TEACHING SCIENCE TO THE BLIND

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ABSTRACT

This project is intended to be of assistance to all teachers of science. Teaching strategies that were developed for this project and used at the Ontario School for the Blind can prove valuable in other areas of teaching. For example, students with low motivation can benefit from a very concrete curriculum. Even teachers at the OAC level will find that tactile diagrams and models are useful in presenting abstract theories. Whether students are blind or sighted, the use of specialized operational tactile definitions can enrich their understanding of concepts and theories and encourage a multisensory approach to gathering information.

The process of teaching science to a visually handicapped student is presented and teaching strategies and adaptations are provided to enhance concept development for high school biology, chemistry and physics. Laboratory procedures and safety considerations are also examined and an outline of the use of microcomputers for educating the visually handicapped is included.

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CHAPTER 1

INTRODUCTION

"Science education, including its practical aspects and ethical implications, should assist students to shape the future for the benefit of all society and to maintain some control of our destiny".[32] It is therefore important that science be presented as a quest for knowledge about nature. It is a search for cause and effect relationships which govern the structure and behaviour of natural phenomena.[32] The quest involves questions, discoveries, interpretations, misconceptions, implications, applications and more questions.[32] To sustain student curiosity, science must be presented as an adventure rather than as a tedious process of digesting the findings of others as though the mysteries of nature were already solved.

There are two facets to the nature of science: the process of inquiry and the knowledge that is produced from this inquiry. The nature of science is consistent, even though scientific knowledge changes constantly.[32] Science has an empirical character because its pursuit is concerned with solutions to problems through experimentation and verification. The investigative process, which generates new knowledge is the characteristic that gives science its unique nature. Science also has an analytical character which challenges students to discover hidden explanations, underlying patterns, conceptual frameworks and theoretical assumptions.[32] Hypotheses, theories and models comprise much of science. Cell membranes are modelled as being fluid and mosaic. Electrons have been compared to orbiting planets. DNA is modelled with colourful plastics and interlocking coded parts. These theories and models enable scientists to visualize explanations which may result in further experimentation, the results of which may constitute revisions of the theory or model in question. This leads us to the understanding that scientific knowledge is constantly changing as it is subject to continual revision.

"The nature of science is such that it demands reaction"[32] Science involves decision making and is part of the behaviour and decision making patterns of us all. Science has a human character because it is a quest, enjoyed and experienced by people. Quantitative measurements are characterized by objectivity and are verifiable, even though they may have some degree of inaccuracy. On the other hand, theories and models related to qualitative observations can be influenced by the personal characteristics of the observer, and therefore this involves subjectivity. However, it is this subjective nature of science that contributes to the dynamics of science.

Science has many disciplines; biology, chemistry, physics, geology and environmental science to name a few. Science is diverse in that its branches have close ties to mathematics, technology, geography, physical and health education, computer studies, engineering, medicine, forestry, agriculture, mining and many other fields.[32] However, all of its branches and applications contribute to overall conceptual networks that are consistent. These scientific concepts may be expressed qualitatively or quantitatively. A few concepts inherent to science include: cause and effect, predictability, orderliness (patterns and laws exist in nature; an example is the Periodic Table of the Elements), entropy (disorder increases in a closed system), equilibrium, change, constancy of behaviour, conservation (for example, energy is conserved in spite of change), and validation (for example, $F = ma$). Understanding key concepts and principles, being able to put scientific knowledge to practical use, realizing that science involves both process and product, and recognizing the usefulness yet sometimes tentative value of theories, are virtues of a scientifically literate person.[33] As science teachers, we should strive to develop scientific literacy for our students. Students would then be able to apply science concepts, theories, processes and values in everyday decision making, interact with our world using an exemplary environmental ethic, and value scientific and technological research and development.[33]

The processes of science include: "identifying a problem, hypothesizing, observing, classifying, measuring, communicating, inferring, formulating theories and models, gathering data, experimenting, analyzing, concluding, explaining and generalizing".[32] These processes are dynamic and therefore the experimental nature of science must be emphasized since this characteristic makes the learning dynamic. Language facility, ability to compute, inquiry skills, manual dexterity, receptive attitudes and social sensitivity can only be fostered in students if the curriculum provides opportunity for them to communicate, calculate, investigate, interact with nature and technology and face societal issues. Therefore the scientific method (based on empirical findings and logical reasoning)[32] is essential to science education.

Students who practice discovery learning will obtain efficient strategies for acquiring, transforming, organizing, storing and using information in ways that are most useful for problem-solving.[15,18] In discovery learning, since the learner acts according to his or her own interests and cognitive structure, there may be greater conservation of memory.[15] Students are motivated when they sense that some of their needs are being met. Problem-solving approaches, properly planned and carried out, provide challenge which can increase student motivation.[16]

Explaining reality is a challenge for all science teachers. We present theories to explain observations and facts. In order to develop full, accurate and meaningful concepts, the science curriculum must be concrete and experiential. There is a particular challenge associated with teaching science concepts to the blind. The sighted student is continually open to visual stimulation, which prompts him to active enquiry and exploration.[30] Touch does not provide this continual stimulation, and although hearing may alert the visually handicapped student to certain aspects of the environment, the meaning of sounds is less easily learned when listening is not supported by visual stimulation.[30] One of the most difficult things to teach a person who has never seen is an abstract concept. Take the concept of a field (a region of influence existing without direct contact, for example, gravity). Sighted students have a difficult time understanding this concept; for the blind student this conceptualization is even more difficult. Another example is the concept of quantification. Measurement provides a numerical dimension to a concrete or abstract concept, for example, mass and time. Here again we see the need for concrete examples, discovery learning and the scientific method.

The goals of a science programme for visually handicapped students fall into three major areas: the development of manipulative skills, the development of science process skills, and the development of science concepts.[23] The manipulative skills and the process skills are closely associated with the selection and appropriateness of the tools and materials the students use.[23] The science concepts need to be presented with special considerations. Herein lies the special challenge in teaching science to the blind. "Learning situations must be engineered so that the student has an experience, and then a concept is attached to that experience in terms of an appropriate operational definition".[23] Here is an example: the sighted student mixes salt with water and sees that the salt has disappeared and the mixture is clear. This gives the sighted student a visual definition of a solution. For a blind student 'clear' has no concrete meaning and therefore the process must be taken a step further. The resulting salt/water mixture is filtered. If no material is reclaimed on the filter paper, then this is the blind student's equivalent of 'clear'. The concept of a solution has now been represented. If a solid material and a liquid are mixed and the two cannot be separated using filter paper, then the mixture is a solution. Note that for the blind student, the usual visual definition must be replaced with an operational tactile definition. Here is another example: the concept of "reflection" can be based on feeling heat from the sun reflecting on the student's face, rather than the more common concept of light or image "reflection" developed with sighted students.[23]

The writer's interest in this area of teaching was stimulated by experiences at the Ontario School for the Blind from 1983 to 1988. The writer was challenged with the development of new courses of study for senior biology, chemistry and physics (chemistry had never before been taught at the Blind School). Learning to read and write in braille, developing methods for producing tactile diagrams, implementing teaching strategies and making adaptations were another part of the challenge. This project grew from that challenge, and it is the author's hope that some of these experiences can be shared with other teachers of science.

The nature of science is first examined and the goals of a science programme for visually handicapped students are described. Chapter two then addresses the topic of teaching science to the visually impaired learner. Discussions include the nature of science, the importance of concrete models and the value of experimentation. The writer describes the production of a braille Periodic Table of the

Elements. Also included here are expectations of the visually handicapped student in the science room, an outline for a practical laboratory procedures test, and a dissertation into the special needs of visually handicapped students.

Chapter three is written to provide specific instructional strategies for concept development in the teaching of biology, chemistry and physics to totally blind and low vision students.

Chapter four describes standard braille equipment, adaptations and special equipment for teaching science to the blind. This chapter gives consideration to safety precautions that should be utilized in laboratory situations.

Chapter five reviews the literature on microcomputers and the blind. Topics include: application and importance of microcomputers in the education of the visually handicapped, evaluation of hardware components, a discussion of the need for braille translation software, an outline of the capabilities of Braille-Edit (a very sophisticated word processing programme), requirements and desirable functions of speech synthesizers and an evaluation of software programmes.

In conclusion, chapter six presents a brief assessment of future needs that are essential if blind students are to proceed to post-secondary education in the sciences.

CHAPTER 2

SCIENCE AND THE VISUALLY HANDICAPPED STUDENT

Overview

The study of science includes processes such as observing, inferring, communicating, classifying, measuring, formulating, generalizing, hypothesizing and experimenting. Blind individuals need to think about and describe things in terms of their own sensory experiences rather than memorize second-hand visual descriptions.[8] This presents some difficulty in a subject such as science, which depends to a great extent on observation. Science also involves a great many abstract ideas that must be accepted on trust.[15] For a blind student, the number of abstract ideas is even greater, but the essential features are the same. For example, magnesium burns with a brilliant flame and all that remains is a white powder. Accepting the explanation that these phenomena are the result of an exchange of electrons among invisible atoms requires a leap of imagination on the part of all students.

Any science student, whether sighted or blind, has difficulty understanding the three dimensional structure of molecules. Chemistry studies the nature of atoms and molecules, the ways in which atoms and molecules interact with each other, and the changes that take place when they do interact. Molecular structure is very important in understanding these basic concepts. Water is the essence of life here on earth, and dominates the chemical composition of all organisms. The unique properties of water center upon its atomic structure and bonding, and the association of water molecules in solid, liquid and gaseous states.[45] Why does ice float? Why is ice less dense than liquid water? Students must first understand the molecular structure of water in order to understand the physical properties of water. This task is no more difficult for a blind student. In fact, blind students can do at least as well if not better in understanding atomic structure. The use of molecular models is invaluable for all students. The blind student, however, may have an advantage here. Since they have never seen the two dimensional structure of a molecule represented on paper, they "see" only the three dimensional model they hold in their hands. They have nothing to confuse it with as it is all they have "seen".

