MODIFYING SCIENCE EXPERIMENTS FOR THE VISUALLY IMPAIRED

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Abstract

Extensive research was completed and documented on blindness and visual impairment, social and educational inclusion, available assistive products, and science education. A teacher resource was produced for Danish middle school science teachers to create laboratory experiments that are accessible to blind or visually impaired students. The manual focuses on specific modification of skills and apparatus to be used in many experiments; it also includes background and general guidelines on teaching blind or visually impaired students.
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Executive Summary

In Denmark, approximately eight children are born blind each year. Since there are so few, it is unlikely that a teacher will encounter more than one student with a severe visual impairment in their career. Therefore, few teachers can gain extensive experience. Teachers who have experience in working with blind or visually impaired students are not trained experts and do not have a way to pass on what they have learned. For this reason, teachers who have a visually impaired student for the first time must learn lessons for themselves that have already been learned by other teachers. The focus of this project was to compile these experiences along with new information in a form that can be shared by teachers as a resource.

National legislation in Denmark requires each town to educate every student in its area, in the best manner possible. In the past, this legislation meant that blind or severely visually impaired students would attend a residential school called Refsnæsskolen. This is no longer the practice; now students are not removed from their local schools for education. To provide the best education for the student, responsibilities are split between the school, the county, and Refsnæsskolen. The local school is solely responsible for the student's education. The student is placed in general education classes, and another general education teacher provides any extra assistance. Neither the primary nor the assistant teacher has special training in the instruction of blind or visually impaired students, but short seminars are available. The county has specialists who provide services throughout the life of each blind or visually impaired person. These specialists provide materials to the school, such as computers with speech synthesis programs.
Refsnæsskolen adapts printed materials into Braille or audio formats, and provides short courses for blind and visually impaired students in Braille reading and mobility training.

Effective instruction requires an understanding of the blind or visually impaired student's method of acquiring and processing information, and their perception of the world. Much of a sighted person's information is stored as abstract concepts, which are largely made up of images that have been collected throughout life. The images are categorized and enable the person to identify objects not previously seen or not fully visible. For instance, a person who has only seen an adult elephant can imagine a baby elephant by seeing the size of its trunk, because the person has seen other baby animals. A congenitally blind person does not have an abstract concept of an elephant that can be manipulated into a different size or shape. Therefore, the learning style of a totally blind student is very concrete. Objects need to be fully explored and connections to the rest of the world need to be specifically identified. Students with residual vision or students who were not congenitally blind have varying degrees of abstract concepts. It is important to note that presenting material concretely improves the comprehension of all students.

For a sighted person, eighty to ninety percent of all information is acquired visually. A blind or visually impaired person acquires this information tactually or audibly. Audible information is often easier to procure than tactual information sources, primarily in the forms of verbal descriptions and talking books. The limitation of audible information is that accurate descriptions can be time-consuming. Tactual information can be in the form of Braille or other labeling systems. These systems must be kept simple because of their large size. Gathering tactual information is the most useful means of
surveying a system. This method is limited because there are many systems that cannot be tactually explored due to their size, temperature, or safety hazards.

Currently, many assistive products are available for use in classrooms and laboratories, including low vision aids, low-tech aids, and high-tech aids. Students with low vision should have devices, such as magnifiers and tinted shields, that help them utilize their residual vision by decreasing glare, increasing size, and improving illumination. Choosing the proper device depends primarily on the type of visual impairment, because a modification that is beneficial to one student may hinder another. There are many low-tech adaptations such as labeling parts of a device or using a slate and stylus for taking notes. Computers, also, have become an invaluable tool for the blind and visually impaired. With the proper software, a computer can audibly read text. Perhaps the most useful devices are the electronic Braille devices. These devices have keys to input Braille and can output audibly, to a computer or printer, or to a refreshable Braille display.

When designing adaptations, it is important to remember that the curriculum in Denmark is not standardized. The national government recommends a set of topics, but individual teachers decide what to cover in their classes. This system leads to differences in laboratory experiments between schools. Due to the disparate structure of science classes in various schools, this project focuses on specific methods for adaptation that can be applied to many laboratories.

There are general principles for making adaptations. The first one is to make as few as possible, called the ‘minimization of adaptation’ principle. There are many situations in which introducing an adaptation will overlook the student’s inherent abilities. It is also
important for the student to try procedures that are difficult and learn how to accomplish them. The second principle is for the adaptations to be simple and unobtrusive. Good modifications are easy to use and can be set up quickly, otherwise they will be impractical in a busy classroom.

Safety is a concern for any student in a laboratory environment. Special attention must be given to blind or visually impaired students, however, because they cannot perceive hazards as readily. Chemicals must be labeled with Braille and/or large, high-contrast print if applicable. Glassware should be placed in stands or clamps when in use, and stored securely to avoid cracking or shattering when not in use. Safety concerns for Bunsen burners can be addressed by labeling the inlet and outlet with high-contrast, non-flammable paint. Placing wire gauze in the flame will produce a bright glow that a visually impaired student can see more readily. Students can trip over power cords so wires should be strung from the ceiling or taped to the floor.

Modifying certain laboratory techniques can make laboratory procedures easier, quicker, and safer. Due to the physical and concrete nature of building models, a visually impaired or blind student will have little difficulty given the proper time to explore unfamiliar components. Setting up an experiment using basic apparatus is also a concrete procedure. Handling flames may be especially difficult, and it is essential that the student learn proper techniques. When identifying gas evolution in an experiment, the blind or visually impaired student can use the same techniques as sighted students, using odor and sound as cues. Rulers and other measuring equipment should have tactual markings at various units, and a blind or visually impaired student needs practice to read them quickly and accurately. Non-toxic and non-staining liquids can be measured using
tactual markings and the student's finger. For measuring toxic or staining liquids, a conductivity device is suggested. This device hangs over the edge of the container and emits a noise when it comes in contact with liquid. Labeling of laboratory equipment should be done using bright, contrasting colors, and large text for visually impaired students. If the student is blind or has severe visual impairment, Braille or different textured material can also be used.

Digital readouts are difficult to adapt for blind or visually impaired students. It may be possible to include synthetic speech components into devices, but the easiest solution is to have the student's partner read the digital output. Devices such as a Geiger counter have audible output, allowing students who cannot see the digital output to access the information qualitatively. Audible output can also be used in place of lights or LEDs when using or testing electrical circuits.

There are a number of tools that require advanced modification. These typically involve light or visual forms of displaying information. An oscilloscope, for example, displays the waveform and frequency information of a sound curve on an electronic display. Attaching a vibrator to the oscilloscope can modify this device so the student can feel the difference in frequency through touch. Measuring pH is another area that is very visual. Litmus paper and electronic pH meters are typically used. Both of these are very visual in nature. Some pH meters can be connected to a computer that can produce speech synthesis, but these are highly inaccurate and require abundant setup time. Again, the best solution is for the sighted lab partner to read the results of the test.

Various devices can be constructed to aid in experiments. One such device is a multivibrator. This device measures the strength of an electrical connection, and
produces both visual and auditory output. Another device is a super-sensitive switch. This device triggers an auditory response when an electrical connection is made.

The background research encompasses the education and learning styles of blind and visually impaired students, statistics, legislation, current modifications and available devices. This information was gathered through an extensive literature review, interviews with teachers and specialists, and classroom observations. These methods were also used to study the educational systems of Denmark and the United States. The experiments and devices that are currently in use in Danish seventh and eighth grade science classes were analyzed for accessibility. This analysis led to the development of modified experiments, adapted tools and skills, and new guidelines for teachers. The background information is presented in sections two through six of this report. The guidelines and experiments are introduced in the form of a teacher's manual within the results and recommendations section.

Numerous adaptations can be developed to make science classrooms and laboratories accessible to blind and visually impaired students. By doing so, the educational experience of all students is improved.
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1. Introduction

In both the United States and Denmark, blind and visually impaired students are becoming increasingly integrated into general education classrooms. This move toward integration is perceived to be a major improvement in their education and social development, but it presents many difficulties for the school systems. The main goal of integration is to eliminate the distinction between handicapped students and their peers. Unfortunately, handicapped students require special considerations.

Science classrooms are particularly problematic for blind and visually impaired students. All students have difficulty understanding abstract scientific concepts, even if their effects can be perceived concretely. The inability of blind and visually impaired students to fully interpret the same concrete phenomena increases this difficulty in comprehending theoretical concepts. Observation is one of the primary skills taught in science classes, but visual cues are obviously difficult or impossible for blind and visually impaired students to see. Other sensory cues can be received by these students, but their significance can be easily lost. Also, there are numerous inherent dangers to all students in a classroom laboratory, which become a greater concern for blind and visually impaired students. Therefore, adaptations are necessary for these students to participate fully in any science classroom.

The presence of a blind or visually impaired student in a science class should not require a significant change to the usual curriculum; this would distinguish them from their sighted peers. Instead, the same topics should be discussed in lecture and the same experiments should be performed in laboratory, with as few changes made for the blind or visually impaired student as possible. Successful adaptations require considerable
time and effort to develop, resources the general education teacher often does not have. Their experience with the needs of blind and visually impaired students can also be limited. Especially in Denmark, where the number of blind and visually impaired students is very low, the probability of a teacher encountering such a student is low. Thus, they can be unprepared for this situation, and after the student graduates or leaves the class the teacher's knowledge gained from experiences can be lost to other teachers.

For these reasons, a manual has been developed that presents advice to teachers who need suggestions for increasing their students' participation in class. This manual includes general advice regarding the instruction of blind and visually impaired students in a lecture setting, as well as recommendations for developing basic adaptations. It also includes descriptions of specific adaptations for skills and equipment, and full explanations for some common experiments used in physics and chemistry laboratories. Any simple devices that are required in the experiments have been designed or improved, and instructions for building them are included.

In order to develop this manual, background research was performed in both the United States and in Denmark. This research covered basic descriptions of eye conditions, legislation, common social and developmental considerations, and issues regarding education. Information was collected from various sources, including books, journals, web pages, and interviews. Teachers, consultants, experts, and students were interviewed to provide more focus on the previous successes and current needs of the educational systems. The curricula of the school systems were used as the source of topics and experiments considered in the manual, so that the recommendations will be useful in the current systems.
2. A Physical Description

In order to understand the sociological issues associated with blind and visually impaired students, one must have an understanding of the physical condition. This understanding is particularly important because of the numerous causes of vision problems and the various levels of sight impairment that are defined by the terms "blindness" and "visual impairment." Each person has a unique combination of cause and level that must be taken into consideration when designing appropriate adaptations.

2.1 Causes of Blindness and Visual Impairment

Visual impairment has a multitude of physical reasons. The diagnoses may include genetic ties, prenatal traumas, and various other causes. Severity ranges from minor vision impairment to total blindness.

