we did a longer beta test, in which students were truly held accountable for the academic outcome of the unit for all members of their group, that they would be able to control the student with the attention problems. It is also possible that the behavior we observed during the beta testing is actually the very best that a hyperactive student could hope to achieve, and that any further attempts at obtaining even more attention would only prove frustrating to the student and his peers. Although the other students in the group had to constantly remind Doug to stay on task, there seemed to be no adverse effects of this behavior on the group learning. With the exception of one student (Belinda), we found that all of the students really enjoyed the experience of working with the science materials, each other, and the software. There was virtually no off task talk. In a case such as this, where they seem to be genuinely intrinsically motivated to participate, it seems possible that it would not help to try to gain even more participation. This is a question we will reserve for further research during Phase II of this project.

3.8.5 Additional Academic Scaffolding May be Required for Some Students

The academic design of the unit was based on a step-by-step inquiry and discovery process. The unit, consisting of 15 lessons, was designed to slowly lead students to an understanding of how electricity works. The three lessons we used for the beta test consisted of:

1. Circuits and polarity—the students used a motor and a battery to discover that the electricity must travel in a "circle" and that if you attach the leads in the opposite direction, the motor will spin in the opposite direction.
2. Circuits and contract points—used a battery, a bulb, and two wires to reinforce the concept of a circuit, and to interest students in understanding how a light bulb works.
3. Conductors and insulators—created a circuit with the motor or light bulb and tested objects from the room to see if they were conductors or insulators.

In the full implementation of the unit we would have done another lesson between two and three, where the students take apart a light bulb to see how the wire goes through the middle of a ceramic base, loops around through the filament, and then attaches to the metal side of the bulb. We chose to skip this lesson and go on to the conductors and insulators lesson, as we only had three sessions available to use for the test.

In our beta tests we found that Gary just "didn't get it." He never seemed to quite understand the point of the lessons, although he greatly enjoyed himself during the sessions and was able to function well, using the adaptations, in the roles. How can we support students who are, because of learning disabilities, unable to reason logically?

First, it is clear that we must have different outcome expectations for such students. If they are unable to meet the same academic goals as the other students in the group, we should establish other goals for these students and then re-examine the design of the software. Vygotsky's theory of proximal development indicates that learning takes place when students are provided scaffolding that assists them in moving from one level of understanding to the next, higher level of understanding. For some disabled students, however, their current level (and possibly, highest attainable level) is far below the rest of the students in the group. It is important to be certain that the software does not get redesigned in such a way that it provides additional academic scaffolding for these students by neglecting the needs of the remaining students. For example, use of a detailed, step-by-step approach to a series of experiments to try might benefit students with these types of disabilities; however, this would turn the lesson into an exercise for the other students, rather than the open-ended, problem-solving experience desired.

We leave the question of how to better support students with disabilities that make it extremely difficult or impossible for them to engage in problem-solving activities for future study. The limited results of this study make us suspect that it is possible that this type of student gains in so many areas while engaged in the group activity that the fact that they do make academic gains similar to other students becomes irrelevant. Also, we saw no indication that their lack of contribution to the hypothesis generation and reason-making discussions created any problems for peers, and their ability to function as members of the group in carrying out experiments was helpful to the entire group. Perhaps, the inclusion of such students in a group actually stimulate more active generation of explanations (which has been shown to stimulate academic growth for the student doing the explaining.) Again, it will require further study to establish the validity of this conjecture.

3.8.6 Some Students Assume All Illustrations are "The" Way to Set Up an Experiment

Some of the graphic illustrations were designed to be ambiguous or not directly applicable to a task at hand, in order to suggest to students that they should try different ideas, but without giving anything away. The illustrations are not created as perfect examples, as students might then rely on the computer to provide hints or hypotheses, when in fact this is the job of the students. In the previously tested sites, the illustrations did not pose a problem. In these tests, however, some students focused in on these illustrations.

For example, in the expansion activities for the third lesson, the students were presented with the screen shown in Figure 32. Gary, when he saw this screen, began asking students if they had a carrot. He asked the teacher. Then, he asked the researcher. Next, he asked anyone within earshot. Although no one responded to him, he continued to ask, just calling out (without any particular target) "Do you have a carrot?" He posed this question nine times over about three minutes before refocusing his attention on what the other students were discussing.