A common question encountered in laboratory work is "what colour is it?". Both blind and sighted students are required to know that acids turn blue litmus paper red. Although a blind student is unable to see the colour change, it is imperative that this knowledge be acquired and that the theory behind why the colour changes be understood (acids release hydrogen ions in aqueous solutions). For free communication with sighted people, the blind chemistry student would have to memorize colour reactions such as the indicator tests for acids and bases or the colour code for flame tests of the elements. The actual colours may be meaningless to a blind student, but the concept of a reaction is very important.

In the integrated setting, the teacher can capitalize on the blind student's special need and at the same time encourage the sighted pupils to make more use of their other senses. This would require no changes in content, only a redirection of emphasis. For example, acids make baking powder fizz. This fizzing can be heard as well as seen, and one can feel gas pressure build up by placing one's thumb over the mouth of the test tube. Blind students have no difficulty identifying gases that smell or 'pop' such as chlorine or hydrogen, or pungent liquids such as ammonia. Crystals, if big enough, have clearly defined shapes, and relatively safe acids such as citric, acetic and carbonic can be tasted.

Learning the symbols for atoms and ions is no more difficult for a blind student than for a sighted one. However, because of the complexity and tediousness of chemical braille, chemical equations and structural diagrams are difficult to braille and take quite some time. Very few people use chemical braille, and it is unknown to most students until they reach grade eleven. Therefore, remedial time should be spent with the blind student attempting to learn this new and difficult code. Please refer to Appendix A for examples of chemical braille.

Although much can be accomplished with ordinary laboratory equipment, the equipment must be modified if a blind student is to make observations independently. A blind student must have his or her own set of materials to manipulate if learning is to be complete and efficient.[23] Blind students, unlike their sighted peers, simply do not have the ability to make passive observations; learning must be active. Consequently, an active science programme demands a definite commitment to materials. Certain materials essential for the teaching of science are not commercially available, and therefore the teacher would have to make them him or herself or have them specially made. For example, a braille version of the Periodic Table of the Elements needed to be developed. The writer was overwhelmed by this task, and needed student feedback to evaluate several models of the table. A booklet version of the table, when field tested with some senior science students, appeared to be inappropriate. The students felt inhibited by it, because they could not scan all of the elements at once. For the same reason, an overlay version of the table also failed the test. These first two models were very primitive, and only provided the student with the atomic symbol and atomic number. There were several other models produced that were too awkward for the students to use. The final version is a braille table approximately 3 metres long by 1.5 metres wide. This is hung at 'finger height' so-to-speak, at the back of the classroom. It has been constructed of many bristol boards, braille labels, textured symbols (felt, cloth and other objects) and shape symbols. The table includes atomic symbol, atomic number, electronegativity and atomic mass. The students like this table, but there are still some disadvantages. At the present time there is only one table in existence. This necessitates students to work at the table at different times, or at different positions on the table. As large as the table is, there is still not enough room to include the name of the element in each given square. A separate key is therefore needed indicating the atomic symbol and the name of the element. The seven periods are indicated on the table, as are the eight groups. This table was completed in 1986 and since then, a committee of the International Union of Pure and Applied Chemists (IUPAC) suggested a new format, replacing groups one to eight with groups one to eighteen. Therefore, a newer braille version of the Periodic Table should now be developed, possibly one large enough to include the names of the elements.

Laboratory work is an essential and very large component of a science course. Laboratories offer students many opportunities to develop skills and abilities that they will find useful in their everyday lives.[18, 32, 48] Process skills that can be enhanced through laboratory work include: learning to observe, sense, compare, classify, measure, estimate, predict, infer, describe, inquire, investigate, experiment, organize data, graph, manipulate equipment, design strategies, control variables, evaluate, synthesize, interpret, explain, theorize, solve problems and understand conceptual schemes.[32] Experimental situations also provide an atmosphere in which the student can develop communication skills, computation skills, interpersonal skills (learning to get along with others and being considerate to those who are handicapped), technological skills (learning how to understand how things work), job-preparation skills (learning to organize time efficiently), and even research skills (learning how to learn; learning how to collect and process data). The reasons given here stress the importance of laboratory work and therefore, even though it would be easier to abandon laboratories for blind students, and simply offer a theory course, extra effort is required on the part of the teacher to make the science course as experimentally oriented as possible.

In order to achieve these important advantages, the blind student must be allowed to participate in laboratory sessions. Most laboratory work is done in groups of two or three students. In the integrated setting, sighted group members should behave naturally - the blind one should share their successes and not be protected from failures. Because blind students are often obliged to rely heavily on other group members, it is desirable that they have a positive attitude and do their share of the work. They gain little by standing back and passively recording the other peoples' results. In a group situation, they should be an asset rather than a burden. Because of their heightened sensitivity in nonvisual areas, they can make a unique contribution by making observations that their sighted classmates might otherwise have missed.

In science, a blind pupil needs more time than the sighted student to handle the equipment, get it going without help, and experience its possibilities. One way to overcome this difficulty is to provide 'open laboratories'. For example, at the Ontario School for the Blind (now called the W. Ross Macdonald School), open laboratories were set up twice a week. Students would come into the laboratory, explore the equipment, and practise simple experimental procedures. Students were encouraged to come to the open laboratory prior to the actual experiment, to familiarize themselves with the equipment and to learn the particular procedure for that week. This pre-laboratory time for the students enabled them to complete the assigned experiment in the given time.

Expectations of the Visually Handicapped Student in the Science Room

1. Visually impaired students should examine the apparatus and materials of an experiment before, during and after the procedure. This facilitates the development of manipulative skills and science process skills and enhances the development of science concepts.

2. Situating partially sighted students as close as possible to all demonstrations reduces the effects of their visual impairment.

3. Concrete examples should be provided to the student so that he/she can learn the meaning of concepts such as volume, mass, density and measure. Of course, the use of concrete examples in all areas of the science curriculum is beneficial for all students, blind or sighted.

4. A partner is often required to help in laboratories, to describe and aid in measurement.

5. The visually impaired student should participate in setting up the experiment, performing the experiment, keeping a record of the observations and cleaning up the experiment.

6. Visually impaired students are required to pass a Practical Laboratory Procedures Test. This assessment is to ensure not only their own safety, but also the safety of all

those around them. This is described later in this chapter.

7. The visually impaired student will be expected to learn how to use the Braille Periodic Table of the Elements.

8. The visually impaired student will be expected to learn braille signs for chemical notation. This is to include the writing of chemical equations and braille-dot chemical formulae.

9. The visually impaired student will be expected to observe tactile diagrams. These are most numerous in Biology, but there are quite a few in the Physics and Chemistry disciplines as well. Tactile diagrams are an integral part of the teaching process, and students must take the time to observe these. Many copies should be available on a sign-out basis for self-study, which should be in addition to the time provided in class.

Practical Laboratory Procedures Test

Laboratories are an integral part of the science curriculum, and any science student, sighted or blind, must be familiar with safety prodedures and equipment. All students must learn to follow instructions regarding proper usage of equipment and expected experimental procedure. They must check equipment for damage, anticipate hazards and plan responses. They must show good housekeeping and proper clean-up techniques. Students must understand the use of protective equipment, secure equipment to prevent spills, and utilize proper disposal methods. Safety in the laboratory involves the prevention of accidents by people through planning and proper performance.[32,33]

One way to address these concerns and reduce risks is to implement a practical laboratory procedures test. Such assessments help ensure student safety. A passing mark on the assessment can be 100 %. Grades seven through OAC obviously have different tests, and tests also differ across the disciplines of science. However, one can be strict about the 100 % passing grade for all grade levels. A student who cannot achieve this can receive remedial assistance and be encouraged to attend the open laboratories. The students can attempt the test as many times as needed until they achieve this goal.

The following is an example of an assessment used in the grade 11 Advanced Chemistry course:[34,38,45,46,47]

The student will be able to safely perform the following tasks:

1. get out the equipment
2. set up a bunsen burner, retort stand, iron ring and gauze pad
3. light the bunsen burner
4. boil water in 1000 ml, 500 ml, 100 ml and 50 ml beakers
5. use beaker tongs to remove a hot beaker from the apparatus and pour the contents of the beaker down the sink
6. pour liquids from graduated cylinders into beakers and/or test tubes of various sizes
7. use a glass stirring rod
8. set up a water bath
9. use an adapted syringe or adapted medicine dropper for measuring
10. turn the stop-cock on a buret
11. use rubber stoppers
12. handle chemicals with care and respect: follow the teacher's instructions to the letter with regard to usage and disposal
13. use an adapted scoop with sliding cover
14. fold filter paper correctly, place it in a funnel, and

use the funnel properly to filter liquids

15. learn the uses of different clamps in the setting up of laboratory apparatus

16. learn the correct procedure for using the digital electronic scale

17. clean all glassware, put all equipment away and leave a neat bench

The assessment described above is only one example. A practical laboratory procedures test must be developed for each science course and tailored to meet the needs of the individual students enrolled in that course.

Special Needs of the Visually Handicapped Student

The goals of education for the blind are no different than the educational goals for sighted children.[3,14] However, the means of attaining these goals are more complex and demand significant modifications, adaptations and extensions of the curriculum and the teaching process.