- Albinism

Albinism is the reduction of pigmentation of the skin, hair, and eyes. Vision problems result from abnormal retina development and patterns in the optic nerve connections. Children with albinism tend to be photophobic, or very sensitive to light. Albinism is not degenerative, so vision will not deteriorate as the child ages. (Scott)

- Aniridia

Aniridia is a condition where the iris fails to form. Children who have aniridia are photophobic, and have increased risk of glaucoma and cataracts later in life. Aniridia is a hereditary condition. The condition is not common; United States statistics show an incidence in one case per ninety thousand births. (Aniridia, Scott)
• **Congenital Cataracts**

   A cataract is cloudiness in the part of the eye known as the crystalline lens. Congenital cataracts are those that form during the prenatal state, as the eye is forming. These cataracts can be caused by either genetic conditions or by a trauma to the eye. Cataracts are treated by removing the lens of the eye and replacing it with an intraocular lens, glasses, or contacts. This procedure needs to be performed within the first six weeks of birth to increase the chances of success. Even with the surgery, most children with congenital cataracts remain visually impaired. Congenital cataracts are one of the leading causes of childhood visual impairment, accounting for 16% of all United States cases. (Schepens, Scott, Viisola)

• **Eye Trauma**

   Around two and a half million Americans suffer eye injuries each year. Between forty and seventy-five thousand of these develop significant visual impairment. Blunt and sharp objects, along with vehicle crashes are the three largest causes of eye trauma, making up fifty-six percent of all eye injuries. Thirty four percent of all eye traumas occur in the age group birth to nineteen years. (Leonard)

• **Glaucoma**

   Glaucoma is a build-up of pressure in the eye. Fluid flow out of the eye becomes blocked, while fluids flowing into the eye are normal. This causes an increase of fluid levels, and therefore increased pressure. The increased pressure can cause serious damage to the eye if untreated. (Scott)
Glaucoma is rare in children, as it occurs in one out of every ten thousand live births. Infants who have glaucoma often have cloudy corneas and are irritated by light and excessive crying. Young adults complain of eye pain and vomiting. (Scott, Viisola)

- **Hemianopsia**

  Hemianopsia results from damage or a malfunction of one side of the optic tract. This causes a reduction or lack of sight on one half of the vision field. Homonymous hemianopsia is the term for when both eyes have vision field loss on the same side. Typical causes include stroke, tumors, and physical trauma. There are no specific treatments, however in the case of a stroke there may be some improvement within the first few months of the incident. (Understanding)

- **Macular Degeneration**

  Macular degeneration is a “physical disturbance of the center of the retina called the macula” (Schepens). The macula is used for reading, watching television, driving, and other activities that need fine detail. Macular degeneration is the leading cause of visual impairment for people over the age of 55. In 1990, an estimated 13,2 million Americans over the age of 40 showed signs of macular degeneration. Of those, 1,2 million were diagnosed with severe, vision-threatening stages. Children can suffer from macular degeneration as well. Common causes include heredity, diabetes, nutritional deficits, head injury, and infection. (Leonard, Schepens)

- **Optic Nerve Atrophy**

  Optic nerve atrophy (ONA) occurs when the optic nerve leading to the brain becomes damaged. This can have several causes, including near-drowning, bacterial or viral infections, lack of oxygen at birth, physical trauma, slow-growing tumors, and ingestion
of various toxins such as methyl alcohol. ONA is commonly linked to other neurological disorders; the damage is not restricted to the optic nerve and may extend to the brain itself. ONA is one of the most common eye abnormalities that lead to visual impairment, accounting for 12% of cases of legal blindness in children. (Scott, Viisola)

- **Optic Nerve Hypoplasia**

  Optic nerve hypoplasia (ONH) is a condition in which a child is born with an underdeveloped optic nerve, resulting in impaired vision. This condition can be the end result of infections, or maternal drug or alcohol intake. The condition is not progressive, and is almost never hereditary. ONH is often linked with multiple disabilities. (Scott)

- **Retinitis Pigmentosa**

  Retinitis pigmentosa (RP) is a genetic condition that is characterized by night blindness and visual field loss. RP is the most common inherited visual impairment, and affects approximately one hundred thousand Americans. It is estimated that one out of eighty people carry the recessive gene for RP. It is degenerative, but for most children central vision will be preserved until early adulthood. There is no treatment in most cases. (Leonard, Scott)

- **Retinopathy of Prematurity**

  Retinopathy of Prematurity (ROP) is characterized by abnormal growth of the retinal blood vessels in premature infants. The sole cause was originally thought to be the use of oxygen therapy on the premature infants, but it is now known that many other factors can play a role of the development of ROP. ROP is not hereditary. (Scott, Viisola)
• **Strabismus, Amblyopia, & Nystagmus**

These are some minor visual impairments that when left untreated will become major impairments. Strabismus is a misalignment of the eyes. Between one and four percent of the childhood population suffers from strabismus. Amblyopia is a reduced vision in one eye. An estimated one to two percent of children are affected by amblyopia. Either case can lead to one or both eyes to become permanently damaged. Nystagmus is a condition where the eye has a hard time focusing on items in the distance and suffers from irregular movements. These, along with similar conditions affect more than thirty million Americans and require strong corrective lenses to compensate. (Leonard, Scott)

• **Xerophthalmia**

Xerophthalmia is simply Vitamin A deficiency. It is the leading preventable cause of blindness in the world. It is estimated that 70% of the 500,000 children who become totally blind annually do so because of xerophthalmia. Vitamin A deficiency is common in India and surrounding areas, mainly due to ignorance of the cheap and available cures. (Edmundsun, Viisola)
2.2 Levels of Visual Impairments

There are different levels of visual impairment, varying from an interference with the quality of life to a total absence of sight.

2.2.1 Low Vision

Low vision is defined as a "significant impairment of vision which cannot be further improved by corrective lenses" (Leonard). A common way to judge low vision is if a person is having problems seeing words in common newspaper print even with glasses or contact lenses. (Leonard) The Danish definition of low vision is a little more precise, specifying a visual acuity of 6/18 or less in the better eye after optimal correction. (Rosenberg)

2.2.2 Visual Impairment

Visual impairment is any trouble seeing even when wearing corrective lenses; including blindness in one or both eyes. (Leonard)

2.2.3 Severe Visual Impairment

Severe visual impairment is defined as the inability to read newspaper print or recognize a friend's face at one arm's length, even when wearing corrective lenses. This definition includes total blindness in one or both eyes. (Leonard)

2.2.4 Legal Blindness

In the United States, a person is considered legally blind when they have a measured visual acuity of 20/200 or less, or a visual field that is less than or equal to 20 degrees in the better eye after optimal correction. 20/200 means that the visually impaired person
can see objects clearly at 20 feet, while fully sighted people can see them clearly at 200 feet. Visual field is defined as the degrees of horizon visible, including peripheral vision. (Leonard) In Denmark, legal blindness, (also called social blindness) is defined as a visual acuity of 6/60 or less in the better eye after optimal correction, a visual field of 20 degrees or less, visual acuity of 6/18 and a visual field of 20 degrees or less, or hemianopsia in both eyes. (Rosenberg)

2.2.5 Total Blindness

Total blindness is having no clinically measured light perception. Total blindness cannot be corrected. (Leonard)

2.2.6 Statistics

According to the following statistics, America has the same, if not lower, percentages of visual impairment as the rest of the world. The one main difference is Vitamin A deficiency in the children of the world. This condition is less prevalent in the United States, and is a greater problem in developing countries where access to a complete diet is more difficult. (Leonard)

2.2.6.1 World Statistics

Approximately 145 million people have low vision worldwide. It is estimated that there are 50 million people who are classified as blind. Approximately 7 million people in the world become blind every year. The total number of blind people is increasing by 1-2 million per year. 1.4 million children fourteen years of age and younger are classified as blind. Blind in this case is defined as having a visual acuity 3/60 or less. Approximately 500.000 children become blind each year. This is an exceptionally large
number, 70% of which comes from Vitamin A deficiency. Vitamin A deficiency is typically associated with malnutrition and a high mortality rate, which helps inflate the annual incidence rate. (Leonard)

2.2.6.2 United States Statistics

Approximately one out of every twenty Americans suffers from low vision. 8,6 million Americans (3 out of every 100) have some degree of visual impairment. 4,7 million, or 1,7%, are considered severely visually impaired. Approximately 1,3 million, or 5 out of every 1000, are considered legally blind. Of those, 260,000 Americans are totally blind. (Leonard)

2.2.6.3 United States Children Statistics

Approximately 1% of Americans under the age of 18 are considered visually impaired. This number constitutes approximately 650,000 children and teenagers. One fifth of those are considered severely visually impaired, which is 110,000, or 0,2% of America’s youth. An estimated 55,000 Americans who are under the age of 20 are considered legally blind. (Leonard)

2.2.6.4 Denmark Statistics

Statistics on visual impairment in Denmark are difficult to attain, because the visually impaired are not required to register their condition. It is estimated that 50% of Denmark’s legally blind citizens are members of the Danish Association of the Blind. In 1991, the total membership count was 12,039, which suggests that the total number of legally blind Danes is less than 25,000. Of these, approximately 80% are over the age of
60. The major cause of visual impairment is age-related macular degeneration. Other leading causes include diabetic retinopathy and glaucoma. (Silver, Rosenberg)

2.2.6.5 Denmark Children Statistics

Danish children's statistics are very reliable, since doctors are required to report anyone 18 years of age or younger who is diagnosed with low vision. As of December 31, 1999, there were 1623 children registered out of a total children's population of 1,265 million. This means that 0.128% of children under the age of 19 suffer from low vision. In 1999, there were 197 new cases, which were due primarily to amblyopia and ONA. Other main causes include nystagmus, RP, hemianopsia, ONH, ROP, and congenital cataracts. (Synsregistrets)
3. Legislative Issues

In terms of legal requirements for the education of blind and visually impaired students, the United States and Denmark have fundamentally different approaches. The intent of both systems, however, is to guarantee the inclusion of these students as fully as possible into classrooms.

3.1 United States Federal Laws

There are two main laws concerning the rights of people with disabilities: the Americans with Disabilities Act and the Individuals with Disabilities Education Act. Both set forth guidelines that affect the education of the visually impaired.