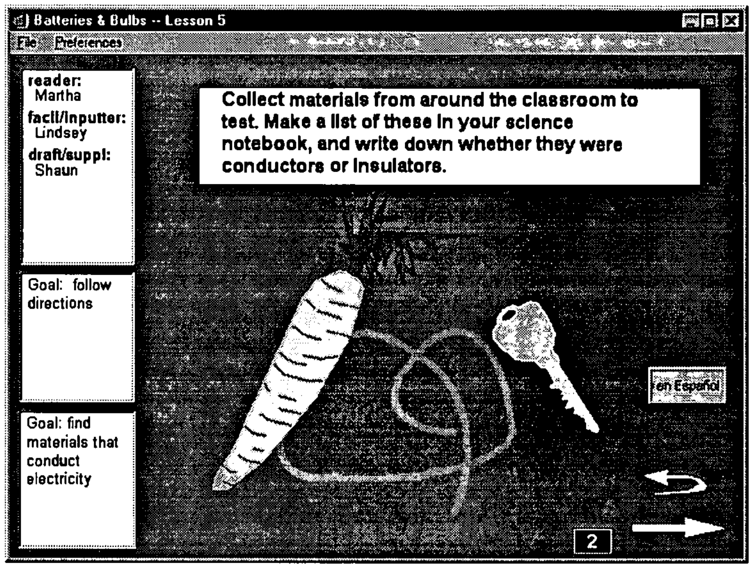

Figure 32. Some illustrations, such as this one, caused students to focus on irrelevant details.

Another example was the expansion activities for the second day of the beta tests (Figure 33). One group spent some time getting exactly the same configuration as illustrated in the picture set up, and were a little disappointed when it "didn't work."

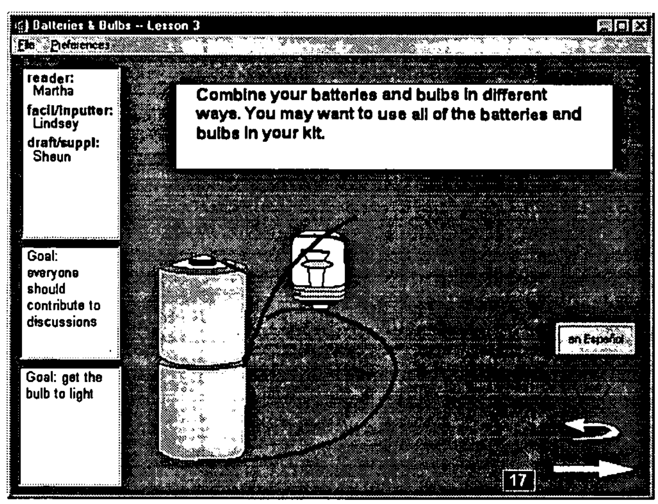

Figure 33. Another potentially confusing illustration.

3.8.7 Some Additional Explanation About Differences in Roles Might be Helpful

We found that some of the students with disabilities were nervous about being put "on the spot" for certain roles, and were reluctant to take these roles on. It wasn't until we explained to them that the software was set up to help them that they relaxed and began to really enjoy working in the (modified) role. While reviewing the tapes of the sessions, it became clear that we should have taken the time prior to beginning the unit to explain that these adaptations were available to the students. In Transcript 27, Gary found out that he was to be the reader for that lesson, and reacted with alarm. As only one researcher was in the room and was working with the other group, this reaction went unnoticed.

Gary (looking nervous, wringing his hands): "I'm the reader. I'm the reader. I'm the reader? I'm the reader. I'm the reader? Oh, no. I'm the reader."

At first, S1 read each single word to him, and then he repeated each word. A few times, she tried to get him to read a simple word by himself (such as "see") and he would try, and groan. The researcher came by and showed him how to use the button on the keypad to activate the computer reading the text, and requested him to listen to it, then try again to read it. This met with limited success, as his reading ability was so low, and his short-term memory was not sufficient to allow him to do this.

Researcher: "You know what sometimes helps, is try this. Let it say it once, and then see if you can say it afterwards."
Computer: "Click on your names to see what jobs I want you to do right now."
Researcher: [long pause] "Want to try it?"
Gary: "Click ya name, to, see, job, now."
Researcher: "That was good! Go ahead! You can click it again if you want"
Computer: "Click on your names to see what jobs I want you to do right now."
Gary: "Oh! I know!"
Researcher laughs with him.
Gary: "Clicka, your names, you see, now, you to do, tonight."
S1 (helping): "Right now".
Gary clicks on button again.
Computer: "Click on your names to see what jobs I want you to do right now."
Gary. "Ooohh! Click-ay, you are, you are special for, you are special..."
S1 and S2 point at the text on the screen and say (in Spanish). "No, here!"
They work through the screen, word by word, for some time, with S1 and S2 reading the words for him and pointing at them. On the next screen they just let the computer read. On the following screen, Gary says: "I can read it. I can read it. I can read it. I want to read it."
Clicks on button for computer to read.
Computer: "Some objects, like wire, allow electricity to pass through them quite easily. We call such objects that allow electricity to pass through them easily 'conductors'".
Gary: "Oh." Moves to next screen and presses button, and allows computer to read. On the following screen he tries to read:
Gary: "Do a ... crayon ... good ... for ... [[conductor?"
S1: "[conductor["
S1 reads the text again aloud.
After this, Gary mostly uses the computer voice.