Upon entering school, the blind child often has a limited experiential base and a resulting language deficit, as well as limited and poorly developed concepts because of a restricted opportunity for first hand experience and observation.[11] Many blind children have a limited ability to learn from secondary learning experiences due to poor orientation, poor mobility and motor skills, poor spatial relationships, and a lack of readiness skills.[4] In addition, many life skills, including self care, grooming, care of possessions and play skills may be either absent or poorly developed.[22]

In contrast to a sighted child, the blind child's vocabulary is often limited due to the absence of visual experience; visual learning styles, visual-motor skills, and certain basic concepts of the surrounding world are absent because there is no visual observation.[10] The regular school system presumes these basic competencies and provides a curriculum designed to teach children how to read, write, do arithmetic, acquire information in various content areas and to develop new skills through the use of these competencies.[27] Special education for visually handicapped children developed to meet their special needs and the developmental lag that many blind children suffer in social and emotional growth.[28]

Social interaction is based on both oral and visual communication.[12,13] But the visible clues are not available to the blind child. He or she is not able to see how other people express their feelings. Since many blind children spend most of their time with adults, they often lack the social skills necessary to interact effectively with their peers.[30] They may also lack a positive self-image necessary to form the basis of future social and emotional growth.[42]

It can be seen then, that a blind student needs a broadened curriculum, the skills of a trained teacher, and special learning materials. However, classroom learning should not be all that a blind child receives from his/her school experience. Athletics and social events, the pursuit of school-related hobbies, daily living skills instruction and orientation and mobility are of great importance, especially at the secondary level. The development of these competencies through opportunity form the focus of peer interaction, acceptance and evaluation, and also cater to individual interests.[35,36]

A great majority of blind students have significant physiological and/or psychological handicaps in addition to their blindness. In order to effectively serve the multi-handicapped blind student, comprehensive programs must be developed so that the educational experience addresses psychological and social development as well as the basic curriculum.[42]

Please refer to Appendix B for an outline of some basic characteristics of blind students that are relevant to the topic of this project.

CHAPTER 3

TEACHING STRATEGIES

Students without detailed vision often lack certain basic concepts (such as left/right, up/down, over/under) and may fail to unify integral components of their environment. These concepts must be taught to visually handicapped students so that they can increase their knowledge base and participate equally with sighted peers whenever possible.[23] Therefore, it is important to develop systematic methods for teaching concepts. The teacher of visually impaired students must consider logical ways of thinking about concepts that provide direction for the instructional process.[23] Concepts should be carefully taught to students using both manipulative materials and verbal explanations whenever possible.[23] Flexibility is important since the design of actual lessons will vary with the needs of particular students and the specific situations in which a concept must be taught. Teachers of the visually handicapped should also be flexible when it comes to assessing a student's understanding of concepts. Both verbal and performance responses should be elicited from the student in the assessment of concrete concepts.[23] This helps to clarify the relationship between a student's language ability and performance skills. The teacher must use his or her judgement to determine which conceptual levels a student can be expected to master, taking into account the student's visual functioning.

The purpose of this chapter is to describe specific instructional strategies for teaching biology, chemistry and physics to totally blind and low vision students.

BIOLOGY

1. A 'Touch Board' was assembled and changed weekly. This simply consisted of tactile objects and pictures hung on the wall at "finger height". This enhanced process skills such as observation, classification, comparison, prediction and interpretation.
2. Interesting objects were kept on the teacher's desk for the students to 'look' at. Examples: animals made from nuts and shells. This again, enhanced process skills such as observation and comparison.
3. There were classroom pets such as rabbits, gerbils, fish, frogs, snakes, turtles and birds. This facilitated health skills (respecting the health and welfare of other people and animals) and interpersonal skills (students worked in pairs caring for the animals).
4. For studies in genetics, a black felt board with white

felt sperm, eggs, and cells was used. The totally blind could feel, and the partially sighted had good contrast with the white on black.

5. An object identification table was set up and changed weekly. Collections on display included leaves, twigs, bark, insects, shells, crustaceans etc.

6. Preserved specimens provided excellent concrete examples of vertebrates and invertebrates.

7. Dissection: The writer has dissected the following with totally blind students: locusts, crayfish, frogs, perch, lamprey eels, dogfish sharks, fetal pigs (including removal from the uterus), chicken legs, cows eyes, hearts, lungs, kidneys, and livers.

NOTE: The teacher would dissect a specimen herself and the students would observe what was done, and then go to their own specimen and do the same. This method took a lot of time, but it did permit the students to dissect on their own.

8. The human torso body model was invaluable.

9. Tactile cell models were made by putting jello in a square tupperware container with objects placed throughout, to illustrate cell organelles in the cytoplasm.

10. Outdoor bird studies were very successful. Students did an ecological survey of birds by identifying their song or mating call. Each spring, classes participated in migration

studies, and one May a Grade 9 Advanced class identified 36 species on the 65 acres of school property.

11. For low vision students: an overhead projector was used to enlarge protozoans collected from a pond study. Samples were placed in a clear petri dish (the bottom of the petri dish must be completely covered with water). Protozoans could be seen as black objects moving against the white overhead screen.

12. Tactile diagrams were used in all areas of the biology curriculum at all grade levels. The production of tactile diagrams involves a lot of time and creativity. Straight edges are best produced with uncooked spaghetti noodles or wooden match sticks. Other useful items include buttons, twist-ties, yarn, pom-poms, pipe-cleaners and apple seeds. Texturing can be done with flour on glue (producing a 'soft' sensation) or with sugar on glue (producing a 'rough' sensation). It is best to sketch the diagram first on paper and then transfer the sketch to braille paper. Objects and labels should then be applied directly to the braille paper to produce the braille master. This master sheet can then be thermoformed, which results in the 'braille photocopy' for the students.

13. Field trips were invaluable - very helpful responses were received from personnel at the Metro Toronto Zoo, Ontario Science Centre, Mountsberg Nature Centre, Chedoke

Rehabilitation Hospital and the Guelph University Arboretum.

14. Outdoor awareness games - these activities help to sharpen the senses and provide the student with an awareness of life and its processes. Students can learn to develop a comfortable feeling in the out-of-doors and may even develop an interest in nature. These games also provide students with an opportunity to understand the ways of nature and develop a concern for the environment and a sense of responsibility for living things. Games may involve touching, tasting, smelling, hearing, grouping, feeling, expanding, filling, observing, scrutinizing, silencing, waiting and empathizing. A few examples of outdoor awareness games include: scavenger hunts, food chain and food web activities, and predator-prey games such as Wolf and Deer, and Stalker.

15. The science section of Trivial Pursuit was brailled and large printed. This was useful at the activity centre for students who had completed classroom work and had extra time on their hands.

Most braille usage in biology involves Grade II Braille, except for the periodic use of Nemeth Math Code or Chemical Braille. Please see Appendix C for an outline of Grade II Braille.

CHEMISTRY

Chemistry can challenge the best of science students. Imagine then, the frustration for those who cannot see to hold a red-hot crucible, to tell if an element changes colour or to see a precipitate forming in the bottom of a test tube.

This section outlines specific teaching strategies for chemistry and also addresses some more advanced modifications to equipment that are used at the post-secondary level of education.

1. Some school boards will give approval for a classroom aide during laboratory periods.
2. Tactile graphing boards are very useful for recording and interpreting data. These can be made by hammering nails into a piece of wood and having students graph with elastic bands.
3. A black felt board with white felt molecules has worked well for illustrating molecular configurations. The contrast is good for low vision students; the totally blind student can feel what is on the board.
4. Pre-measure all acids and bases for each lab group.
5. Pre-mass chemicals for each lab group.

6. For low vision students: add food colouring (colour depends on the student's individual contrast needs) to water and have the student measure the required amount of water in front of a white backdrop. White boards with platforms can be made, upon which the beaker, flask or graduated cylinder sits. The contrast helps many low vision students. Large print labels can also be placed directly on the white backdrop.

7. Perform as many demonstrations as is possible. Demonstrating an exothermic chemical reaction is an excellent one for the visually handicapped. This topic can demonstrate the concept of 'exothermic' or the concept of 'metal displacement' or can be used to determine mass relationships in a chemical reaction. The reaction between cupric chloride and aluminum foil in water provides the visually handicapped student with auditory, tactile, and 'smell' observations. Note: tactile only in the sense that they can feel the heat produced after the reaction has occurred by touching the outside of the beaker in which the reaction occurred.

8. Tactile atomic model kits are invaluable (wooden ball and stick models, styrofoam and toothpick models, wooden ball and spring models, etc.) Blind students were found to have the best success with the wooden ball and stick models. Toothpicks tend to break, and totally blind students have

difficulty working with the springs.

9. Tactile models of the atom can be produced with pipe cleaners and pom-poms.

10. A Periodic Table of the Elements in braille is essential. (see a discussion of this in chapter two)

11. Tactile models of 's' and 'p' orbital configurations can be made with pipe cleaners, pom-poms and uncooked spaghetti noodles.

12. Tactile models of ionic crystals can be made in various ways. Straws and styrofoam balls is one method.

13. Formula games help students practice formula writing. These were produced in both large print and braille. Games of this sort can be developed simply as a set of quiz cards, or as a board game.

14. Programmed nomenclature worksheets were prepared in braille and large print.

15. Acid-base neutralization procedures can be reviewed by the visually handicapped student with "Titrate", a Public Domain Software Program.

16. Students were most welcome at all of the planned field trip destinations. Local industries were very cooperative and helpful.

Please refer to Appendix A for examples of Chemical Braille.