3.1.1 Americans with Disabilities Act

The Americans with Disabilities Act was passed in 1990 regulates equal access and accommodation for people with disabilities. The ADA redefines equality and who is responsible for providing it. This law changed the old method of accommodation that was "separate but equal", to a belief that society must be changed to be accessible, with the least restriction, to everyone. (Wehman)

The ADA stipulates that no segment of the population should be excluded from any area of society. It requires that all social aspects become fully integrated and accessible. The central idea of the law is "reasonable accommodation" and the means of achieving this goal. As defined, reasonable accommodation is far reaching and mandates that the mechanics of life need to be suited to all people, including the 43 million people in the United States with disabilities. The full use of all senses is not to be incorporated in the design of a program, a building, or a bus. Reasonable accommodation is also defined
differently for different segments of society; a large company with financial resources is expected to make better accommodation than a small shop. (Wehman)

3.1.2 IDEA

The Individuals with Disabilities Education Act (IDEA), also passed in 1990, sets forth guidelines for the elementary education of individuals with disabilities. It replaces the Education for All Handicapped Children Act of 1975. Where the ADA mandates that an individual has a right to all the services they would have if they were not disabled, the IDEA stipulates the implementation of integration within the school system. (Wehman)

IDEA states that all students are entitled to free appropriate public education (FAPE). Also, according to a 1991 amendment, FAPE should be in a least restrictive environment. Public school systems are required to provide assessment of the student to analyze his abilities and needs in academic, social, and life skills. Then, schools must provide a specialized program to best instruct and incorporate the student. (Wehman)

3.2 Danish Laws

There is one basic Danish law concerning the education of the visually impaired student. Paragraph 20, stk. 1, identifies who is responsible for the education of students with disabilities. All children in Denmark are entitled to nine years of education and it is the responsibility of the local school to supply that education. The local school has the responsibility to provide whatever is necessary to create the best education for the blind or visually impaired student. If the student’s education requires more than 60.000 kroner then the country also provides support for the student. This figure is currently being debated and may change to be a higher figure. [Nygaard]

There are many theories of how to best educate people with disabilities, and there is no consensus for the best method. The systems in practice range from full separation in special programs to full integration, with varying degrees of program assistance in the middle. This lack of uniformity results from the individualized nature of visual impairment and from the various advantages and disadvantages of each type of system. The debate continues as to the degrees of full integration and specialized, individualized help that are optimal for each student.

4.1 Inclusion Vs Separation

The United States is currently undergoing a change from a separated education system to an integrated one. This change is difficult because each student is different and has a special set of needs, and therefore requires a specialized program that will adjust to the student's changing needs. Despite these difficulties, the society recognizes the social need of all students to be included in their community. [Terrio Lawler] Denmark has instituted a system that is primarily integrated, with fully residential programs offered only for multiply handicapped students. Both ideological and practical reasons exist for this system: Denmark strives for equality among all of its citizens, especially because there are so few blind and visually handicapped students in the population. [Silver]

4.1.1 Advantages of Special Schools or Special Programs in Schools

A study was performed in 1974 of the Braille reading speeds of students in both residential and integrated settings. It found that the average speed of the students in residential schools was notably higher than in integrated settings: 149 words per minute
compared to 116. Integrated educational settings have improved since 1974, but the study illustrates that in specialized settings, students can acquire information more easily. There are a number of reasons why this setting is conducive to education. (Ponchillia)

Teacher ability is the first distinguishing factor from general education. In a separate special program the teacher is trained to educate students with a certain disability. This training gives the special program teacher an advantage over general education teachers. Special program teachers will also have significantly more experience in working with a specific type of student. (Bishop) In this situation the teacher will not have many of the obstacles that are present in an integrated classroom, as discussed under section 4.1.3 "Issues of Inclusion". Also, special teachers are most likely to be abreast of the most current knowledge and teaching strategies in their field. (Bangert)

The main difference in systems, other than the teacher’s ability, is the specialty of the program. The program’s separate system is specifically designed for the disabled student. Instead of modifying an existing curriculum to fit a diverse class, the program is tailored to fit the learning style of the student. (Bangert) Specialized programs also have access to the best materials. In a program where all students will use adapted technology, there is a greater chance that it can be purchased and put to good use in the program. (Martin) Also, students often need special equipment or material to learn the subject at hand. Some inclusive programs, especially those in small or under-funded places, are frequently unable to obtain equipment or to teach students proper usage. (Terrio Lawler)

4.1.2 Advantages of Inclusion

Inclusion programs have numerous advantages, especially in the areas of social development. These programs are beneficial to both students and teachers.
On the large scale, an integrated situation is comparable to the real world. Therefore, a student with a disability who functions in an integrated system will be more attuned to functioning in society. Likewise, as American society becomes more integrated, it is crucial for people to be accustomed to an integrated setting from a young age. Society needs to understand how to interact with people with disabilities. [Bangert]

It is important to note that students who are educated in an integrated system are better adapted to society and function more independently throughout life.

4.1.3 Issues of Inclusion

Although full integration into school life is commonly seen as the best choice for education of people with disabilities, there are many aspects that need to be considered and addressed. These fall into two categories: educational issues and social issues. The educational issues will be discussed in a later section.

- Social Skills

A student who is blind or visually impaired has a difficult time learning social skills. Since 80 to 90 percent of the information received from communication is non-verbal, students who are unable to gather that information miss social cues, and do not have visual feedback on their activity. For instance, a visually impaired student who is doing something socially unacceptable will receive unkind looks from other students and will be avoided, but will not be aware of social feedback. (Sacks)

- Peers

In an integrated system there may or may not be other blind or visually impaired students for peers. Students in special programs have many other students with whom
they can relate. A small school district it is unlikely to have more than one student with such a disability, whereas in a larger district it is more likely. (Sacks)

- **Acceptance of Other Students**

  The acceptance of a blind or visually impaired student into a social situation has many factors. Because the other students are not used to interacting with the student, they may choose not to interact with him, or react negatively to him. This interaction is greatly influenced by the socialization skills of the blind or visually impaired student. (Sacks)

- **Real World Functionality**

  A student who is schooled in an integrated situation will be more adept functioning independently in the world itself, which is an integrated setting. Also, a student who goes to school in his hometown and with the people he lives close to will have much more interaction with the people and places of his neighborhood. [Martin]

### 4.1.4 Methods of Inclusion

We have researched various methods for improving inclusive education.

- **Teacher Training**

  A properly trained teacher can encourage accepted social interaction and behavior. These teachers can be a resource for the student by giving correct feedback to improve the student’s interaction. They can also be a resource for the other students in the class by helping them to understand and interact with blind or visually impaired students. (Bishop)
- **Social Training**

  A student unable to perceive the non-verbal cues of social interaction can be taught to better understand and act within the social norms. Also, through proper training, the student can increase positive peer interactions and overcome the shyness experienced by many visually impaired people. (Sacks)

- **Education of Other Students**

  The teacher or another adult can train the sighted student in the class or school about the visually impaired student’s condition and abilities. They can explain the needs of the visually impaired student and demonstrate proper interaction. Once the other students cease to be afraid of the student they will likely seek him out as a friend and help him with the things he needs. (Sacks)

- **Study Buddies**

  Other students can be used as ‘study buddies’. In this way a sighted student who is near in proximity to a visually impaired student helps him or her with cues that are only visually available, such as changes in placement of items or advising when another person is coming. This should be a reciprocal relationship, with both students helping each other. (Webster and Roe)

- **Mobility Instruction**

  For social interaction with peers the visually impaired student needs to be able to function by themselves without an adult. They should be instructed on the layout of buildings and rooms so they may move about without assistance. Also, peer help should be encouraged when possible. Sighted peers can learn how to properly assist in guiding the visually impaired student. (Ponchillia)
4.2 Educational Issues for Inclusive Learning

There is still a great deal of concern about the educational benefits and shortcomings of the inclusive model. The general consensus in both the United States and Denmark is that the inclusive model is the preferable method of educating blind and visually impaired students, but the model is by no means perfect. Because the physical and mental needs of blind and visually impaired students are the same everywhere, both countries face the same issues in providing optimal education for all students.

4.2.1 Obstacles for Schools

A school system has the responsibility of ensuring that the teachers are prepared to instruct a visually impaired student. A teacher may have many issues that need to be addressed before and during the student's time in the classroom. Along with the teacher's personal concerns, the subject matter can prove to be an obstacle. The subject is often visual or abstract, and the school needs to resolve these issues in order for the student to learn the material. [Bangert]

4.2.1.1 General Education Teachers

General educators are usually not trained in the methods of instruction for all types of students; they often have little or no background educating students with disabilities. Lack of background or training leads to instruction that may not satisfy the student's needs. [Martin]

A teacher must be especially organized when they have a visually impaired student in class. There are two reasons for this. The first is to give the vision impairment specialist advance notice of the material to be presented in class, so that the specialist can properly
prepare the material for the student or assist the teacher in making a more accessible plan. The other reason for a teacher to be especially organized is the learning style of the blind or visually impaired student; this will be discussed in detail later. [Dougherty]

General education teachers have many students and responsibilities. Because of these duties the teacher often does not have enough time to prepare the lesson to suit the visually impaired student, or to spend time with the student personally. Since general education teachers are not all instructed in special education methods, there could be trepidation associated with having a visually impaired student in class. This trepidation can be a function of the teacher's own prejudice of people with disabilities, or their unease with their lack of knowledge of effective instruction. The teacher's uncertainty can lead to avoidance of the student or to over-conscientious treatment, which in turn leads to self-conscious behavior in the student. [Dougherty]

This lack of experience with visually impaired students also makes it difficult to gauge the students' abilities accurately. In Worcester, the general education teachers receive profiles of the visually impaired student describing the student's condition. Unfortunately, these are not necessarily read or the details are forgotten. [Martin] Most often, the teacher will overcompensate for the disability, resulting in a lowering of standards. (Bishop) Teachers must be instructed to maintain the same standards for the visually impaired student that is held for the rest of the class. The visually impaired student may have more difficulty with certain units, but lowered standards give the student a false sense of accomplishment, which will eventually have to be corrected with detrimental effects. [Terrio Lawler]
A specialist or support teacher can be an immensely useful resource when dealing with the issues described above. In the United States, the teacher of the visually impaired is a specialist in the education of blind and visually impaired students. Thus, they are a constantly available source of information, advice, and assistance. The addition of another teacher in a classroom, however, can be upsetting to the general education teacher. A teacher can be uncomfortable with another teacher in the room; they may feel they are being examined or evaluated. They may also feel threatened by the addition of another authoritative adult in an educational situation. [Dougherty] Another complication is that the general education teacher tends not to feel responsible for the visually impaired student, and relies too heavily on the second teacher to translate all of the lessons. [Terrio Lawler] Even if the general education teacher would like to devote more time to the student, this is often difficult in large classrooms. Consequently, it is very tempting to simply let the teacher of the visually impaired teach the student individually. [Martin] The general education teacher must make an effort to teach to the visually impaired student along with the rest of the class. The teacher of the visually impaired is only a last resource if there are no other options for the general education teacher, or if the visually impaired student needs help with a specific task. [Terrio Lawler]

In Denmark, the same issue arises if the support teacher provided for some classes is perceived as being or actually becomes a replacement for the general education teacher. Even if this situation does not develop, the support teacher is still not a specialist regarding blind and visually impaired students. Therefore, the general education teacher
does not have the same resources if they want to increase their ability to educate the blind or visually impaired student directly. [Gaardhøje]