Transcript 27. Gary discovers that he is to be the reader on the third day of the lessons and is not certain he can take on this role.

When Carrie found out that she was to be the reader on the first day of the lessons, she asked if someone else could take on that job. I told her that it would be all right. The other students in the group told me that Carrie couldn't read. I told them that we would be able to help with the problem. After she began, Carrie was quite excited to use the software and found she could use the "read aloud" feature with the earphones to allow her to take the role of "reader" in her group. For all but the longest passages Carrie was able to repeat, verbatim, what she heard on the computer.

The different capabilities offered for students with disabilities did not cause any problems for the regular education students. They did not complain about it being "unfair" that the students got extra help. I think this is because all of the students knew each other from class, and they knew that the adaptations were necessary to permit that student to take those active roles in the lesson. The only time that we were questioned about an adaptation was when Frank (one of the special needs students) heard the computer in the other group talking (when Gary was using this feature of the software.) Frank briefly questioned it, but was quickly satisfied by the response (Transcript 28.)

Frank to Researcher: "How come their computer talks?"
Researcher: "Well, some students need some extra help."
Frank: "Can our computer talk?"
Researcher: "It can, but no one in this group needs that extra help."
Frank: "Oh."

Transcript 28. Frank questions why the other computer talks,

3.8.8 Some Additional Modifications in the Design Might be Needed for Deaf Students

Although Belinda could not hear what the reader was saying, she could read the directions on the screen to assist her in knowing what to do next. For example, as draftsperson, she began opening the notebook before the reader even finished reading this direction, as she had completed reading the instructions on the screen.

As draftsperson, Belinda needed to write down the ideas of what to test for conduction during lesson three. When students were giving ideas of things to test, Belinda watched the students carefully to lip read what they were saying. She missed a few of the items students suggested, and unless other students picked the idea up and repeated it within her sight she had no way of knowing that it was missed. When students suggested writing wood, she looked surprised and asked, "Wood?" Students replied affirmatively. She repeated, "wood?" Students again said yes. She looked at me and said "wood?" The reader, sitting next to her, turned directly towards her and said "wood: double-u, oh, oh, dee" and then Belinda wrote it in the notebook.

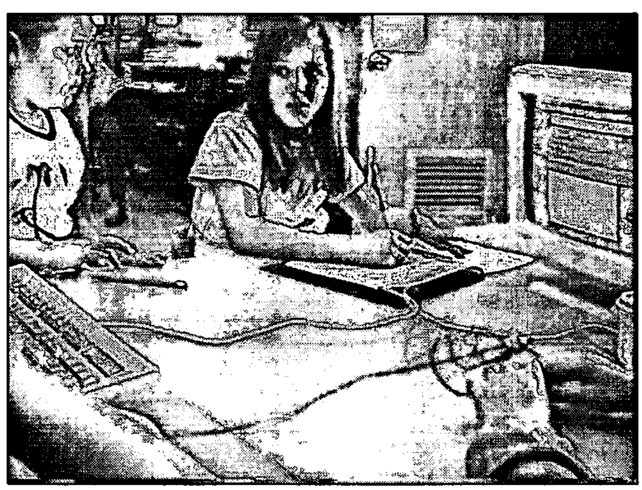

Figure 34. Belinda is not certain what the other students expect her to write.

As demonstrated in Transcript 15 (page 65), it was very difficult to get Belinda to engage in conversation during the beta test of the software. As Belinda is almost entirely deaf (hearing only some sound but unable to distinguish speech) she relies upon lip reading to understand conversation. However, during hands-on science, she needs to focus visually on the materials at hand. This presents a problem, as much of the conversation, including hypothesis-making and the formulation of scientific explanations, occurs spontaneously during hands-on science exploration. The teacher can facilitate the language development by using a wrap-up session at the end of each lesson in which the students must present results, but this will still not alleviate the problem of how a deaf child can be assisted in joining in with peer conversation during the lesson. We leave this question for future study.

4 Discussion and Summary

Overall, the goal of this study was to determine whether software could be developed that would facilitate cooperative group work in classrooms in which students with disabilities have been included. A hands-on science curriculum was determined to be an ideal subject, because it:

- provides many opportunities for open-ended problem solving and collaborative work,
- is a subject in which students with disabilities are often included (while mathematics and reading are often taught as a pull-out program in a special education classroom),
- offers an opportunity for disabled students to gain skills which they will find useful in later life (both in academic situations, and later, for job opportunities in a field in which they are currently underrepresented), and
- provides many opportunities for cross-curriculum experience (including reading, writing, communication skills, and logic development.)