At the University of Louisville, in Kentucky, a project for the National Science Foundation is seeking to make University laboratories accessible to blind chemistry students.[17] The main difference between a lab limited to the sighted and one accessible to the blind is the use of computers.[17] The researchers have interfaced a simple home computer with a voice synthesizer that reads out information. The computer and voice synthesizer are connected to a scale and a thermometer. For experiments involving test tubes, blind students use tubes anchored in rings of cork. A light beam that shines into the tube through a hole in the cork indicates when liquid rises to that level and sets off a buzzer.[17] A similar technique is used for experiments that produce a colour change in a liquid. A light beam shines through the fluid and activates a tone when the liquid starts to change its hue.[17]

PHYSICS

Intelligent decision-making increasingly requires a conceptual background in the physical sciences. Therefore, science education must concern itself with the essentials of physics which will provide a basis for students in analyzing and assessing related societal concerns.[18,18,24] Physics is basic to almost all the other sciences; to careers in fields as diverse as music, aviation and the health sciences; even to leisure activities such as photography and sailing.[33]

Some areas of the physics curriculum can be presented to the totally blind and low vision student with relatively little difficulty. However, there are some areas that present a definite challenge. The following section outlines specific teaching strategies that are useful in teaching this discipline.

1. Sound and energy discussions: Sound a tuning fork and place it in a full beaker of water. This demonstrates that sound is a form of energy as the water is displaced.
2. Magnets: field lines can be mapped with iron filings which can then be sprayed with two or three coats of varnish for a permanent record.
3. Simple meter: mount a braille compass inside a coil of wire - this allows the student to make measurements of its

angle of deflection and see how the angle varies with the flow of current. This permits the blind student to experience the action of a simple meter.

4. Simple circuit boards: buzzers can be varied to allow the student to detect differences. For example, buzzers in a circuit instead of lightbulbs allow the blind student to determine whether or not the circuit is complete.

5. Points of reference: if students need a point of reference for an experiment, for example, a particular amplitude for a pendulum experiment, use a piece of string and tape it down to the lab bench.

6. Field trips: blind students have been most welcome for special studies at the Ontario Science Centre and the Chedoke Rehabilitation Hospital.

7. Tactile diagrams were used in all areas of the Physics curriculum.

8. Tactile graphing boards are very useful for studies in speed and acceleration.

9. Acceleration carts: the ticker tape was used as by a sighted student, but then the teacher placed a braille dot wherever the ticker tape showed an imprint. Braille rulers were then used and students could compile their own data.

There were some difficult areas of the physics curriculum to present to the blind. These areas included:

<u>Light</u> - ray box experiments

- convex/concave mirrors
- refraction (air, water, prism experiments)
- lens applications (cameras, eye, telescopes)

<u>Electricity</u> - circuit diagrams

<u>Electrons Moving in Gases</u> - cathode ray tube

- fluorescence

The writer was not comfortable teaching these areas of the curriculum and there were little or no resources to draw upon. A lot of work needs to be done in these areas of physics in order to make these topics more 'teachable' to the blind student.

The braille used in the teaching of physics involves largely Grade II Braille and Nemeth Braille Code. Please refer to Appendix D for a discussion of the Braille Code and to Appendix E for the Nemeth Braille Code.

CHAPTER 4

ADAPTATIONS, SPECIAL EQUIPMENT AND SAFETY CONSIDERATIONS

Standard Braille Equipment

The standard braille equipment for the teaching of any science course would include: brailler, braille paper, braille ruler, braille compass, braille protractor, braille, taped or large print textbook, tactile graphing board (this can be homemade using wood and nails; the student graphs with either string or elastic bands), tactile diagrams, abacus, and a talking scientific calculator.

Braille and/or large print labels should of course be placed on all equipment, cupboards, shelves, racks and chemicals.

Adaptations and Special Equipment

The science curriculum must be experiential in order to build meaningful concepts of the surrounding world for students who cannot see. The lab provides an atmosphere for hands-on learning. Although the following list may seem extensive, such adaptations are important to provide concrete opportunities for the visually handicapped student to learn.

1. Braille Periodic Table of the Elements
2. Large print display electronic scale
3. Adapted scoops with sliding covers for picking up solids and powders
4. Syringes with clicking dials for dispensing liquids
5. Adapted medicine droppers (releases one drop at a time)
6. Buzzers with different lengths of electrodes to measure volumes of liquids in test tubes, flasks, beakers, and graduated cylinders
7. Tactile model of the atom
8. Braille samples of Lewis Dot diagrams
9. Concrete electron configuration model
10. Tactile molecular model kits
11. Tactile models of 's' and 'p' orbital configurations
12. Samples of chemical braille

13. Tactile examples of single, double and triple covalent bonds

14. Braille energy level charts (showing electronegativity of the elements)

15. Samples of braille chemical formulae

16. Tactile model of an ionic crystal

17. Concrete examples of homogeneous and heterogeneous mixtures

18. Tactile floating scales to measure liquid levels

19. Large print and braille formula games

20. Large print and braille programmed nomenclature worksheets

21. "Titrate" - a Public Domain Software Program

22. Modified Syringes with 5 and 10 ml steps

23. If possible, an interface to connect a microcomputer and voice synthesizer to a scale, thermometer and oscilloscope

24. Adaptations (tactile and voice) to existing software programs that would permit increased computer usage in the teaching process

25. Adaptations to most physics equipment (ticker tape and acceleration carts, voltmeters, ammeters, oscilloscopes, ripple tanks, audiogenerators). Such adaptations usually involve braille labels.

26. Most biology models do not need adaptations other than braille labels. Examples are: leaf, eye, heart, cell, DNA.

27. Stuffed (taxidermy) animals are wonderful for the blind and low vision student. At the W. Ross Macdonald School there is an extensive collection which includes: a deer, moose, bear, beaver, mink, birds of prey, fish, turtles, a crocodile, an alligator, and an iguana. The students loved to touch the animals, an opportunity which they could not have at the zoo.

28. Trips to the zoo were very educational, however. There were many types of animals that the zoo staff were able to hold and let the students 'feel'.

29. Tactile sperm, egg, zygotes, chromosomes, and chromatids for the study of genetics

30. Tactile cell model (see 'jello model' described in chapter three)

31. Tactile models of bacteria and viruses

32. Concrete examples whereever possible, for example, in the Vascular Plant unit: roots, stems, leaves, seeds, flowers and fruits.

33. Preserved specimens

34. Videos and movies are useful in the teaching process, and need no adaptation. Blind and low vision students enjoy listening to movies. However, video tapes stress the visual mode of learning, and audio tapes would be more valuable for the blind student. The problem is that audio tapes are not readily available and there is no selection for senior science topics. This is an area of great need.

SAFETY CONSIDERATIONS

Having a visually handicapped student in close proximity to hazardous chemicals causes concern, and rightly so. However, when certain steps are taken to ensure the safety of all involved, there seems to be no valid reason for preventing a visually handicapped student from taking a science course and fully participating in laboratory work.[30] In many circumstances, blind and partially sighted students have been refused enrollment in biology and chemistry courses because the school board felt that it would be 'too dangerous' for all concerned.[31, 37] With a little extra effort and creativity, a lab can be set up in such a way that it permits full participation on the part of the visually handicapped student.

The following is a list of safety considerations and regulations that were developed for laboratory situations. Most of these are based on common sense, but some have been added in consideration of the visually handicapped student.

1. Set up the lab and classroom in a neat, organized fashion. Do not overcrowd storage shelves - ample space for equipment makes accidents less frequent, and makes it easier for the blind student to reach out and look for the desired piece of equipment. All materials in the lab and classroom should be labelled in both large print and braille. It is of great importance for the teacher to keep things in place, and not move things around without telling the students. Also, things should not be left out with the intention 'I will put it away later'. If a student knocked a rack of test tubes off a lab bench and the rack should not have been there in the first place, it certainly cannot be the student's fault.

2. Use safety goggles when heating liquids and at other times when required. Some totally blind students will prefer not to wear them - they will often say "but I'm blind anyway"! Safety goggles not only protect the eyes, but also protect the face. It should be a rule that safety goggles be worn when required. If a student refuses, they should be dismissed from the lab.

3. Take the usual precautions when working with electrical equipment, but be sure that the blind students know where electrical outlets are, and where cords are plugged in.

4. Select reactions that minimize hazards in the lab.

5. Pre-measure all acids and bases for a visually

handicapped student, and use only dilute acids where possible.

6. Instruct students in the proper use of solutions that may be poisonous, reactive or corrosive. Have them keep liquids and solids away from the mouth, wash hands after working with chemicals, and tie back loose hair or clothing. Bracelets or other dangling jewellery should not be worn, as it could catch on glassware and cause it to fall.

7. Ensure adequate ventilation when using toxic gases.

8. When placing the alkali and alkaline earth metals in water, put a wire screen or gauze above the beaker. Do not attempt to collect the gases released by potassium and sodium. When collecting and testing the gases produced when lithium and calcium are reacted with water, ensure that no air bubbles are present in the test tube prior to collecting the gases.

9. Ensure adequate ventilation when reacting metals and non-metals with oxygen.

10. Secure any cylinders used as gas sources.

11. Select the gases used with safety in mind.

12. Handle gases and mercury with care.

13. Warn students that gas measuring tubes are easily broken. Be certain that liquid can escape from the bottom of the tubes so that gas pressures do not build up.

14. Use simple dry cells instead of power supply units.

15. Caution students not to taste chemicals when testing for the properties of acids and bases (unless this is strictly controlled by the teacher who has made an exception to this rule).

16. Whenever possible, use common and non-toxic chemicals for systematic precipitations. Avoid complex cyanide precipitates and the evolution of hazardous gases when preparing electrolytic cells.

17. Impose the regulation that the visually handicapped student pass a practical laboratory procedures test. This assessment ensures their safety and also the safety of all those around them. (See Chapter 2)

18. Instruct students that they are not to go inside the fume hood station.

19. Students should work in a designated area of the lab bench and braillers and braille paper should be kept off the bench. Small lab tables can be placed to the side of the lab bench for recording purposes.