4.2.1.2 Subjects Taught

Some subjects are more difficult than others to teach and to understand. Therefore, a major obstacle in teaching some general classes can be the material. [Dougherty] There are many simple techniques that can be taught to general education teachers that will improve the quality of education for both the visually impaired student and the class as a whole. The curriculum does not have to be adjusted for the visually impaired student. [Banigan-White] Sometimes, however, minor adaptations will make many tasks easier and general education teachers should be open to these changes. [Bangert]

The level of adaptation required depends on the material being presented to a class. Subjects such as mathematics, science and geography are the hardest to teach to blind and visually impaired students. These subjects contain abstract concepts that are difficult to understand without assistance in understanding an abstract world. [Bangert]

Teaching methods in the United States and Denmark have changed significantly over the years. In the past, information was procured from teacher’s lectures and from reading books. Now, more of the teaching is done with visual aids and in class demonstrations or experiments. This different way of teaching can be more difficult for a visually impaired person to learn from, since the information is often not clearly stated or explained. [Martin] In Denmark this is a particularly prevalent issue, because in most cases the laboratory is connected with the classroom. Thus, hands-on experimentation is an even more integral part of the students’ education. [Gufler, Brown]
Since the emphasis on visual aids has increased, there is a need to adapt diagrams and figures so the visually impaired may also access that material. One method is to use a raised line drawing kit, as described later; the material will then be accessible tactually. Another way is to modify the visual aid for low vision students. Depending on the range and scope of the student’s vision, the placement and size of the modification may be varied. [Bangert] In the United States, these modifications to visual aides can often be produced or procured by the teacher of the visually impaired who is associated with the school. In Denmark, however, these visual aides must be created by the general education teacher, the support teacher, or requested considerably in advance from the county resource center or from Refsnæsskolen. [Nygaard]

4.2.2 Obstacles for Students

In order for a visually impaired student to learn in an integrated school system, they must surmount many obstacles themselves. Issues including the student's concept of the world around them and social skills must be overcome. Additional physical disabilities must also be dealt with for successful integration into mainstream education.

4.2.2.1 Concrete Vs. Abstract

The learning style and method of comprehending the world is different for a blind or visually impaired person and a person who has full use of their vision. People with full use of vision often think of items in the abstract whereas visually impaired think in very concrete terms. For example, a fully sighted person can walk into a room, see a table, and know what it is because they have an abstract picture of what a table looks like. A congenitally blind person who is in contact with the table does not know what it is until
he explores it. Because there is no preconceived notion of ‘table’, the visually impaired person does not know the difference between a tabletop and board supported in any other manner, even floating in space. [Bangert]

4.2.2.2 Additional Physical Problems

In addition to having a visual impairment many students also have other physical problems. These include a general weakness in the muscles from so little tone developed as a baby. This condition results from the student’s unwillingness to move appreciably through its surroundings, as well as the overprotective concerns of the parents. This lack of tone can mean that the student does not have well-developed fine or gross motor skills, so they may be unable to perform intricate or strenuous movement. Also, many of the conditions that cause vision loss cause other ailments. For instance, ONA, ROP, and xerophthalmia are all linked to neurological conditions. [Martin]

4.3 Approaches Towards Educational Issues

There are diverse solutions to the many issues facing integrated education. They involve addressing the issues on various levels: the administrative, classroom, and student levels.

4.3.1 United States Teacher Model

The information about teacher models used in the United States was collected through literature review and through an interview with the head of the special education department in Worcester, Maggie Terrio Lawler, and with teachers of the visually impaired in Worcester, Massachusetts: Keefe Bangert, Cheryl Dougherty, and Lenore Martin.

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4.3.1.1 Diverse Methods

There is no universal plan to the method in which the visually impaired should be educated. Many different strategies and programs are currently in use. Therefore, a student may encounter different strategies if they move between schools or towns. What is universally understood is that every student is a different case. Their individual needs must be recognized and met in a flexible program that will allow for the student's changing needs. (Wehman)

4.3.1.2 'Least Restrictive Environment'

The ADA mandates that a 'least restrictive environment' should be created. This means that a blind or visually impaired student should have the same education that other students do. This education will take place in the same schools and classrooms, with the same teachers and classes. The student should be distinguished as little as possible from his sighted peers. (Wehman)

4.3.1.3 Training for the Teacher of Visually Impaired Students

The competence of the teacher of the visually impaired is as important as the capability of the general education teacher for visually impaired students in integrated classrooms. (Head) Not surprisingly, there are few institutions that offer advanced programs in visual impairment education. In the New England area, Boston College offers a master's degree. The University of Birmingham, England has both full-time and correspondence courses in this field. Course topics include background information on the causes and condition of being blind or visually impaired, assessment procedures, and the teaching of Braille, mobility, and certain curriculum areas. (Best) In the United
States, there are no national standards or guidelines for the content of these advanced
degree programs, although teachers of the visually impaired are strongly in favor of
establishing them. The teachers also advocate accreditation program to raise standards
and increase consistency. (Head)

4.3.1.4 Types of Teachers of the Visually Impaired

There are two common types of teachers of the visually impaired: itinerant and
consultative-collaborative. The itinerant teacher is the most common type, while the
consultative-collaborative type is used in areas where there are not enough teachers of the
visually impaired per school district, although both types travel between schools. (Flener)
Itinerant teachers serve only one school system, and possibly only certain schools within
that system. They function as consultants to general education teachers, provide special
modified educational materials and in-class assistance, consult with the students’
families, and facilitate social integration with the students’ peers, among other tasks.
They may provide orientation and mobility training, or a specialist may do so. (Orlansky)
Consultative-collaborative teachers serve several school districts and therefore cannot
attend as many classes with specific blind or visually impaired students. So, their
purpose is primarily to support the general education teachers outside of class by
performing administrative duties, adapting materials, and consulting with the general
education teachers and families about the visually impaired students’ educational
programs. (Flener)
4.3.1.5 The Itinerant Model

In the itinerant model, a school system has several teachers who travel between the various schools and work one-on-one with the students in the program. Each teacher is responsible for only a few students, with whom they work on a regular basis. When adequate resources are available, this is the preferred model of assistance. [Terrio Lawler]

4.3.1.6 The Itinerant Teacher as a One-on-one Assistant

Itinerant teachers work individually with a few visually impaired students outside of class, although they are usually not allowed to provide educational services to students outside of the school day. They also attend several general education classes. Itinerant teachers help the students modify any behavioral peculiarities (often termed “blindisms”) and to interact with their sighted peers. Of course, these teachers also provide necessary materials such as textbooks, modified materials such as homework assignments and handouts, and real objects to replace models and drawings. These duties increasingly become the teacher’s sole function as the student gets older. [Terrio Lawler]

4.3.1.7 The Itinerant Teacher as a Classroom Assistant

When the itinerant teacher is in the general education classroom, they are considered to be guests of the general education teacher. They have no authority over the class curriculum or activities. [Martin] The relationship between the itinerant teacher and the general education teacher can be very open and supportive, but too often becomes strained. The itinerant teacher must always maintain the role of an available resource and a supportive assistant, and never appear to be an added burden on the general education teacher. [Bangert] If the general education teacher desires, the itinerant teacher can
provide cues during class to help incorporate the teaching techniques mentioned above. [Martin] Otherwise, the sole purpose of the itinerant teacher becomes the modification of materials and the assistance to the visually impaired student with skills and class participation. Ideally, the general education teacher will readily approach the itinerant teacher for support, and will accept the itinerant teacher's suggestions regarding the structure of the class to optimize the learning experience of the visually impaired student's. [Bangert]

4.3.2 Danish Teacher Model

Educational assistance for the visually impaired has the distinguishing characteristic that it focuses on the social abilities of the student as well as the educational aspects. As in the United States it is an inclusionary model, where the student participates in a general classroom with a general education teacher. All assistance is supported by the national government. [Nygaard]

4.3.2.1 Supplies

The student is supplied by the state with all the equipment that he requires. These supplies and the funding for them may be procured by the state government, the county government, the town, or the school, depending on the equipment and the school's location. Supplies can include computers, scanners, Braille devices, or mobility equipment. [Brown, Nygaard]

4.3.2.2 Modification of Materials

Refsnæsskolen, a residential school in western Zealand, handles all modifications dealing with Braille books and raised line drawings for the entire country. They produce
standardized tests for the students and modify textbooks. When a test is modified sometimes the questions are not only produced in Braille but also changed to meet the needs of the student. Refsønnskolen modifies or produces images from textbooks and the student uses a scanner and Braille output device to follow the text. Due to the tremendous time requirements involved with modifications, material must be sent well in advance. Even with advanced notice, Refnønnskolen is not able to reproduce everything. There is no modification of weekly material, such as handouts, into Braille. The student uses his equipment or teacher aid to assist. [Gaardhøje]

4.3.2.3 Assistance for the General Education Teacher

Support personnel for a visually impaired student typically includes the general education teacher, the teacher who acts as an aid to the student in class, and the county consultant. The county consultant is trained in the needs of visually impaired students and assists teachers and schools. [Nygaard] Classroom assistance is provided on the basis of need. When a student needs extra assistance in a class, another teacher (not a specialist) is assigned to provide this assistance. This teacher has received extra training through seminars and workshops provided by Refnsønnskolen or the county consultants. The extra teacher will assist the student in different ways in different classes. For instance, in a laboratory environment the assistant can be the student’s hands when precise technique is required. Support teachers are used in less than half of the classes and the general education teacher is still responsible for the education of all students. [Gaardhøje]
4.3.2.4 Special Classes for Students

The Refsnæsskolen has many functions in the lives of blind and visually handicapped students. Those students who attend public school take special classes at the Refsnæsskolen periodically. These classes are often for orientation and mobility or Braille education. These subjects cannot be taught effectively in the school system because the general education teachers do not have enough training to do so. 

4.3.2.5 Social Education

In Denmark the educational system is responsible for the social education of all students. Blind and visually impaired students need extra assistance in understanding social behavior, as discussed in section 4.1.3 "Issues of Inclusion." This assistance is provided from two sources. The first, and continuing, source is the county consultant who is in contact with the family beginning when the visual impairment is first discovered. Their assistance continues in many forms throughout childhood, including social meetings and trips with other students. The second source is the general education teacher or assistant teacher who is with the student on a daily basis. [Nygaard]
5. **Existing Modifications**

The integration of blind and visually impaired students has been an ongoing process for a number of years. Consequently, a considerable amount of information currently exists for use in integrated classrooms. This information includes expert advice for developing adaptations and lists of commercially available products. These adaptations incorporate both simple and technologically complex solutions to various common issues.

5.1 **Adaptations**

Some adaptations are required for a visually impaired student to receive information presented in a classroom. These adaptations will vary from student to student and must be constantly evaluated for their effectiveness. Both physical materials and procedures can be modified for visually impaired students.