The results of this beta test provide a promising indication that the software is not only feasible, but can provide opportunities for students to develop communication skills through learning to cooperate with other students in small groups. This was accomplished by designing the software to take over the myriad time-consuming tasks that a teacher normally must perform, making it possible for teachers new to cooperative learning and/or hands-on science to implement the curriculum. These tasks, which are well suited to computer logic, include:

- rotating student roles during cooperative learning so that each student has an opportunity to develop a variety of skills,
- handling absences by combining roles and modifying the rotations in a way perceived as fair by students,
- keeping track of the differential needs of students and adapting to these needs by providing appropriate support (such as read-aloud features for students unable to read, lower reading levels for students incapable of reading at grade level, providing language translation for ESL students, supporting alternative input devices for students with physical disabilities, etc.),
- providing just-in-time instruction to students so that they can smoothly move through the lessons without interruptions for instructions from the teacher, or trying to remember a complex series of steps,
- providing a range of media and teaching methodologies to support students with different dominant learning modalities,
- providing academic scaffolding for students to facilitate learning in their zones of proximal development,
- provide students with the tools and skills (both social and academic) to act as collaborative partners in learning,
- permitting differential rates of completion of materials, so that each group of students can take the time they need to get through the material for each lesson, but each group will start at the same point on the subsequent lesson,
- instructing students in materials management so that the teacher does not need to maintain the science materials or pass out and collect supplies,
- presenting open-ended problems that are interesting to students and thus create a motivating learning environment, and
- requiring students to focus on social goals as well as academic goals, thus providing students with a reference to use for claiming the rights and insisting on the responsibilities for the assigned roles.

We found that students were able to work cooperatively, even if they had little experience in working in groups. We also found that the disabled students were able to work productively in the environment. Those features of the software designed to assist students in working together were effective, and little or no interventions by instructors was required to keep students on task and actively engaged in the learning activities.

Recommendations for Further Study

The feasibility for the software has been more than adequately established by the present study. This study has demonstrated many possible benefits for students with a range of disabilities. Some aspects of the software design need some reconsideration; these include:

- potential changes in the draftsperson role for students that lack the physical or mental capabilities to write or draw figures
- potential incorporation of more direct methods for retaining the attention of hyperactive students
- potential addition of more levels of academic scaffolding for students unable to reason logically
- better support for students that are deaf and must rely on lip-reading or sign language to communicate with peers and teachers

Some aspects of the software were not tested during the beta test cycle. Although most other adaptations were tested, those added for sight-impaired and blind students were not tested. Also, most notably, what needs more testing is the software-teacher interface. During the beta tests, the researchers and special education teachers performed in the place of the regular education teachers. The teachers did have a chance to try some of the special features built in, which include:

- easy entry modules for setting up student information
- ability to change student information on-the-fly, in the middle of a lesson, if the teacher observes the need to do so (for example, switching the reading level down to a lower level for a student having difficulty)
- ability to modify the text of the lesson where this might be helpful
- ability to customize the social goals for the lesson, based on the needs for the class or for that particular group

Before this software is market-ready, we feel that the following needs to be done:

- Development of four additional complete units (one each in mechanical engineering, biological sciences, botany, and physics.)
- Re-examination of some aspects of the design (as listed previously).
- A longer term study (a full unit or more than one full unit) of the effects of using this software in classroom settings in a variety of regions, considering both social as well as academic outcomes.

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Appendices

Appendix A: Text from Computer Screens for the Lessons 2, 3, and 5

Lesson 2, High Reading Level

Text of lesson number: 02
L02N01H
Last time you worked on the Batteries & Bulbs unit you talked about what you already knew about electricity.
L02N02H
In this lesson you are going to begin to explore electricity with motors and batteries. Your challenge today is to connect a battery to a motor to make the shaft spin.
L02N03H
Click on your names to see what jobs I want you to do right now.
L02N04H
Today, our social goal is:
Be sure all group members check for agreement.
L02N05H
Suppose your group gets asked a question, and only one group member gives an idea.
Whose responsibility is it to make sure that others give ideas and to check for agreement?
L02N06H
Look at the diagrams of a motor and battery below.
%manipulatorName%, pick up a motor and point at each part.
Everyone in the group should name the parts together.
Then, pick up a battery and name its parts.
L02N07H
I will show you how to put a piece of masking tape on the shaft of the motor to make a fan.
L02N08H
Watch the video to see how to put the tape on the motor shaft.
L02N09H
You may watch the video again if you need to. In a moment we will try some experiments.
L02N10H
Today, your experiment will be to try connecting the motor to the battery in such a way that the fan spins.
L02N11H
%draftspersonName% should sketch in the notebook all the ways the group connected the batteries and motors that made the fan spin. Also, draw pictures of the ways that the group connected them that did NOT make the fan spin.
(see the example of a notebook, below)
L02N12H
Use crayons to show the color of the leads.
L02N13H
You may pick up the motors and batteries and begin your experiment now. You have 6 minutes to complete the experiment. (%inputterName% , click on the arrow to start the timer)
L02N14H
L02N15H