20. Use common sense when working with bunsen burners.

21. Scissors for dissection should not be 'too sharp'. Blind students should not use scalpels.

22. Use scoops with sliding covers to permit the blind student to lift powdery or granular substances from a jar without touching the solid.

23. Tape pieces of apparatus or electrical connections to a

work surface once they are positioned in their proper places.

It should be mentioned that the teaching strategies outlined in the previous chapter (chapter three) were conditional on the development of this special equipment and these safety precautions discussed here in chapter four.

CHAPTER 5
MICROCOMPUTERS AND THE BLIND

The Application of Microcomputers

The technological revolution and the current information explosion has led to perhaps the most important crossroad in the history of education and rehabilitation of blind people. Linked with effective education, technology is the blind person's most powerful ally in learning to live in a sighted world. Sensory aid technology can provide virtual equality to blind and visually impaired individuals with their sighted peers, and can enable them to function as capable members of society.[28] Using the appropriate device, blind and visually handicapped persons can independently access, process, store and transmit the same information handled by sighted people.[25] Microcomputers are used by the sighted and the blind to manipulate information. The difference lies in the form in which the information is displayed - on a video screen, in regular print, large print, braille, or synthetic speech. The computer, unlike humans, has neither preferences nor prejudices. Microcomputers reduce disability, enhance ability, and facilitate more effective interaction with other people and the environment.[7]

Visually impaired students are largely precluded from using microcomputers effectively without special means of access. Access technology is defined as "the equipment, equipment interfacing, software, and instructional materials enabling independent use of microcomputers by visually impaired persons".[2] Equipment includes devices that produce tactual or auditory output and/or enlarging visual output. A number of adaptive devices, many of which utilize a braille keyboard, have appeared on the market which has increased employment opportunities for the blind. However, despite this, adaptive devices have limitations that give rise to a strong potential for problems due to mis-matches in application.[21]

The technology was developed to improve the life of the visually impaired person, but often it further complicates it. The equipment is expensive and often the individual requires extensive training.[20] Very little evaluation is being done on the expanding technology or to explore optimum ways in which it can be used. Software tends to be of poor quality, and more often than not, turns out to be incompatible with the hardware components.[7]

This chapter evaluates various hardware components, and assesses editing programs with respect to their ability to transcribe materials into braille. The basic requirements and desirable functions of a speech synthesizer are also discussed. Most importantly, a set of criteria is presented, which will aid in the evaluation of software to be applied in the education of the visually impaired.

Evaluation of Hardware Components

When a visually impaired individual is choosing a particular system, all possibilities must be kept in mind; the various roles the devices can play, the susceptibility of the device to becoming obsolete due to the rapidly changing technology, and the cost (adaptive devices can range in price from $100. to $30,000.).

This evaluation looks at two hardware systems, the Brailink and the Versabraille. Brailink is a self-contained, portable, intelligent computer terminal with braille display. The terminal can be used off-line or direct on-line to the computer. Versabraille is a braille information centre that combines the functions of word processor, computer terminal and read-write notetaker all in one. Its power and friendliness make it attractive to new and experienced computer users. It is a self-contained, portable unit which can be linked to a computer via a standard serial interface.

Please refer to Appendix F for an extensive discussion of advantages and disadvantages for both the Brailink and the Versabraille. Appendix G consists of responses by blind and visually impaired students to a questionnaire relating to their school and personal use of Brailink or Versabraille.

Based on referenced documentation and student responses, it would appear that the Versabraille system's advantages far outweigh its disadvantages. Since the widely used software Braille-Edit has been specially designed for the Apple with the use of Versabraille, it predisposes that the Versabraille is far superior to the Brailink.

Graphic representation is not possible when using the Brailink or the Versabraille. If graphics appear on a CRT screen they cannot be translated into braille symbols, or spoken if the adaptive device is a speech synthesizer. At this time, graphics cannot be emulated by any available device for on-line computer interaction by the blind user. There is therefore, a need for custom software designed especially for use with an adaptive display for the visually impaired.

References will be made later in the chapter to other access devices which interface with the Apple IIe microcomputer. A brief overview of these is provided in the following appendices:

Appendix H - The Cranmer Perkins Brailler

Appendix I - DP10 and Visualtek's 19" Monitor

Appendix J - The Optacon

Appendix K - The Kurzweil Reading Machine

The Need for Braille Translation Software

Braille translation programs have two separate functions. The first function is to transcribe material from print into Grade II braille. This is accomplished by typing material on a microcomputer keyboard and then having it run through the braille translation software in the microcomputer to produce the Grade II braille. The braille may be output to a hard copy braille embosser such as the Cranmer Perkins Brailler or to a paperless braille display unit such as the Versabraille.

The second function should be appropriately referred to as reverse translation.[28] Software with this capability enables a blind person to prepare text on a paperless brailler in Grade II braille and to have it transcribed into print via the use of a microcomputer loaded with the reverse translation software and interfaced with an ink printer.

Both of these functions have important implications. This is a wonderful resource to blind persons seeking to use a paperless braille display unit for word processing applications. It is also helpful to students and teachers alike in bridging a communication barrier. Since Grade II braille is the standard code for literature, braille translation software can serve to produce braille material on a large scale. The automation of braille transcription has general advantages that apply to braille production on a small scale (for use in an office, school or conference setting), and on a mass scale for a large number of users. The advantages include:[28]

- the overall potential for speed and accuracy
- the possibility of correcting errors without recopying entire pages of braille
- the possibility of automatically designing and revising special formats before printing to avoid errors and the need for recopying

In the educational setting, the word processing capability of composing in braille and printing out copies in ink leads the student to the following activities:

- proofreading
- revision
- attention to correct spelling and grammar

Educators note that "blind students using an electronic braille display device together with a microcomputer and reverse braille translation software have improved their overall academic grades by 10%".[28]

Braille-Edit

Braille-Edit is a sophisticated word processing program, allowing the user to write, edit, correct, and print out well-formatted letters, reports and papers. The program will insert, delete, switch and rearrange paragraphs, underline, centre, do page numbers, and page design. It also lets you transform the Apple keyboard into an electronic braille-writer, with six designated keys for the braille cell and dot combinations. Then, instead of using automatic print-to-braille translation, the braille can be produced manually. For partially sighted people, the program features five screen display formats: normal, high resolution, wide, large print and braille dot pattern.[6]

Braille-Edit contains two powerful translators. It translates from print into Grade II braille and also back-translates from Grade II braille into print. The program also provides for translation of braille Nemeth Math Code into inkprint. The "Global Replace" feature allows the user to correct an error automatically wherever it occurs in a text file by giving a single command.

Braille-Edit makes it possible for simultaneous use of speech and braille and screen display. This is an extremely valuable breakthrough because it eliminates the communication barrier between blind and sighted users. "It is a useful program that performs all of the functions featured on its menus, and probably makes the Apple IIe computers more accessible to blind people than any other system".[1]

Braille-Edit does have some disadvantages. It does not make all programs that run on the Apple accessible to the blind user. It is not particularly useful in programming the computer, and it does not translate inkprinted math into braille Nemeth Math Code.[7] Also, it is somewhat cumbersome because it encompasses two sides of an Apple disk and involves frequent disk movements. However, according to Henry Brugsch, a blind user of the system, Braille-Edit is still the best talking word processor available at the present time.[8] The alternative to Braille-Edit would be a very costly undertaking because each commercial program developed would require parallel development of a blind-users version of that program.

Please refer to Appendix L for a discussion of the Braille Code and Translation Software.

Mandatory Requirements and Desirable Functions of a Speech Synthesizer

Computer software is becoming more and more screen oriented. Since voice output is not exactly comparable to screen output, there is a need for specialized software designed for efficient voice output.

Speech is a serial medium; once the word is spoken, it is gone. Therefore, spoken output alone does not enable the blind user to interact with the computer. The talking terminal must have the proper functions for review to inform the blind user of what he or she needs to know.[8]

Mandatory requirements must be met in order for the user to function at the minimum level. Desirable functions save time and promote accuracy, capability, and user-computer friendliness.

MANDATORY REQUIREMENTS:

1. ability to hear the data as it is typed
2. ability to review the text
3. ability to listen to text accessed without data loss

DESIRABLE FUNCTIONS:

1. can instantly stop the voice on a word
2. minimizes hand movement when receiving text
3. verbally announces error corrections
4. can adjust speech rate

5. provides review memory
6. verbalizes punctuation and special symbols
7. distinguishes between upper and lower case letters
8. identifies a column
9. can automatically spell unusual letter combinations
10. synchronizes print and voice
11. can expand letters to their phonetic equivalent
12. can mark text for review
13. can skim read
14. can search memory
15. can say numbers as words
16. can supply personalized vocabulary
17. can redefine the keyboard
18. can traverse tables
19. can pronounce nonprintable computer characters
20. can suppress repetitious characters
21. provides for off-line preparation

Voice synthesis can be used either to augment visual or tactual access or as the sole medium of access. Voice synthesis is available in special terminals such as those specially designed for blind persons, namely Echo II in conjunction with the Apple IIe and the Versabraille. Please refer to Appendix M for further information on Echo II.

The speech synthesizer, if appropriately matched with microcomputers and driven with specially developed software, can provide the blind user with enhanced employment, educational opportunities and daily living activity with independent functioning. Hope and confidence are inspired, and the blind user has the means to compete in a sighted world.

Criteria for the Evaluation of Software Programs to be Used in the Education of the Visually Handicapped

Selected, adapted or specially developed programs must meet certain criteria developed for software evaluation. Ashcroft[2] has suggested that software to be used with visually impaired students should first meet the criteria relevant to the selection of quality software for any student and any educational application. There are, however, additional criteria that must be considered if visually handicapped students are to benefit from microcomputers.