5.1.1 **Minimization of Adaptation**

The modification of educational materials is one of the most prevalent issues in accommodating an integrated visually impaired student. Materials should only be modified if absolutely necessary, because modification emphasizes the disabilities of the student. Creating modifications also complicates the work of both the general education teacher and the teacher of the visually impaired. If adapted materials are not mostly identical to the original materials, the general education teacher must make special provisions for the visually impaired student to keep pace with the rest of the class. [Dougherty] Unfortunately many materials require drastic modifications, which the teacher of the visually impaired must attempt to minimize. For example, page numbers
of Brailled books must correspond with the numbers of printed books, or the general education teacher will constantly have to convert instructions when discussing the text.

[Terrio Lawler]

5.1.2 Avoidance of Adaptation for Basic Skills

Visually impaired students, like all students, possess inherent potential intelligence, abilities and skills. Every student should be able to participate in every facet of the classroom, which is why some modifications are necessary for blind and visually impaired students. However, modifications can easily overcompensate and ignore the visually impaired student’s inherent abilities that may not have developed yet. Before modifying any part of the curriculum, an assessment should be made regarding the possibility of teaching the visually impaired student basic skills. This assessment will reduce the need for future adaptations or permit the use of less intrusive modifications, and increase the visually impaired student’s independence. Basic skills are useful in various activities and environments, whereas adaptations tend to be functional only in specific, instructional settings. Thus, necessary adaptations should be chosen to be as universally applicable as possible, because they replace these basic skills. (Lueck)

5.1.3 Methods for Adaptation

Adaptations can be applied to activities, items, or environments. Their purpose is to maximize the visually impaired student’s participation without drastically altering their surroundings. In general, adaptations can: change the physical environment, change the rules, change the conventional strategy, change the routine, reduce the complexity,
provide devices or cues, highlight relevant stimuli, and offer personal assistance. There are innumerable ways to achieve these alterations. (Lueck)

5.1.4 Availability of Previously Developed Adaptations

Because visually impaired students have been integrated in schools for over 75 years, many adaptations have been explored. This is an advantage for the visually impaired student, as textbooks and devices are commonly available. Often, though, the best method of adaptation is not taken from an outside source, but rather is developed by the teachers for a particular student's needs and abilities. [Banigan-White] Time is a limiting factor in the creation of new adaptations, especially in the fast-paced environment of a classroom. [Dougherty, Martin]

5.1.5 Complications

Adaptations for blind or visually impaired students must involve tactile and auditory stimuli. This is not always a simple task. While the adaptations may translate visual stimuli directly and accurately into tactile and auditory forms, the result of the stimuli may not be what the teacher intended. The same information cannot always be completely conveyed using a different sense. For example, the appearance of a uniform ball of putty may not convey the texture as being soft and pliable; similarly, texture and sound may not convey appearance. [Bangert]

5.1.6 Raised Line Drawings

The most typical adaptations are Braille transcriptions and raised line drawings, because they are universally applicable to almost any written material. Raised line drawings simply replace lines and shapes with elongated bumps, which to a sighted
person appears to convey the same information. This is not always the case, however, because the visually impaired student cannot absorb all of the information simultaneously as a student can do visually. A raised outline of a square does not necessarily convey the desired concepts of shape and area. When tracing this outline with the fingers, the lines may seem arbitrarily drawn, especially if the student cannot identify where they began tracing on the shape. The student may not be able to recognize that there is an enclosed shape at all. Similarly, for a complicated figure (for example, a bird), the student may not be able to identify the picture because the configuration the lines with respect to each other and their contour will be lost as the student's hand moves around the drawing. Raised line drawings have been found to be very useful when properly presented to experienced readers. (Hinton) Their usefulness, however, is often overestimated. [Bangert]

5.1.7 Basic Guidelines for Adaptations

Modification guidelines depend on the degree of visual impairment of the particular student. The most important aspects of are the conveyance of concrete ideas, less detail, and tactile differences or visual contrast. Detail clutters an already less-than-ideal environment, and is unnecessary in the communication of critical idea. This issue applies to both written and verbal communications. Tactile differences cannot be too subtle, and often a great variety of them are needed. Fortunately, simple materials such as glue, felt, and puff-paint are suited for many types of adaptation and easily procured. Visual contrast is achieved best by using black and white, or bright complementary colors if necessary. Low vision students have difficulties in interpreting visual stimuli, and
complex designs and color schemes are more likely to frustrate than interest them. [Bangert]

All adaptations should be kept as simple as possible, to make them easy to develop and to use. They should also be unobtrusive, as the goal of adaptation is to integrate the visually impaired student into a sighted environment. Blatant differences will highlight the student’s disability, and possibly damage the student’s social development. [Martin]
In all cases, real objects are preferred over any two-dimensional adaptation, regardless of quality. Once the student has a firm comprehension of the real object, models and drawings can be used more extensively because they can remind the student of the object. [Banigan-White, Terrio Lawler]

5.2 Current Available Products for the Visually Impaired Students

With today’s technology there are many products that are available the visually impaired. These products range from very high technology, such as Braille computer output, to very low technology, such as an abacus. Appendix C there lists companies that supply these products with their addresses.

5.2.1 Low Vision Aids

There are many products that are produced in the United States as low vision aids. It is important for a visually impaired student with some vision to learn to use as much of it as possible. This will help with his understanding of the concepts of the world. (Ponchillia)
5.2.1.1 Mechanical Aids

There are many mechanical devices that can assist in utilizing low vision. It is important to select a device that will fit the needs of the student. Additionally, it is important to remember that a student who is uncomfortable with the aid will have difficulty learning to use it effectively and will not use it unless coerced. Finally, it is important to consider how the student will appear to others. (Ponchillia)

- **Telescopes** - Telescopes can be used to enlarge items that are far away.
- **Microscopes** - Microscopes are used for items that are close by and too small to see clearly.
- **Telemicroscopes** - Telemicroscopes are glasses with small magnification devices attached to them.
- **Electric Magnifiers** - Electric magnifiers use electric processes rather than mechanical ones to produce an enlarged image.
- **CCTV** - Closed Circuit Television is a large unit that allows a person to see on screen very enlarged images of an object placed in front of the camera. This large system is often used for text.

5.2.1.2 Low Tech Aids

There are a number of simple methods to increase the useful vision of students. Each focuses on one aspect of interference with vision and how to decrease it. (Ponchillia)

- **Illumination** – Increasing the illumination of objects causes them to be easier to see. This illumination can be accomplished by extra lights or lamps, or by increasing the wattage in existing lights.
• **Glare** - A white paper reflects light and this excess light interferes with the ability to focus on one area. Black paper with lines cut out of it reduces the glare from the rest of the sheet so the person can focus on the line they are reading.

• **Contrast** - Some colors contrast with others more effectively; for instance, it is difficult to see yellow text on a white paper. To increase the contrast, dark blue or black on white boards, or white on black boards should be used. For reading printed material, a yellow filter will increase the contrast of black on white in the form of yellow sunglasses or a yellow filter.

5.2.2 **Computers**

Computers are a powerful tool that can help considerably with the education and daily lives of many people. There are both special programs and special components of computers that can assist visually impaired students. Computers can be a difficult item to learn to use, and because of time and cost considerations their use is often not taught. [Dougherty]

• **Screen Magnification, Lighting, Contrast, Glare, And Size**

The specifications of the screen settings can greatly change its visibility for those with low vision. Increased lighting and contrast and decreased glare will make the computer more accessible. Larger or smaller monitors may be purchased to fit the user’s vision. Also, magnifiers that fit over the screen can be purchased.

• **Enlargement Software**

Software is available that will enlarge screen content. This software often does not need to be acquired separately, but rather is included in commercially available packages such as Microsoft Windows.
• Operating Systems

Some operating systems are better suited for use by visually impaired users than others. Macintosh computers are more conducive to this function than IBMs. Also, DOS programs tend to be less visually oriented. [Bangert]

• Braille Output

For a blind or visually impaired person to interact with a computer there is a Refreshable Braille Output device. This is a mechanical device that produces a single line of Braille at a time. These devices are expensive but very useful.

• Verbal output

Another means of computer interaction is to use software that converts text into verbal output. These programs are less expensive than Braille output devices. For this application, Apple computers are considerably more proficient. [Bangert] The only screen reader currently available in Danish is JAWS, a Windows-based program produced by Henter-Joyce, Inc. [Brown] <http://www.hj.com/JFW/JFW.html>

• Verbal Input

Currently, some voice recognition software is available for computer use. Several companies produce this type of software in English. Few, if any, software programs can recognize Danish, however. [Brown]

• Braille Printers

A Braille printer may be purchased that prints Braille from a computer. There is also a model that produces Braille and print on the same page.
5.2.3 Electronic Braille Devices

According to many teachers of the visually impaired, electronic Braille devices are the most useful devices for students. The most common model in the United States is Braille 'n Speak but there are other models, such as Braillelite and Type 'n Speak. These models are fairly expensive, but exceedingly versatile. Most models accept Braille input and provide verbal output, or can be interfaced with computers and printers to produce both text and Braille output. These models are available in numerous languages, including Danish. [Terrio Lawler]

The electronic Braille device used most commonly in Denmark is the mini*log, a Danish product made by Tactilog. [Brown] Its functions are similar to those of the Braille 'n Speak. Information is input through a keypad with 16 keys. There are two outputs on the mini*log, a refreshable Braille display and a visual readout. The visual readout is not found on other products and is helpful for the sighted when working with a student using the mini*log. The product is also able to interface with computers and printers, but there is no verbal output. [Nygaard]

5.2.4 Talking Devices—Thermometers, Scales, and Calculators

There are ‘talking’ devices that can be utilized in the classroom including temperature gauges, scales, and timers. Talking calculators are very useful in a science classroom. Many of these products are available as kitchen aids. Use of these devices in the laboratory is limited by their degree of inaccuracy and the time delay between taking a reading and receiving voice output. [Gufler]
5.2.5 Reading Devices

There are products available that will audibly read text. These can be either in the form of a large machine or in the form of a pen. Severely impaired persons may encounter difficulties when using the pen, because it requires very accurate placement of its tip over the text to be read.

5.2.6 Recording Cassette Devices

A tape recording device can be used in the following ways. Tape recorders are easy to find and are available in many varieties.

- **Recording for note taking** - The devices can be used to record a lecture or instructions and to be accessed at a later time.
- **Personal notes** - Recording devices may also be used to take personal notes, such as a daily planner or a quick note of something to do that would be too time intensive to write in Braille.
- **Indexing passive, tonal, voice** – This device can be indexed in a number of ways in order to re-access the recorded material: changes in sections can be marked with changes in voice or speaking style, or they may be marked with some sort of tone.

5.2.7 Cassette Players

Regular cassette players are commonly available. Special cassette players for the visually impaired have features including a tactual difference between buttons. These players also have the ability to be played at high speed so the listener can move through material more quickly, thought it requires practice to utilize the high-speed feature.
There are also special cassette players for Talking Books that can be obtained from the Talking Book program in the United States. (Webster and Roe)

5.2.8 Textbooks

Textbooks can be accessed through Braille editions or through talking editions of the book. Federal funding exists to produce copies of any textbook in either form, but the companies that produce them must have considerable prior planning and have enough demand for the book, since they do not have time to fill all requests.