1. When you connected the red lead to the positive pole of the battery, which way did the fan spin?
%inputter%, type your group answer in the yellow box.
L02N16H
2. When you connected the brown lead to the positive pole of the battery, which way did the fan spin?
Talk about your answer.
L02N17H
3. Can you think of a motor that causes cooling? Where can you find this motor?
%draftsperson%, write the answer in the notebook.
L02N18H
4. Can you think of a motor that causes heating? Where can you find this motor?
Write the answer in the notebook.
L02N19H
5. Can you think of a motor that causes something to move? Where can you find this motor?
Write the answer in your notebook.
L02N20H
6. Talk about how well the group shared ideas and made agreements.
L02N21H
Now you may choose from a few activities to complete.

Lesson 2, Low Reading Level

Text of lesson number: 02
L02N01L
Last time, we talked about what we know about electricity.
L02N02L
Today, we will use electricity. We will use motors and batteries. We will try to make the shaft spin.
L02N03L
Click on your names. See your jobs.
L02N04L
Today, our social goal is:
Be sure to check for agreement.
L02N05L
If a question is asked, you should all give ideas. Then, you need to check to see if you agree.
Who should check to see if you agree?
L02N06L
Look here at the motor and battery.
%manipulatorName%, pick up a motor. Point at each part.
Everyone in the group should name the parts together.
Then, pick up a battery and name its parts.
L02N07L
I will show you how to put tape on the shaft of the motor to make a fan.
L02N08L
Look at the video.
L02N09L
See how to use the tape? We will start to use the supplies in a moment.
L02N10L
Your experiment today is to try to make the fan spin. Use the battery. Use the motor.
L02N11L

%draftspersonName%, draw in your notebook all the ways your group made the fan spin. Also, draw pictures of the ways that did NOT make the fan spin.
Look at the example.
L02N12L
Use crayons to show the color of the leads.
L02N13L
You may pick begin your experiment now. You have 6 minutes.
(%inputterName% , click on the arrow to start the timer)
L02N14L
L02N15L
1. When you put the red lead on the positive pole of the battery, which way did the fan spin?
%inputter%, type your group answer in the yellow box.
L02N16L
2. When you put the brown lead on the positive pole of the battery, which way did the fan spin?
Talk about your answer.
L02N17L
3. Can you think of a motor that causes cooling? Where can you find this motor?
%draftsperson%, write the answer in your notebook.
L02N18L
4. Can you think of a motor that causes heating? Where can you find this motor?
Write your answer in your notebook.
L02N19L
5. Can you think of a motor that causes something to move? Where can you find this motor?
Write your answer in your notebook.
L02N20L
6. Talk about how well your group shared ideas and made agreements.
L02N21L
Now you may choose what to do.

Lesson 3, High Reading Level

Text of lesson number: 03
L03N01H
Last time you worked on the Batteries & Bulbs unit your group experimented with batteries and fans.
L03N02H
Today, you will be experimenting with a light bulb and battery.
Your task is to get the bulb to light.
L03N03H
Click on your names to see what jobs I want you to do right now.
L03N04H
Today, your social goal is to be sure everyone in the group contributes to discussions.
L03N05H
This means that every time there is a discussion, every person should say something.
L03N06H
In the yellow pad below, write three things you could say to members in your group to encourage them to talk.
(Use kind and helpful words!)
L03N07H

You will use your battery, bulb, and wires to try to make the bulb light.
The supplier, %manipulatorName%, will be the first to try.
L03N08H
Then, %manipulatorName% will pass it to the next person.
Each person must get at least one turn.
L03N09H
The draftsperson, %draftspersonName% will draw a picture of each member's try.
%draftsperson%, make sure you draw the ones that DO NOT work as well as the ones that DO WORK.
L03N10H
Remember, take turns! Everyone contribute!
(Please start now. Click on the arrow to start your timer.)
L03N11H
L03N12H
Did you talk today in your group? Ask each person to answer, then click on 'yes' or 'no' for each member of your group.
L03N13H
L03N14H
Now you may choose from one of the enrichment activities.