The following criteria for software evaluation are recommended with justification of their importance for a blind or visually handicapped user. The criteria are ranked from most crucial (or mandatory) to less crucial, as determined by the writer.

1. Is the Software Copy-Protected? Synthetic voice and braille access to software is limited to programs which are specifically designed for that purpose (and there are very few of these), or to those that are not copy-protected. It would be desirable to acquire access to copy-protected software which would increase the availability of materials to the visually handicapped user.

2. Are Software Commands Entered only from the

Keyboard of the Microcomputer? Access devices such as cassette braille machines cannot input to programmes which use commands from the microcomputer's keyboard. Also, the program must be executed with the RUN command in order for it to be accessible.

3. Does the Software Contain Graphics Essential to the Understanding of the Program? Braille and voice synthesis devices cannot convey pictures, nonprint symbols, or other graphics to the blind user. Currently, software programs including graphics are virtually inaccessible to visually impaired students without remaining vision.

4. Can the Software Material be Appropriately Translated into Grade I or Grade II Braille? A software program containing mathematics, musical symbols or chemical notation cannot, at present, be translated into Grade II braille.

5. Is the Format of the Program Essential to Understanding it? Braille machines and voice synthesis devices can only produce material line-by-line. If the material is presented in columns or some other unusual format, the blind user would find the material difficult to read and comprehend.[2]

6. Is There a Time Constraint Associated With the User's Success of the Program, and Does the Material Scroll off the Screen Beyond the User's Control? When access

devices are used, the reader needs more time to examine and study the material. This is because braille is displayed much more slowly than the same information on a CRT screen. If time is a constraining factor, and the user cannot control this timing, then the visually handicapped user is at an immediate disadvantage.

7. Can the Program be Interrupted and Saved at any Point? Due to the slow output with access devices, and therefore the extended duration of the program, then it is advantageous to the blind user to be able to stop the program at any place and restart it again at the point where it was interrupted.[2]

8. Does the Software Permit Screen Review Character by Character and Announce the Location of the Cursor? In a word processing setting, it is essential that the blind user be able to determine the cursor position, the indicator of where in the text the next character will be entered.

9. Is there Documentation to Supplement the Software, and is the Documentation Copy-Protected? If reading materials are required for the successful independent use of the program, then these materials would have to be provided in braille or audible form. If the user support materials are not available to the blind user, then the program itself may be useless.

10. Will Access Devices Modify the Program in any way?

Access technology may lead to an increase in the program's complexity. For example, braille or voice output cannot emulate graphics. Even if most of the program is in text, a few graphics may be helpful to sighted users. This again, puts the blind user at a distinct disadvantage.

11. Could the Access Technology Cause any Untoward Effects on the Computer or the Software? The braille device may be sensitive to certain characters or sequences that may be issued by the computer for some unrelated purpose, and vice versa. Therefore, electronic interfacing of access devices may change the reliability of the program.

12. Is Sound Used to Reinforce Visual Material? Sound facilitates access for the visually impaired student. However, will the original sound be modified in any undesirable way by the peripheral voice synthesis device?[2]

13. Does the Software Provide Flexible Review Capabilities Such as a Line Editor to the Voice Output User? A line editor facilitates review of material through voice output. The computer can repeat a line or several selected lines when the appropriate command is entered on the keyboard. When the computer regenerates these lines, then the voice output module can again speak them. Without this, the user may be able to hear the voice output module vocalize information one time only as it is being displayed on the screen.

14. Is the Program Driven by Menu or by Command Language? For the blind user, the menu format is especially slow because the menu must be listened to, or reviewed in braille line by line. It is also easy to forget options listed earlier in the menu. Therefore, although commands must be learned, command-language format is better for the blind user.[1]

15. Does the Software Distinguish Between Upper and Lower Case Letters? Due to the nature of the braille code, and the difficulty in developing accurate braille translation software, without the differentiation between upper and lower case letters (simple as this might seem) the blind user will encounter severe reading difficulties.

16. Are key Concepts Highlighted in Inverse Video? The Optacon, Versabraille and voice synthesis devices cannot switch between normal and inverse. Therefore, key concepts highlighted in this manner would not come to the attention of the blind user.

17. Are Unusual Colour-background Combinations Used? Versabraille and voice synthesis devices cannot emulate colours. Some colour graphics nearly blend in with the background on monochrome monitors which makes reading with the Optacon or DP10 Visualtek virtually impossible due to insufficient contrast and resolution.[2]

18. If Problems Arise While Using a Program With an

Access Device are any Parameters Available to Solve the Problem? Documentation for the computer system (hardware or software) and the access device should reveal problems that may be encountered, and how to deal with them. However, since this field is so new and rapidly advancing, empirical studies would have to be carried out before any such documentation became available.

Present Needs and Future Considerations

There are both advantages and disadvantages to the use of microcomputers in the education of the visually handicapped. However, the advantages of computers far outweigh the disadvantages. With the ever-increasing technological advances and hence the upward trend in the capabilities of access devices, hopefully all of the disadvantages will soon be overcome. Access equipment remains extremely expensive because of the thin market demand for it. However, the Government of Ontario has implemented an Assistive Devices Program, making microcomputers, cassette braille reading machines and other microcomputer-based devices more accessible to blind and visually handicapped students. Presently there is a need for knowledgeable people who can work this equipment and make it useful to visually handicapped students. There should also be some sort of system of sharing information among persons using computer access technology. Another important step would be to acquire access to write-protected programs which would increase the availability of materials to the visually handicapped user.

The Ontario Ministry of Education recognizes these needs. In a recent memorandum from D.A. Penny, Assistant Deputy Minister of Education, Technology and Development, [39] it is noted that software for educational purposes should develop thinking and problem-solving skills. The Ministry has asked for proposals for developing programs that (1) will enable students to create and manipulate sound and (2) that will help students to develop personal management and life skills.

There is a tactile graphic display being developed by D.R. Maure and B. Seltzman of the American Foundation for the Blind. The proposed device would consist of a matrix of 256 pins by 256 pins which would be capable of producing a page of paperless braille 40 characters wide and 25 lines in length. Besides a braille page, the device should have the potential to display graphics - charts, maps, diagrams etc. [28] This would be an invaluable addition to access technology for microcomputers.

There is a possibility that in the not too distant future a braille note-taking machine may turn out to be a full-featured computer with integrated braille keyboard and display. If this be the case, there will be no need to connect to another computer system. Who knows? Maybe even colours will be represented on the screen by thermal sensations emitted by the computer!

Summary

There is and there will continue to be a great need for specialized software development to meet the unique needs of blind and visually impaired computer users. Computers can remove some of the barriers for the visually handicapped. There is the freedom to work when one wants to work; students can move from dependency on teachers to independency. There is freedom to use print media, and freedom to produce perfect documents without the help of a sighted proofreader.

Teachers must strive for independence for their students. Through technology, the blind student can receive training on various pieces of equipment and then utilize them for word processing, computer literacy, programming and computer assisted instruction. Employment opportunities will be opened up - clerical positions, telephone expeditor positions, bookkeeping and accounting, self-employment, managerial positions, and computer related vocations such as programmer and systems analyst. This should provide the visually handicapped individual with sufficient reason and motivation to familiarize himself/herself with the basics of interacting with microcomputers. It should also provide the sighted with a reason to make this possible.

CHAPTER 6

CONCLUSION

Loss of vision can be a threat to one's independent self and lead to a poor self-image. In an unfamiliar world of darkness there is frustration and disorientation. "Coping and growing with a permanent loss of vision is a human challenge faced daily by a visually handicapped student."[19] For educators, the challenge is to develop independence and self-confidence in the blind student. The teacher must have strong positive attitudes, be flexible and encouraging in order to help the student develop confidence in learning.

Teachers of the visually handicapped must be aware of the special needs of their students, and must strive to teach concepts in meaningful ways. In order to do so, special equipment and adaptations are required. There is a great need for the production of audiotapes for the senior sciences. An up-to-date tactile version of the Periodic Table of the Elements should also be produced. Curriculum materials for the study of light and electricity in senior physics are also needed for the visually handicapped.

In all areas of science education microcomputers are very valuable. It would be desirable if all classrooms for the blind were equipped with microcomputers and the necessary hardware for braille and print transcription. At this time there is a high demand for braille translation software and for access to copy-protected programs that could be adapted for the visually handicapped user. The future may even bring tactile graphic displays having the capability to produce charts, maps and diagrams. Someday, thermal sensations emitted by the computer may even represent colours on the screen. Presently, the greatest need in this area is for knowledgeable people who can operate the equipment and make it useful to visually impaired students.

Totally blind students have graduated with Masters Degrees in electrical engineering; there are blind physiotherapists and blind researchers. It must be stated however, that there are certain branches of science at the post-secondary level that are presently inaccessible to the blind. Some of these fields include medicine, nursing, laboratory technology and some engineering disciplines.