- **Tactual Books**

  Braille is the only code that literature is written in, but there is a special code for math and science known as the Nemeth Code. Books in Braille are more concrete and require more active participation than talking books. These books allow the reader to easily reread and index a section. Unfortunately, Braille books are very large and a print textbook may be many volumes in Braille.

- **Talking Books**

  There is a much larger selection of talking books than Brailled books, and they are easy to use. The drawback of talking technical references is that the reader must be very knowledgeable in the subject and be able to explain in correct detail what the graphics of the book contain. This makes it difficult to produce good quality audio textbooks.

- **Sources of Adapted Textbooks**

  In the United States, Braille and talking books may be obtained from Recording for the Blind and Dyslexic, whose inventory can be accessed at www.rfbd.org. Approximately 4.3% of their 80,000-book inventory consists of grade-school science
textbooks. The audio textbooks are read by volunteers who have some background in the appropriate subject. [Kline]

In Denmark, Refsnæsskolen provides all Braille and talking books for use in schools. They need at least six months notice prior to the beginning of each school year to arrange for materials to be ready. Refsnæsskolen can also make minor modifications during the school year, however it takes a minimum of two weeks to complete. [Brown, Gaarhøje]

5.2.9 Abacus

An abacus is a device consisting of many organized beads used to do mathematical calculations. With the advent of less expensive talking calculators the abacus is becoming obsolete.

5.2.10 Low Tech Labeling Aids

Many items can be labeled for easier use by the visually impaired, such as medicine bottles or lists of cabinet contents. These labels may be applied using one of many techniques. (Soucy-Moloney)

- **Braille** - Braille is the most widely used code but there are others.
- **Nemeth Code** - Nemeth Code is a mathematical and scientific code.
- **Fishburne** - Fishburne is similar to Braille but it uses lines and some dots. It is only available in a small labeling device and is not widely used.
- **Texture** - Certain Items can be labeled in different textures instead of writing. For instance, Mike Gorse’s parents made a Connect Four game with one half of the pieces covered with felt.
• **Notches, Rubber Bands, Placement or Removal of Label** - There are many small ways to make an item feel differently by placing a certain texture of cloth on it or removing or notching the side or top of the item.

• **Tactile Graphics Kits** - Tactile Graphics Kits are used to modify information such as graphs or angle diagrams by encoding them on metal foil.

### 5.2.11 Low-Tech Writing Aids

Adaptive writing aides can be used to write in Braille or print.

• **Braille Slate and Stylus** - The slate and stylus is a method by which one can write in Braille. The blind or visually impaired students use the stylus to put the raised marks in the correct spots, although all symbols must be written backwards to be read properly on the other side of the page. This is a very slow method.

• **Adaptive Writing Aids and Guides** - There are many guides or outlines that can be used to put lines in the correct positions. For instance, there are guides with rectangular holes to delineate check lines or envelopes.

• **Braille Writer** - A Braille Writer is much like a very large typewriter with seven keys (one for each of the six dots in a Braille cell and a space key). The keys are depressed to write in Braille.
6. Science Curricula

Schools in both the United States and in Denmark use curricula guidelines for each grade level, but each teacher has considerable opportunities for individualizing their own class syllabus. [Brown] This individualization leads to a long list of science topics discussed at the seventh and eighth grade levels. Because of considerable differences between the Danish and American school systems, topics from American grades other than seventh and eighth are included in this study, in order to be comparable to topics in Danish classes.

The focus of these science classes is to give the students a basic scientific understanding of the world around them. The concept of natural and technological systems is introduced, demonstrating that a small portion, or system, of the world can be isolated and examined in detail. Students examine factors that can change the system, and the results of these changes. In Denmark particularly, however, the interrelationships between the system being studied and the surrounding systems are also emphasized. Students are not taught each subject solely within the confines of the classroom or lab. Rather, they learn how science is an integral part of the world around them.

A fundamental aspect of science is the observation, collection, and organization of data. In order to conduct these observations, students are taught the detailed use of common measuring devices such as rulers, graduated cylinders, and balances (double pan and triple-beam). Students are taught measurement systems for such quantities as mass, weight, volume, and density. These units also lead into the study of physical properties of systems, including melting points, boiling points, color, solubility, and texture.
6.1 United States Science Curricula

All United States students take science throughout their schooling. A science curriculum, like all curricula, has moved from a lecture format to a combination of lecture, labs and other hands-on experience.

6.1.1 Middle School Science Curricula

Education in middle schools touches upon a variety of scientific disciplines. Interrelationships between different scientific disciplines can be clearly demonstrated by this approach. The common disciplines addressed are earth, life, biological, and physical sciences. (Davis) The presence of science and technology in everyday life is also a critical issue in encouraging students to pursue scientific studies. Curricula recommended by the United States Department of Education and several state departments of education were used in compiling a list of common lecture and experimental topics taught in United States middle schools.

6.1.1.1 Scientific Disciplines and Basic Topics

Chemistry and matter, motion and forces, energy, and electricity are units within most middle school curricula, which introduce basic topics in chemistry and physics. These units focus primarily on definitions, fundamental components and properties, methods of measurement, and observation and applications of systems. For example, dry cell batteries may be observed and their properties identified, but the chemical reactions involved will not be discussed in detail. The objective of these units is to introduce students to the disciplines of chemistry and physics, not to discuss details.
Although units within life and earth sciences may be of the same length as chemistry and physics units, more of these units are included. Thus, middle school curricula tend to be characterized by these disciplines. Earth science includes the study of the biosphere, the planet itself, and the solar system, potentially extending to the discussion of galaxies and the universe. Life science covers various types of living systems, from the organization of ecosystems to cell theory to genetics and heredity. The study of ecosystems includes the classifications of living things, biological systems, the human body, food webs and nutrition. Cell theory examines the differences between the different kingdoms (i.e. animals vs. plants vs. protista, etc). Genetics and heredity are essential to the study of evolution, which also ties into the history of the Earth.

6.1.1.2 Demonstrations and Labs

In-class demonstrations are a common element of science classes. The teacher sometimes will perform complex and dangerous procedures during a lecture or lab, so that students will be able to observe safely and quickly. Conversely, teachers will also perform simple procedures, which do not warrant the preparatory time or quantity of materials required to involve the students. These demonstrations are very different from labs, because they involve no hands-on experience for the students.

Labs in middle school may or may not encompass more than one class period and may or may not be scheduled regularly. They are often simple, and directly demonstrate and reinforce concepts discussed in class. Labs can also offer opportunities for students to explore details that were not covered in lecture for themselves. Labs are designed to develop the students' interest in science and teach the practical lab skills. Labs are
almost always performed in pairs or groups of students, encouraging peer interaction and allowing more complex labs within shorter time periods.

6.1.2 High School Science Curricula

The objectives of high school science courses are similar to those of middle school courses: to relate the various disciplines of science, to make connections between the "real world" and science and technology, to develop students' critical thinking skills, and to increase the students' interest in scientific studies. (Anderson) High school science classes address topics in more depth than middle school classes, but the same principles apply. Each discipline has one course devoted to it, and most often only one science course is taken per year. This arrangement unfortunately does not easily lead to the illustration of interrelationships between scientific disciplines, and thus requires more effort on the part of the teacher to discuss other applications of the material.

High school teachers usually assume that students have no prior scientific knowledge from middle school courses, and begin with the language, notation, measurement, and physical properties of systems. Students are taught tools and methods used within each discipline, including advanced technology, problem-solving techniques, estimated error analyses, and informational resources.

6.1.2.1 Chemistry

Chemistry, the study of the structure of matter, addresses the topics of the transformation, composition, structure, and properties of substances. (Public) The following lists of topics and experimental subjects were compiled from a high school chemistry curriculum in Connecticut. [Klein]
Topics

General chemistry courses focus on fundamental concepts that are applicable both to the study of all branches of chemistry and to other subjects such as biology. Such topics are typically:

• The structure and properties of matter
• Historic and modern atomic theories
• The periodic table
• Chemical bonding
• Formulas and nomenclature
• Formula math
• Components and types of reactions

• Chemical equations
• Stoichiometry
• Gas laws
• Solutions
• Acids, bases, and salts
• Energy

Advanced topics are covered in shorter times and in less depth, and could include:

• Organic chemistry
• Nuclear chemistry
• Equilibrium

• Kinetics
• Oxidation-reduction reactions

Labs

High school level chemistry labs almost always require more than one hour to complete. In school systems where periods are less than one hour, two consecutive periods are scheduled specifically for lab. Safety in a chemistry laboratory is more of a concern than in other sciences because of the abundance of hazardous materials (acids, oxidants, flammables, glassware, etc.). For this reason, discussion of safety issues is a part of every lab, and students are required to wear safety glasses and sometimes smocks.
Laboratory topics and techniques can include:

- Flame tests
- Distillation of water
- Paper chromatography
- Titration of acids and bases
- Measurement of pH (chemical indicators, digital meters)
- Acid-base reactions
- Solutions (various phases, conductivity)
- Verification of the gas laws
- Close examination of properties of a particular compound
- Verification of trends in periodic properties
- Properties of particular types of reactions (replacements, evolution of gases)
- Reactivities of metals
- Determination of empirical formulas
- Verification of the conservation of mass during reactions

6.1.2.2 Physics

Although physics is the most fundamental natural science, it is taught last in most tracks because of its highly abstract nature and heavy reliance on mathematics. Physical phenomena are common to the students' everyday experiences, but concepts of forces, vectors, and impulse can be difficult for students to incorporate into their thinking. Physics is also one of the most quantitative sciences, so experience with measurement and problem-solving techniques, including many advanced mathematical methods, is essential. (Public) The lists of topics and experimental subjects below were compiled from a science department curriculum guideline in Connecticut. (Curriculum)

Topics

Physics courses in the United States focus primarily on mechanics and waves, with less emphasis on optics, acoustics, and electromagnetism. General physics topics are typically:

- Scalar vs. vector quantities
- Linear motion
- Two-dimensional motion
- Forces
- Mechanical Energy
- Impulse and Momentum
- Properties of Waves
- Basic thermodynamics
• Static electricity
• DC electrical circuits
• Laws of planetary motion and universal gravitation
• Light

Advanced topics could include:

• Semiconductors and Superconductors
• Photovoltaics
• Ceramics

• Sound
• Heat and Temperature
• Fluid Mechanics

Labs

Physics labs often draw directly from experiences in everyday life. Therefore, these labs are usually easy to develop and can enhance the students' understanding of the abstract theories presented in lecture. Common objects (books, lightbulbs, thermometers, pulleys, etc.) and procedures can be used to illustrate many physical concepts. Physics also involves advanced technology to obtain measurements. These technologies can include such devices as voltmeters, ammeters, oscilloscopes, calorimeters, and electromagnets.