Lesson 3, Low Reading Level

Text of lesson number: 03
L03N01L
Last time you made a fan with a battery and motor.
L03N02L
Today, you will use a light bulb and battery.
Your task is to get the bulb to light.
L03N03L
Click on your names. See your jobs.
L03N04L
Today, your social goal is to be sure everyone in the group talks.
L03N05L
When your group talks, each person should say something.
L03N06L
Type in 3 things you could say to others to get them to talk.
(Use kind and helpful words!)
L03N07L
You will use your battery, bulb, and wires to try to make the bulb light.
%manipulatorName%, will be the first to try.
L03N08L
Then, %manipulatorName% will pass it to the next person.
Each person must get at least one turn.
L03N09L
%draftspersonName% will draw pictures.
%draftsperson%, draw the ones that DO NOT work. Also, draw the ones that DO WORK.
L03N10L
Remember, take turns!
(Please start now. Click on the arrow to start your timer.)
L03N11L
L03N12L
Did you talk today in your group? Click on 'yes' or 'no' for each person

L03N13L
L03N14L
Now you may choose what to work on.

Lesson 5, High Reading Level

Text of lesson number: 05
L05N01H
Last time you worked on the Batteries & Bulbs unit your group found out about what is inside of a light bulb.
L05N02H
Today, you will be experimenting with materials from the classroom to see if they conduct electricity.
L05N03H
Your social goal for the day is to follow directions.
L05N04H
Click on your names to see what jobs I want you to do right now.
L05N05H
You have seen that electrical current can travel through wire. The electricity traveled through wire from the battery to the light bulb, and also from the battery to the motor.
L05N06H
Some objects, like wire, allow electricity to pass through them quite easily. We call objects that will allow electrical current to pass through them easily 'conductors'.
L05N07H
Other objects will not allow electrical current to pass through them. We call these object 'non-conductors' or 'insulators' (you can use either word -- they mean the same thing).
L05N08H
Do you think a crayon is a good conductor?
L05N09H
A group of students decided to test a crayon to see if it would conduct electricity or not. They hooked up a battery and light bulb to the crayon like this. They think that if the bulb lights, it would mean that the crayon conducts electricity.
L05N10H
Another group of students did not agree. They decided to hook up a battery, motor, and wires like this to a crayon. They think that if the motor spins, it tells them that the crayon conducts electricity.
L05N11H
Now, look around your desks for five objects that you could test to see if electricity will pass through it or not.
L05N12H
Some ideas of things you might test are pencils, scissors, and paper clips.
L05N13H
Can you think of anything else that electrical current will pass through?
Talk with members in your group and find out if anyone has an idea.
%draftspersonname% should write down your ideas on page 5 of your science notebook.
L05N14H
Can you think of a way to find out if electricity will pass through an object?
Talk with members in your group and find out if anyone has an idea.

%draftspersonname% should write down your ideas on page 5 of your science notebook.
L05N15H
Have your written down at least two things that you think electricity will pass through?
And at least one idea on how to test if electricity will pass through these things?
%facilitatorname%, you should be sure that %draftspersonname% has written these ideas in the notebook.
L05N16H
Let's check and see if you are doing a good job at your social goal for today.
L05N17H
Your group is good at following directions!
L05N18H
Your group is good at following directions!
L05N19H
You should test at least three items from your class. Write the name of the objects, and the result of the test, in your notebook. You may begin your experiment now.
L05N20H
Now you may choose from one of the enrichment activities.
L05N21H
Now you may choose from one of the enrichment activities.

Lesson 5, Low Reading Level

Text of lesson number: 05
L05N01L
Last time you found out about what is inside of a light bulb.
L05N02L
Today, you will experiment with things in your classroom to see if they conduct electricity.
L05N03L
Your social goal for the day is to follow directions.
L05N04L
Click on your names to see what jobs I want you to do right now.
L05N05L
You have seen that electrical current can travel in wire. The electricity traveled in wire from the battery to the light bulb. It also went from the battery to the motor.
L05N06L
Some things, like wire, let electricity pass easily. We call such things 'conductors'.
L05N07L
Other things do not allow electrical current to pass through them. We call these object 'non-conductors' or 'insulators'. You can use either word. They mean the same thing.
L05N08L
Do you think a crayon is a good conductor?
L05N09L
Some kids wanted to test a crayon. They wanted to see if it would conduct electricity. They hooked it up like this. They think that if the bulb lights, it means the crayon conducts electricity.
L05N10L

Another group of students did not agree. They decided to hook up a battery, motor, and wires like this to a crayon. They think that if the motor spins, it tells them that the crayon conducts electricity.
L05N11L
Now, look around your desks for five objects that you could test to see if electricity will pass through it or not.
L05N12L
Some ideas of things you might test are pencils, scissors, and paper clips.
L05N13L
Can you think of anything else that conducts electricity?
Talk with your group and find out if anyone has an idea.
%draftspersonname% should write down your ideas on page 5 of your science notebook.
L05N14L
Can you think of a way to find out if things conduct electricity?
Talk with your group and find out if anyone has an idea.
%draftspersonname% should write down your ideas on page 5 of your science notebook.
L05N15L
Have your written 2 or more things that you think conduct electricity?
And at least one idea on how to test it?
%facilitatorname%, be sure that %draftspersonname% wrote these ideas in the notebook.
L05N16L
Let's see if you are doing a good job at your social goal for today.
L05N17L
Your group is good at following directions!
L05N18L
Your group is good at following directions!
L05N19L
You should test 3 or more things. Write the things, and if they conduct, in your notebook. You may begin your experiment now.
L05N20L
Now you may choose from other things to do.
L05N21L
Now you may choose from other things to do.