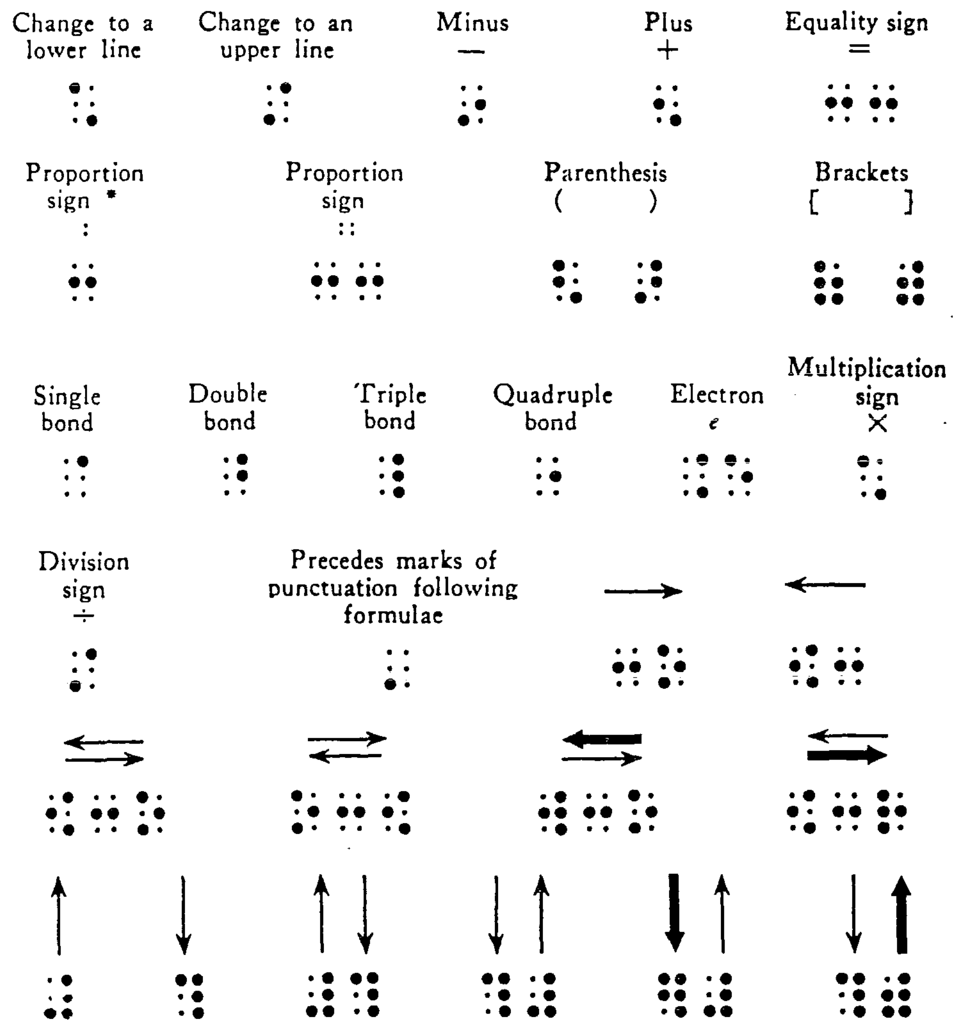
This project has identified a number of techniques specifically adapted for teaching biology, chemistry and physics to the blind. The nature of science was examined and the inherent value of experimentation and concreteness was addressed. Adaptations, special equipment, laboratory procedures and safety considerations were proposed. The literature review on microcomputers was followed by a brief assessment of future needs and student potential.

The writer would like to close with the motto of the Ontario School for the Blind:

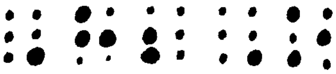
"The Impossible is Only the Untried".

APPENDIX A: Chemical Braille[5]

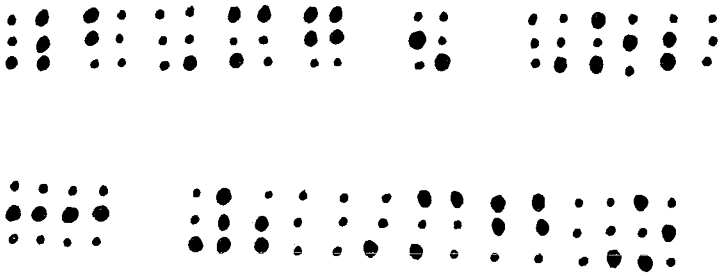
Signs Used in Chemical Braille



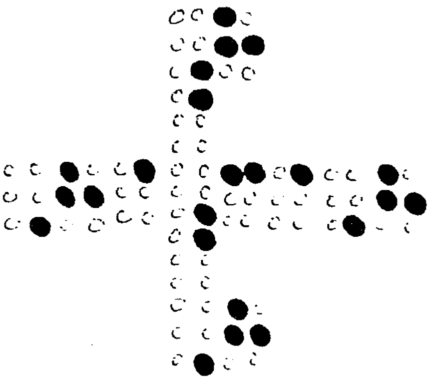
Examples in Chemical Braille:

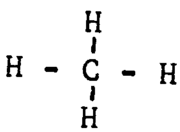


H_2O



$2Mg + O_2 = 2MgO$





APPENDIX B: General Characteristics of Blind Students

The experiences of faculty at the Ontario School for the Blind has led to the following consensus regarding general characteristics of most blind students:

1. More concentration is required when examining tactile diagrams than is required when looking at a picture. The hands move over the tactile picture and the students must analyze and interpret what they feel. Extra effort is placed on other senses and with the high degree of concentration required, blind students tend to tire easily.
2. Visually handicapped students should be taught organizational skills. They should have neat lockers. They should have separate binders for each course with a braille label on the outside of each binder. Notes should be clearly dated and have page numbers. Their microcomputer cassettes should have braille labels for easy access. Organization helps blind students manage their time more efficiently.
3. Many blind students suffer emotional problems related to feelings of low self-esteem. Some students have not accepted their blindness and resent anyone trying to help them learn braille and other tactile skills. Some blind students are easily angered and frustrated - teachers must

be patient, encouraging and understanding.

4. Over 50% of blind students have additional physical handicaps (diabetes, epilepsy, cerebral palsy, deafness) that may make tactile work difficult.[23] One-on-one assistance with tactile work is usually necessary with all blind students, and more time is needed for those that have additional handicaps.

5. Tactile diagrams are often a lesson in frustration; very simple manoevers are made extremely difficult and tiring with no visual input. The teacher must be patient, encouraging, and provide adequate time for tactile diagram analysis. If the students are constructing their own diagrams with tactile materials, evaluations should be based on the tactile picture being formed and not on the neatness of the product.

APPENDIX C: Grade II Braille

about	ab
above	abv
according	ac
across	acr
after	af
afternoon	afn
afterward	afw
again	ag
against	agst
ally	⠰⠽
almost	alm
already	alr
also	al
although	alth
altogether	alt
always	alw
ance	⠨⠑
and	⠯
ar	⠜
as	⠵
ation	⠠⠝
bb	⠆
be	⠆
because	bec
before	bef
behind	beh
below	bel
beneath	ben
beside	bes
between	bet
beyond	bey
ble	⠼
blind	bl
braille	brl
but	⠃
by	⠴
can	⠉

cannot	⠸⠉
cc	⠒
ch	⠡
character	⠐⠡
child	⠡
children	chn
com	⠤
con	⠒
conceive	concv
conceiving	concvg
could	cd
day	⠐⠙
dd	⠲
deceive	dcv
deceiving	dcvg
declare	dcl
declaring	dclg
dis	⠲
do	⠙
ea	⠂
ed	⠫
either	ei
en	⠢
ence	⠰⠑
enough	⠢
er	⠻
ever	⠐⠑
every	⠑
father	⠐⠋
ff	⠖
first	fst
for	⠿
friend	fr
from	⠋

ful	⠰⠇
gg	⠶
gh	⠣
go	⠛
good	gd
great	grt
had	⠸⠓
have	⠓
here	⠐⠓
herself	herf
him	hm
himself	hmf
his	⠦
immediate	imm
in	⠔
ing	⠬
into	⠔⠞
it	⠭
its	xs
itself	xf
ity	⠰⠽
just	⠚
know	⠐⠅
knowledge	⠅
less	⠨⠎
letter	lr
like	⠇
little	ll
lord	⠐⠇
many	⠸⠍
ment	⠰⠞
more	⠍
mother	⠐⠍
much	mch

must	mst
myself	myf
name	⠐⠝
necessary	nec
neither	nei
ness	⠨⠎
not	⠝
o'clock	o'c
of	⠷
one	⠐⠕
oneself	onef
ong	⠰⠛
ou	⠳
ought	⠐⠳
ound	⠨⠙
ourselves	ourvs
ount	⠨⠞
out	⠳
ow	⠪
paid	pd
part	⠐⠏
people	⠏
perceive	percv
perceiving	percvg
perhaps	perh
question	⠸⠟
quick	qk
quite	⠟
rather	⠗
receive	rcv
receiving	rcvg
rejoice	rjc
rejoicing	rjcg
right	⠐⠗
said	sd

sh	
shall	
should	shd
sion	
so	
some	
spirit	
st	
still	
such	sch
th	
that	
the	
their	
themselves	themvs
there	
these	
this	
those	
through	
thyself	thyf
time	
tion	
to	
today	td
together	tgr
tomorrow	tm
tonight	tn

under	
upon	
us	
very	
was	
were	
wh	
where	
which	
whose	
will	
with	

word	
work	
world	
would	wd

your	yr
yourself	yrf
yourselves	yrvs
you	
young	

God

accent sign

apostrophe '

asterisk *

bar /

bracket (or brace) [opening

bracket (or brace)] closing

capital sign, single

capital sign, double

colon :

comma ,

dash —

dash, double ——

decimal point .

ellipsis . . .

exclamation point !

fraction-line / or —

hyphen -

italic sign, single

italic sign, double

letter sign

number sign #

parenthesis, opening (

parenthesis, closing)

period .

question mark ?

quotation mark, double, " opening

quotation mark, double, " closing

quotation mark, single, ' opening

quotation mark, single, ' closing

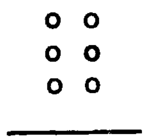
semicolon ;

termination sign

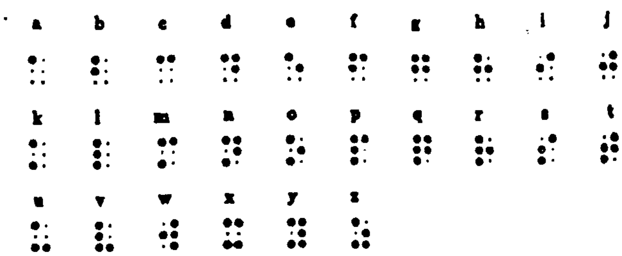
APPENDIX D: The Braille Code

The braille code is a system of embossed characters formed by using combinations of six dots consisting of two vertical columns of three dots each (this is known as a braille cell). The system was developed in 1824 by Louis Braille, a 15 year old blind student in France The 'raised dot' system was published in 1829. Louis Braille worked out an alphabet, numerals, punctuation marks and later, a system for writing music.