Laboratory topics and techniques can include:

• Measuring work done by various processes (lifting, pushing, travelling)
• Properties of simple machines (levers, pulleys, inclined planes)
• Mechanical advantage and efficiency
• Illustration of torque
• Friction
• Compound forces
• Distinctions between heat and temperature

• Surface tension, cohesion, adhesion, buoyancy
• Crystals
• Properties of light (brightness, color, intensity, etc.)
• Magnetic fields
• Properties of electrical circuits
• Thermoelectricity
6.2 Danish 7th and 8th grade curricula

The physics and chemistry curricula in Danish schools have several forms. In some, physics and chemistry are taught in separate classes, one per year. In others, the subjects are taught separately in some grades, while in other grades one course covers both subjects. Also, the subjects can be combined throughout all grades. [Brown, Gaardhøje]

There is no standardized curriculum at any level of the Danish school system. The only framework of a course is the subjects that it covers (i.e. only physics, only chemistry, or both). The teacher decides which topics will be taught at any time, for how long, and which labs will be included. Students may be allowed to have some input into this curriculum, depending on the teacher. [Brown]

6.2.1 Scientific Disciplines and Basic Topics

Since no topics are mandated, the topics covered during seventh and eighth grade science classes vary greatly from teacher to teacher. Certain topics are commonly taught because of their importance, their ease of comprehension at this grade level, or their presence in most textbooks, but this overlap is largely coincidental. [Brown]

In general terms, the focus in Danish schools tends to be 50% electricity and magnetism, 40% chemistry, and 10% mechanics, radioactivity, and other subjects. These subjects are emphasized based on their perceived utility to the students throughout both their education and their professional lives. [Gufler]

Several Danish textbook series reflect these percentages. The list of topics below has been compiled from the following Danish textbooks and laboratory manuals: Prisma Fysik (8, 9, 10U), Prisma Kemi 8/9, and Ny Prisma Fysik og Kemi (7,8)
- Laboratory Safety
- Measurement
  - Units
  - Techniques
  - Devices
- Graphing
  - Manual
  - Computerized
- Energy
  - Sources, production
  - Forms – kinetic, potential, chemical, mechanical, natural, nuclear
  - Transformations, conversions
  - Uses
- Electricity and Magnetism
  - Polarity
  - Static electricity
  - Conductivity
  - Permanent and Electromagnets
    - Relationship, conversion between electricity and magnetism
    - Relationship between electricity, light, and heat
    - Voltmeters, galvanometers, ammeters
    - Ohm’s law
    - Circuitry elements and design
- Light
  - Diffraction, Reflection, Refraction
  - Absorption, heat, and color
  - Prisms
  - Beam properties
  - Lasers
- Sound
  - Properties of waves
  - Oscilloscopes
- Chemistry
  - Periodic table and properties
  - Molecules, ions, formulas, bonding
  - Phase changes
  - Solutions and mixtures
  - Reactions
  - Acids and bases, pH
    - Metals and nonmetals
    - Gases, pressure
    - Electrolytes
    - Chromatography
    - Fire
- Biology
  - Life cycles
  - Plants
  - Osmosis
- Motion
  - Newton’s laws
  - Position, velocity, acceleration
  - Gravity
  - Air resistance
  - Pendulums
  - Trajectories
  - Springs
- Radioactivity
  - Subatomic structure
  - α, β, γ radiation
  - Geiger counters
- Astronomy
  - Astronomical bodies—rotation, revolution, phases, trajectories
  - Stars
  - Constellations

6.2.2 Demonstrations and Labs

The structure of classes varies between schools, affecting the structure of lectures and laboratories. In some schools, the class may be taught in short periods every day. In others, the class may be once or twice per week for longer periods of time. Labs may be
during separate periods, or included in the lecture period giving the teacher the ability to balance lecture and lab time. [Brown]

Labs or demonstrations are available for virtually all topics covered in a curriculum. Hands-on exploration is an integral part of the class instruction. [Gufler, Brown] The list of labs below has been compiled from several laboratory manuals. Danish teachers have identified these labs as being important to their curriculums, needing adaptations, or having been adapted previously. [Brown, Gufler] The lab manuals used were Ny Prisma Fysik og Kemi 7A, 7B, and 8, Spørg naturen 4: Bevægelse og energi, Spørg Naturen 5: Elektricitet og magnetisme, and Fysik/kemi og punktlæsere: Temahæfte 2.

- Basic lab skills
  - Identification of laboratory equipment
  - Safety procedures
  - Measuring devices and techniques
  - Estimation
  - Building models
- Electricity and Magnetism
  - Properties of electricity
  - Circuit components and construction
  - Ohm’s Law
  - Conductivity, Electrolysis
  - Static electricity
  - Properties of magnets
  - Induction
- Energy
  - Various forms of energy
  - Transformation of energy
  - Absorption vs. reflection
  - Insulation
  - Latent heat, specific heat
- Waves
  - Properties of waves
  - Properties of light
  - Properties of sound
  - Resonance
- Mechanics
  - Newton’s Laws of Motion
  - Speed, acceleration
  - Gravity and air resistance
  - Propulsion and projectile motion
  - Forces and work
  - Friction
  - Oscillating systems/periodic motion
  - Mechanical devices
- Chemistry
  - Atomic and molecular structure, bonding, isomers
  - Solutions and mixtures
  - Reactions of metals and acids
  - Neutralization
  - Combustion
  - Organic molecules and reactions
  - Crystallization
  - Temperature changes, thermometers, thermostats
  - Phase changes
  - Properties of gases
  - Air pressure
  - Plants – starch, photosynthesis
7. Methodology

Due to the scientific nature of this project, it is essential that we document not only what we did, but also how we did it. This methodology encompasses all aspects of this project, ranging from background research performed in the United States to documentation of the final report.

7.1 Background Information Research

The preliminary research was directed towards understanding the condition of being blind or visually impaired. Local libraries and the Internet were initial sources for information on this topic. A vocabulary of terms relating to visual impairment was developed. The causes and statistics of visual impairment were also included in this research, mostly through books and journal articles.

Primary focus was placed on issues and problems associated with these conditions. The information was first researched through literature and the web sites of organizations dealing with the blind and visually impaired. This gave us a firm understanding of the general problems faced by the visually impaired, their peers, and others. Interviews with teachers of the visually impaired and employees at various organizations gave more detail about the specific problems in the classroom. We also found sources of adaptations that had already been developed as solutions. These sources were usually found in the same books or web sites mentioned above. The most widely applicable adaptations were included in our background, as well as all of the suggestions from our interviews. We also used the catalogs given to us by the teachers, and the catalogs' web sites, to research available technological devices.
The legislative issues in the United States were researched using books and journal articles written about the ADA and IDEA. Interviews with the teachers included discussions about the effects of these laws on teachers and students. All literature regarding the Danish legislation of schools was in Danish. Therefore, information regarding the appropriate laws was obtained from an interview with an educational consultant.

Information about the United States science curricula was gathered through personal connections with schools in our states and through other state education department websites. In order to get the most representative list of topics and experiments, the information from all sources was compiled and the more common subjects were included in the final lists. Danish science curriculum was discussed at length in the interviews with teachers. Textbooks and laboratory manuals were also consulted.

7.2 Interviewee Selection

We chose to use interviews to obtain information both in the United States and in Denmark. The interviewees were chosen in order to provide the necessary information.

In the United States the information collected included background on visual impairment, general instruction of the visually impaired, learning styles, and education obstacles. To meet these goals we chose four teachers of the visually impaired and the Head of Special Education Services in Worcester as well as a congenitally blind college student. Interviewees were chosen because of their expertise and availability. Michael Gorse was qualified because he is congenitally blind and had experience in the United States education system. Maggie Lawler, the Head of Special Education Services in the Worcester School District was chosen because of her job and experience. The other four
people we interviewed were teachers of the visually impaired. They were chosen because of their experience with the education of visually impaired students as well as having available time to meet with us. Due to time constraint, most sources were found in Worcester and one was in Connecticut. Other cities and states were not included, because it was determined that the interviewees could inform us of major differences between cities. Also, our project did not focus on differences between educational systems but rather on gathering information that would be useful for designing adaptations.

In Denmark, interviews were chosen in order to obtain information about the Danish system. The contacts we interviewed were chosen by our sponsor, The Visual Impairment Knowledge Center. The Center chose the interviewees because the sponsor had more knowledge of and contacts with the educational system in Denmark. The interviewees included teachers who had experience with visually impaired students, a county consultant, a teaching consultant, and a teacher at the residential school. These sources had been chosen to represent various aspects of the Danish educational system. All have had classroom experience with visually impaired students.

7.3 Interview Procedure

Interviews were designed to get the most effective information from each source. Prior to each interview we obtained background information on the position of each interviewee. A list of interview questions was made specific to each interviewee. During sessions, interviews were conducted as dialogues with the questions being used as a framework.

Before any interviews were conducted, we completed an extensive literature review on the necessary background information regarding visual impairment. Once
interviewees were chosen, we learned about what their job entailed and what expertise they had. Based on this, we were able to formulate questions that the interviewee would be able to answer accurately. The interviews always began with questions about experience and education. These gave each source credibility.

In the United States we had done research on blindness and visual impairment and the systems used to effectively educate the blind and visually impaired. However, because the application of theory varies in every situation, we inquired about the interviewee’s experience. The inquiries included how the laws affected their work, how well teachers adapted their style, how well the students actually learned, and what shortcomings existed in the system.

Upon arriving in Denmark we had an extensive knowledge of the conditions of visual impairment and how it affects education. We were not able to perform a literature review on the Danish educational structure pertaining to the education of visually impaired students because the information is in Danish. Therefore, interviews in Denmark contained background on workings of the educational system, as well as the interviewee’s individual experiences. The interviews focused on specific science experiments and their associated difficulties. From these interviews, we collected information on how classes are conducted and what experiments needed adaptations.

The interviews were conducted in a dialogue format. This format was chosen because we wanted to allow the interviewee to place emphasis on what they deemed important. Also, much of the information collected was based on personal experiences and abstract ideas and more effectively vocalized in conversation.
Each interview was different depending on the source and time restrictions. Some were limited to 30 minutes; in which case, we focused only on specifics. Some were over the course of a full day and included minimal direct questioning. Regardless of the format, in each interview we collected the information that was needed and the personal information to give them credibility.

7.4 Classroom Observation Selection

Classroom observations were conducted only in Denmark. The purpose of the project is to create accessible designs for Danish classrooms, and knowledge of United States classrooms was deemed inapplicable to our future studies in Denmark. Also, due to school vacations and schedule conflicts, observations in the United States were not possible.