Appendix B: Technical Specifications Document

Technical Specifications (the "short" version)

1= create a new working beta
2= make software more generalized (graphics, text)
3= program in Java

<u>Platforms and programming environment</u>

1 Windows 3.x + Win 95 + Win NT and Toolbook
3 Internet/Intranet and Java

<u>Changes in current interface</u>

1 Build in support of new hardware:
1 joystick - select sentence to "speak" or hear
1 break out language sentence by sentence
1 have narrator read text
1 highlight text sentence by sentence
1 play back digitized speech keypad
1 do schools have joystick ports?
1 does the joystick provide enough functionality?
1 can we have two options available?
1 headphone/speaker support for read text
1 audio recorder (for blind notetaking)

<u>Changes in software:</u>

1 enlarged text and text color
1 double-click on field to enlarge
1 double-click on field to change color
1 define keypad for blind inputters
teacher utilities
1 define student disabilities so can rotate
1 examine social goals -- need a special set?
1 redesign sections that required student typing
1 multiple levels of reading
1 if blind student, have reader describe the video
1 role switch module needs to be rewritten
1 modernize look of interface
1 Braille pages for each unit

<u>Other code change details...</u>

2 Make code more modular
2 generic text routine permitting different reading levels, easy modifications of text by instructors
2 database of text information?
3 Begin examining changes to code to Java coding

Appendix C: Parent Permission Slip Forms Used

December 10, 1996

Dear Parents,

I would like to introduce myself—my name is Dottie Natal, and I am a developer of educational software. My company, Imagen Multimedia, has been involved in creating software for use in schools for six years now. We work closely with teachers, students, and parents in developing software that helps turn computers into powerful tools for learning in the classroom.

We received a grant from the Department of Education to develop a prototype for software that can be used with small groups of children as they explore hands-on science materials. We've used it in three classrooms now, and find that students just love the experience of using the computer and the science materials. They also love the fact that the software is designed to assist students in learning how to work cooperatively together in a small group.

We have modified our original design so that the software provides support for students with disabilities. As you are probably aware, students with disabilities face many problems in being accepted in regular classrooms. Sometimes it is because they had difficulty in communicating with the other students. Sometimes it is because other students treat them differently. In most cases, getting students to work together to solve a problem can bridge the communication gaps, and all of the students in the group benefit tremendously. Students learn to focus on their strengths rather than their weaknesses, to see the strengths of their classmates, and to value a range of contributions to problem solving. And, of course, solving science problems helps all students learn about science topics as well as learn how approach problems in a logical way, using scientific reasoning.

We would like to ask your permission to have your child involved in our software testing and research. This involvement will be in the classroom, with a group of other students. The lessons will only be for three days, taking less than one hour each day. We've never had a child <u>not</u> enjoy the experience, and I'm sure your child would welcome a chance to use the science software and work in a group with other children. We will be observing students, sometimes interacting with them, and videotaping them as they use the software. The videotape will be used by our research team to evaluate the effectiveness of the software. It may be shown to other researchers, but the children will not be identified by name. It will not be used for any commercial purpose and will not be shown to the teacher or any other staff associated with the district.

If you and your child would like to be involved in our project, please sign this permission slip and hand it back to your teacher. If you prefer your child not be involved in the study, please return it, also.

Thank you for taking the time to read this. For more information, you can call Dottie Natal at (805)735-7576.

___ I would like to have my daughter/son involved in this hands-on science project with computers
___ I prefer my son/daughter not be involved in this hands-on science project.

Child's name:____

Parent's name:____

Signed:________________________________ dated:_______________

Do you have a computer at home? ___ yes ___ no
If yes, what kind?____

Appendix D: Student Workbook Pages for Lessons 2, 3, and 5

Science Notebook **Date:_______** **Page** **2**
Cuaderno de Ciencias **Fecha:______** **Página**

Sketch your motor and batteries.
Has un dibujo de tus motores y baterías.

Did it spin? Which way?
¿Giró el motor? ¿En qué dirección?

3. Can you think of a motor that causes cooling? Where can you find this motor?
¿Puedes pensar en un motor que es usado para causar enfriamiento? ¿Dónde puedes encontrar este motor?