Today there are many variations of the braille code: Literary Grade I, II, and III Braille, Nemeth Math Braille, Music Braille, Chemical Braille and Computer Braille.



1 cell



APPENDIX E: Nemeth Math Braille

1 2 3 4 5 6

7 8 9 0

APPENDIX F: Brailink vs. Versabraille[2, 28, 41]

BRAILINK - Advantages

1. Keyboard can be switched between two modes: (i) terminal type operation, the standard 56 key QWERTY mode and (ii) the 6 key Perkins mode permitting contracted Grade II braille for faster reading.

2. Dual tape drives can permit the programmer to download a program in draft form from the computer to the left tape and also read a program stored on the right tape for comparison.

3. The unit is contained in an executive style briefcase.

4. The 48 character braille strip permits one-half of a CRT line to be read at once.

5. Each mini-cassette stores 75 pages of braille.

6. Additional serial interface is available to drive printers, floppy disk, etc.

BRAILINK - Disadvantages

1. Weight 9 kg (20 lb)

2. Cannot be run off battery

3. Not as portable as Versabraille

4. Mini tapes are not as available to purchase as the full size cassette tapes

5. No software programmes for Grade II braille can be used with Brailink

6. When in braille mode, you must use computer braille

instead of the standard Grade II braille; not many blind people known how to do computer braille.

7. Cost - U.S. $9,000.00

VERSABRAILLE - Advantages

1. Can function as a stand-alone unit with a braille writing keyboard and mechanical braille display.

2. Keyboard of 6 braille keys is similar in size, shape and spacing to the Perkins Brailler which is good for consistency for the blind user.

3. One standard cassette has the capacity to store 400 braille pages, and each braille page has the capacity for 1000 braille cells.

4. Weight 4.5 kg (10 lb)

5. Size 9 1/4 " x 14" x 4 1/2 " which enhances portability

6. Reliable, durable and versatile

7. Model P2D is available for international customers which includes braille translation for five languages - French, German, Swedish, British-English and American-English Braille.

8. Purchaser has the option of upper-case braille characters identified by vibration (Model P2D).

9. Software, Braille-Edit, has been written for Apple, especially for use with the Versabraille as a word processing system.

10. Information from the cassette can be transferred to the computer's memory, and the computer can be used to print the information in braille or in sighted, store it, or send it to others via an electronic mail system.

11. Cassettes can store audio recordings as well as electronic braille.

12. Features a search retrieval system

13. Can be battery operated and is rechargeable

14. Editing feature allows insertions, erasures and write-overs without disturbing surrounding text.

15. Can be interfaced with a braille embosser or ink printer and a duplicator overlay allows files from one Versabraille to be copied onto tape running on a second Versabraille.

VERSABRAILLE - Disadvantages

1. Braille display length only 20 braille cells
2. Battery life is short - 3 hours maximum
3. Battery charger must be carried separately
4. Cost - U.S. $6,950.00

APPENDIX G

Questionnaire to Students Using Access Devices

NOTE - Students voluntarily agreed to fill out this questionnaire. The students involved in this study use either Brailink or Versabraille for school and/or personal use.

STUDENT 1:

Age: 15 Sex: F Grade: 9

Has used Versabraille for four months

General opinion - likes it very much

Advantages - faster and more accurate for taking notes in class and for printing out assignments than a standard brailler. Appreciates the fact that sighted printouts make the teacher's work easier (teacher does not have to mark the braille).

Problems - none encountered to date except that in the beginning, not enough time was spent with her at the school to teach her how to use the device.

STUDENT 2:

Age: 17 Sex: M Grade: 11

Has used Versabraille for one year

General opinion - likes it very much

Advantages - no longer needs to use a typewriter for projects, therefore printed assignments are more accurate. Note-taking is faster and more accurate, and more easily reviewed for study purposes. He appreciates the editing capability, and finds that he does not lose notes like he used to when using hardcopy braille.

Problems - would like to learn more about the capabilities of Versabraille, but cannot seem to get help from the school's Assistive Devices Personnel.

STUDENT 3:

Age: 17 Sex: M Grade: 11

Has used Versabraille 19 months

General opinion - likes it

Advantages - makes note-taking faster, editing capability makes his work more accurate, and the bulkiness of hardcopy braille is no longer a problem. Cassettes are easily stored in his locker, and each cassette is labelled for a different school subject.

Problems - he has occasionally found a bug in the software program, but has no difficulty with the Versabraille itself.

STUDENT 4:

Age: 16 Sex: M Grade: 11

Has used Brailink for one year

Has used Versabraille for three months

General opinion - he found too many problems with the Brailink and therefore traded it in and acquired the Versabraille which he finds far superior.

Advantages of Versabraille over the Brailink - very fast and accurate; uses in class for note-taking; finds it more portable than Brailink. If he wants hardcopy braille, he interfaces with the Cranmer Brailler, which electronically produces braille faster than he could manually, and with more accuracy. He prefers the use of regular cassettes instead of the mini-cassettes that he had to use with the Brailink. The fact that the Versabraille can be run off battery is also an advantage to him.

Problems - none

APPENDIX H: Cranmer Perkins Brailler

Equipment for tactual access has become increasingly available during the past ten years. The newest device is the computerized version of the popular Perkins Brailler, which provides blind people with a familiar way to experience the benefits of computers. This mechanical braille device has paper readout and utilizes a braille keyboard. When interfaced with the Apple IIe, any information in the computer (except math code or chemical code) can be transformed into braille. A Nemeth Braille software program is being developed for complex mathematical equations.

The Cranmer Perkins Brailler contains a set of steel pins arranged in the 2 x 3 braille grid. These pins can be raised or lowered to produce the braille pattern. Word processing can be used to make corrections before a braille copy is produced.

Specifications:

- 27 lbs.
- 16" x 10 3/4" x 9 1/2" (therefore it takes up less desk space than a typewriter)
- 4000 character memory
- produces hardcopy braille at a rate of 10 characters per second
- cost: U.S. $2,750.00

APPENDIX I: DP10 and Visualtek's 19" Monitor

- Visualtek magnifies letters on the screen up to 16X their usual size
- the DP10 is the only Apple-compatible large print display processor designed especially for low vision computer users
- user control panel lets the user set the scanning rate at which letters move across the display screen
- most commercially available text-oriented software will operate without any modification - educational programs, word processing, spreadsheets, database software and more
- cost: U.S. $3,200.00

APPENDIX J: Optacon

- converts letters to a tactile form
- consists of a small camera, an electronics unit, and stimulator array of 144 miniature rods
- the electronics unit interprets the light pattern received by the camera and sends signals that cause certain rods to vibrate
- vibrating patterns are learned by the blind user
- the device overcomes the disadvantages of braille, but it is very slow
- cost: U.S. $4,295.00

APPENDIX K: Kurzweil Reading Machine

- the device possesses pattern recognition, speech synthesis and text-to-speech conversion
- the user can control the speed of reading and adjust the tone of voice
- the machine can be requested to spell out words or mark certain words for later reference
- reading can be stopped at any time
- the last few lines or words can be repeated
- punctuation and capitalization can be announced
- cost: U.S. $29,800.00

APPENDIX L: The Braille Code and Translation Software

The code that most computers understand is ASCII (American Standard Code for Information Interchange). When braille translation software is in operation, text input to the computer is changed into an ASCII code for the correct braille representation. This is not a simple matter - not as simple as regular print. There is a 1:1 relationship between ASCII code and print letters, but the relationship between ASCII code and Grade II Braille is more complex because there is not a 1:1 relationship between Grade II Braille and print. Grade II Braille makes use of a lot of contractions and symbols based on the spelling, pronounciation and expected frequency of the print word. When a 'y' stands alone in American Grade II Braille it means 'you'. The braille dot pattern 'rcv' means 'receive', and 'ac' means 'according'. The use of braille signs is context sensitive. For example, the sign for 'the' is for use when 'the' stands before a noun as an article, but not when it occurs in the middle of a word such as 'sweetheart'. Another problem is that many braille signs have no alphabet equivalent, therefore the task of the programmer of braille translation software is to code in all the braille rules, and all the exceptions to the rules (AND THERE ARE MANY) governing the correct transcription from print words into this specialized language. The signs and contractions of

Grade II Braille are particular to distinct national languages, so that even English braille comes in two versions, American and British.

APPENDIX M: Echo II

- consists of an electronic circuit board and a speaker to be used inside the Apple II computer
- it is designed to convert text-to-speech and to audibly indicate the position of the cursor for review purposes
- it comes with software that modifies the disk operating system so that no special commands are needed to make it talk
- speech quality is NOT perfect - two or three sounds need improvement
- text can be spoken as it is typed, or after each carriage return
- will repeat any block, line, word or character on the screen
- its speed is its major advantage; its fastest speech is faster than all but the most costly voice synthesizers
- disadvantage - in order to provide adequate speech production, Echo II substracts a significant amount of capable memory (8K)
- cost: U.S. $149.95

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