4. Can you think of a motor that causes heating? Where can you find this motor?
¿Puedes pensar en un motor que es usado para causar calefacción? ¿Dónde puedes encontrar este motor?

5. Can you think of a motor that causes something to move? Where can you find this motor?
¿Puedes pensar en un motor que es usado para causar que algo se mueva? ¿Dónde puedes encontrar este motor?

Notes and questions / Apuntes y Preguntas

Science Notebook **Date:______** **Page** **3**
Cuaderno de Ciencias **Fecha:______** **Página**

Sketch how you connected the battery, bulb, and wires to get the bulb to light.
Has un dibujo de como conectaron la batería, la bombilla y los alambres para hacer que la bombilla encendiera.

Notes and questions / Apuntes y Preguntas

Science Notebook **Date:_______** **Page** **5**
Cuaderno de Ciencias **Fecha:______** **Página**

Can you think of a way to find out if electricity will pass through an object?
¿Puedes pensar ty en alguna manera, de como saber si la eléctricidad va a pasar por algún objecto?

Five conductors or insulators:
Cinco conductores o aisladores:

	Conductor	Insulator (aislador)
1. ______________________	☐	☐
2. ______________________	☐	☐
3. ______________________	☐	☐
4. ______________________	☐	☐
5. ______________________	☐	☐

Notes and questions / Apuntes y Preguntas

Appendix E: Teacher Manual Pages for Lessons 2, 3, and 5

Lesson:	Batteries & Bulbs Lesson 2
Supplies Needed:	Student Science Notebook, page B&B 2 Science Kits with 2 batteries 2 motors 2 pieces of masking tape, 6 inches long
Advance Preparation:	Cut strips of masking tape approximately 6 inches long, one for each group.
Academic Goals:	Students will experiment with getting a fan to spin
Social Goal:	Be sure all group members check for agreement
Whole Class Wrap-up:	What way did the motor spin when you connected the red lead to the positive pole and the blue lead to the negative pole of the battery? How about with red to negative, blue to positive?
Main Science Concepts:	Electricity travels in a direction.
Vocabulary Introduced:	motor leads (pronounced with long e sound) battery positive pole negative pole shaft
Think & Write:	Imagine an object operated by a battery and motor that would make your lives easier. How would it look? How would it work?
Find Out More Topic:	Batteries
Experiments to Try:	Combine your batteries and motors in different ways. If you want, you can use tape, scissors, and paper to make some kind of machine with your batteries and motors.

Lesson: Batteries & Bulbs Lesson 3

Supplies Needed: Student Science Notebook, page B&B 3
Science Kits with
- 2 batteries
- 2 light bulbs
- 4 pieces of wire, any color

Advance Preparation: None

Academic Goals: Get the bulb to light

Social Goal: Get the group back to work

Whole Class Wrap-up: Have the draftsperson from each group sketch on board one configuration their group made, without saying whether the bulb]it up or not. Have the class raise their hands if they think the drawing shows a bulb that would light If a drawing is not clear, have the group's reader explain it. You might ask: What do you think the critical points are on the battery? On the bulb?

Main Science Concepts: There are critical points on batteries and bulbs that must come in contact with the wires before the bulb will light.

Vocabulary Introduced: none

Think & Write: Open your notebook and write a description of how to light a bulb with a battery and wires. Then, have someone else try it. See if they can follow your directions.

Find Out More Topic: Electric cars

Experiments to Try: Combine your batteries and bulbs in different ways. You may want to use all of the batteries and bulbs in your kit

Lesson: Batteries & Bulbs Lesson 5

Supplies Needed: Student Science Notebook, page B&B 5
Science Kits with
- 4 batteries
- 4 light bulbs
- 4 motors
- 4 pieces of wire 4 battery holders

Advance Preparation: Prepare a large chart with two columns: Conductors and Nonconductors. Before students begin on the computers, show them how to put a battery in the battery holder.

Academic Goals: Find materials that conduct electricity

Social Goal: Follow directions

Whole Class Wrap-up: Have the reader of each group read one item from their list that conducted electricity, and one that did not. Write these in on the chart. If there is a disagreement about whether an item will conduct electricity, have the supplier from a group come up and try the experiment in front of the class.

Main Science Concepts: Some items conduct electricity, others do not. To test an object to see if it a conductor, you must create a circuit for the electricity and see if the object will allow the electricity to flow or will stop the electricity from flowing.

Vocabulary Introduced: conductors
nonconductors
insulators

Think & Write: Write a definition for conductor and insulator Make the definition simple enough that a third grade student could understand what you mean.

Find Out More Topic: Superconductivity

Experiments to Try: Collect materials from around the classroom to test. Make a list of these in your science notebook, and write down whether they were conductors or insulators.

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