In Denmark we observed totally blind students in inclusive settings in two schools, Lindebjergskolen in Roskilde and Bjørnehøjskolen in Helsinge. The science teachers in these schools were previously contacted by The Visual Impairment Knowledge Center and had expressed interest in our project. There are very few blind students in Denmark; therefore, having two students in Zealand is a high percentage of the total number of blind students in the country.

Information was collected in general science classrooms at two schools. One observation was in a classroom in Roskilde. There we observed a seventh grade class and examined the available lab equipment. The second was in Vordingborg where we met with a science teacher and performed common laboratory experiments, thereby becoming familiar with the equipment available to both sighted and visually impaired students.
7.5 Observation Procedure

The method of observation in classrooms was to meet with the teacher before the class, silently sit through class, and meet with the teacher again afterward. A teacher helped familiarize us with the facilities and provided us opportunities to ask questions.

Prior to attending a class, we spent time with the teacher asking about the class format and the day's topics. During the class, we took notes on what we observed. We focused primarily on the teaching style, class participation, participation of the blind student, interaction between the blind student and the rest of the class, and what extra help was given. The classes were in Danish but since the subject matter was familiar we were able to follow the lecture. After the class, we discussed our observations with the teachers and asked questions that arose.

When observing the lab in Vordingborg, we learned what students normally do in class and what apparatus they use. Performing the experiments was particularly useful because it allowed us participate in a common Danish laboratory experience.

Our observations were performed in order to understand the method of Danish laboratory instruction and technique, and observe the incorporation of blind students. This understanding was attained via classroom observation and lab work.
7.6 List of Interviewees and Observations

United States Interviews

<table>
<thead>
<tr>
<th>Contact</th>
<th>Position</th>
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<tbody>
<tr>
<td>David Banigan-White and Kathryn Summ</td>
<td>Vision Specialist</td>
</tr>
<tr>
<td>Kim Charleston</td>
<td>Collection Development Officer</td>
</tr>
<tr>
<td>Keefe Bangert</td>
<td>Teacher of the Visually Impaired</td>
</tr>
<tr>
<td>Michael Gorse</td>
<td>Congenitally blind WPI Student</td>
</tr>
<tr>
<td>Cheryl Dougherty</td>
<td>Teacher of the Visually Impaired</td>
</tr>
<tr>
<td>Lenore Martin</td>
<td>Teacher of the Visually Impaired</td>
</tr>
<tr>
<td>Maggie Terrio-Lawler</td>
<td>Head of Special Education Services</td>
</tr>
</tbody>
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Denmark Interviews

<table>
<thead>
<tr>
<th>Contact</th>
<th>Position</th>
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</thead>
<tbody>
<tr>
<td>Klavs Bisgaard</td>
<td>General Education Teacher, Science</td>
</tr>
<tr>
<td>Kristina Eskelund Nielsen</td>
<td>9th grade student</td>
</tr>
<tr>
<td>Bent Gufler</td>
<td>Educational Consultant</td>
</tr>
<tr>
<td>Hans Nørgaard</td>
<td>County Consultant</td>
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</tbody>
</table>

Denmark Observations

<table>
<thead>
<tr>
<th>Contact</th>
<th>Subject</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jørgen Petersen and Poul Gaardhøje</td>
<td>9th grade fysik</td>
<td>Lindebjergskolen, Roskilde</td>
</tr>
<tr>
<td>Eric Brown</td>
<td>7th grade fysik</td>
<td>Lindebjergskolen, Roskilde</td>
</tr>
</tbody>
</table>

7.7 General Recommendation Compilation

General recommendations are ideas for adaptation that can be used in any laboratory experiment and do not include the application of adaptive technology. These guidelines were compiled from numerous sources, including interviews both in the United States and in Denmark, literature sources, and our own observations in the classroom setting.
The recommendations are divided into three sections: chemistry, physics, and general teaching methods.

7.8 Topic and Experiment Selection

In the United States, the science curriculum was researched but no specific topics were focused on either in the literature review or during interviews. We assumed that the Danish curriculum would be different, and therefore emphasis on various topics would be different from the United States system. Upon learning that the curriculum was not standardized in Denmark, the input from teachers became the only source of direction regarding specific topics to include in our project.

All of the teachers that were interviewed were asked to list the topics and experiments that they believed to be most important, most difficult to teach, or most difficult to adapt. These questions were also asked via an e-mail list to other teachers not directly interviewed. The interviewed students were also asked which topics and experiments were the most difficult and the easiest, so we could get a complete picture why some subjects were more difficult than others to comprehend or to perform.

The resulting suggestions were compiled and the final topics and experiments were chosen based on the following criteria:

- Mentioning by several teachers
- Particular difficulty for teachers to adapt
- Compatibility with our time constraint.

Because the curriculum is not standardized, many topics and particularly experiments are used by very few teachers. Therefore, there were a large number of topics and experiments to consider, some of which did not require much adaptation. We wanted to
focus on creating adaptations that could be widely used and that teachers would not be able to develop by themselves in a timely fashion. We included as many topics and experiments as we felt needed considerable adaptation and as our time would allow.

7.9 Experiment Analysis

We analyzed the procedures and material requirements of the experiments chosen above to identify the components that made the experiment unsuitable for blind and visually impaired students. We did not perform these experiments during the analysis process, although we have performed many of the experiments, or similar ones, during the course of our education. Analysis was performed primarily by critically reading the experiments, looking for problematic components mentioned by teachers, students, and literature sources. Some experiments had already been analyzed by teachers, in which cases their concerns were included. However, we specifically analyzed all of the experiments during this project.

7.10 Experiment Adaptation

Once the problematic components of each experiment were identified, the experiment was adapted to either eliminate or change them for easier accessibility to blind or visually impaired students. The components were not necessarily adapted separately – the experiment was redesigned as a whole, to minimize necessary adaptations. Skills that are useful in multiple types of experiments were adapted individually, however, so that they were useful in more than one experiment. Recommendations and adaptations were kept as simple and as universal as possible, to allow the teacher to alter different experiments without negating the usability by the blind or visually impaired student.
Ideas for adaptations came from previously adapted experiments and devices, and from new concepts created during the project. Many adaptations were presented to the teachers during the project to obtain feedback as to their feasibility and whether they make the teacher's job easier, based on the teacher's experience.

7.11 Device Selection

A small but integral part of this project was the creation of devices designed to aid in the visually impaired student's lab experience. The principal method of choosing these devices was through personal interviews in Denmark. During these interviews, the issue of constructing devices was only briefly touched upon, due to the nature of both the project and the question.

This project's main emphasis is the development of general instructions and adaptations that can be used for a broad range of applications. While some devices can be used in multiple experiments, many devices are for one specific task. As more devices are suggested, the focus of the project shifts away from universal adaptations to more individualized ones. Due to time constraints, this method of adaptation is not possible.

In order to think of a device that has a theme of universal adaptation, the interviewee must have considered all experiments and discovered a common problem with many of them. Once this is done, a proper device can be engineered to compensate for the shared problem. In this light, a proper answer to the issue posed to the interviewee requires substantial consideration previous to the interview.

Considering the nature of the project and specific topic, an indirect approach was used in the interviewing process, allowing the interviewee to voice pre-formed ideas while not allowing narrow focus answers to the question. This serves the purposes of
attaining properly developed ideas for devices while eliminating the need to question the validity of these ideas for devices. This also ensures that the time and human resources available for this project are not allocated to the development of devices that serve too narrow a focus.

7.12 Device Design

Once a device is suggested, the engineering process to develop a prototype began. This process involved four basic steps: analysis of any current adaptations, designing the actual device, meeting resource requirements, and final production.

To properly develop an adaptive device, we needed to examine currently available for adaptations. This ensures that we did not waste resources on an engineering process that had already taken place. To do this, the original interviewee that suggested the device was questioned. This, along with discussion at meetings with sponsors and other persons associated with the project, was sufficient to discover the current state of adaptive devices in the suggested area.

During the design phase, we planned the devices we were going to construct. The adaptive device must meet certain design requirements including ease of use, short setup time, and minimization of adaptation. Through interviews both in the United States and in Denmark, we discovered that all adaptations must be easy for the teacher to prepare due to time constraints on laboratory procedures. Additionally, the inclusion principle dictates that there should be as little as possible distinguishing the visually impaired student from the other students. This research indicates the construction of a device that is as simple as possible.
In order to construct devices, we needed to acquire the proper materials and work space. After the design phase, we developed an itemized list of necessary equipment. We received the proper materials from Ingeniørhøjskolen Københavns Teknikum (IKT), Copenhagen's Engineering and Technical University. With these materials and the room IKT set aside for our use, we met our resource requirements.

The final construction of adaptive devices was completed as the design phase dictated. The prototypes were then tested, ensuring successful use in a laboratory environment.

7.13 Results Documentation

To determine a proper documentation method, we had to consider the content of our project. Different types of documentation were used for various sections.

Since the goal of the project is to develop a teacher resource, we decided to compile all of the necessary background information. This background contains information from literature, interviews, and classroom observations. We deemed that it was necessary to deviate from the typical literature review, which has information from just literature, to allow for a complete picture. For this background information the section heading and paragraph format was used, organizing the data into easy-to-read and -navigate packets to create a comprehensive guide. Complete reports of interviews and classroom observations are also included in the Appendices A and B.

There are four different sections in the teachers' manual. The first section provides background information on how blind and visually impaired students learn, along with some general classroom guidelines. The second section, ‘General Guidelines for Making Adaptations’, is written in four separate sections mirroring the format of the background
information. The next section, ‘Laboratory Adaptations’, includes adapted laboratory equipment and new devices. The adapted laboratory equipment is also formatted similarly to the background section. The portion dealing with new devices in this section shows a schematic diagram of the necessary circuitry, instructions of how to construct additional units, and proper setup and use in the laboratory environment. The final section, ‘Specific Experiments’, is written in laboratory manual format, depicting proper setup and use of equipment, equipment needed, and applicable questions to ask the students. This section is provided to demonstrate how the general recommendations, adapted apparatus, and new devices can be applied to laboratory experiments.

Documentation methods were selected to provide the most easy-to-read and complete picture for the reader. Our goal is for this manual to be helpful to teachers with no experience with visually impaired students.
8. Results and Recommendations

As described in the methodology section, the results of this project are in the form of a teacher's manual, which serves as a resource for science teachers with a blind or visually impaired student. It is meant to be an independent, self-contained document. Included in the manual are sections detailing the learning styles of blind and visually impaired students, as well as guidelines for educational settings with blind or visually impaired students. These sections are a compilation of the background research performed during this project. Guidelines are also presented for making adaptations to laboratory equipment and associated skills. Finally, examples of modified experiments are given, which highlight the recommendations regarding adaptations mentioned above.
Teacher’s Manual for Adapting Science Experiments for Blind and Visually Impaired Students

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1 Introduction

This manual is designed for teachers and aides working in science classrooms with students who are blind or have a visual impairment. It is composed of three main sections: background educational information, adaptations of laboratory tools and skills, and full experiments. It is designed to be a reference throughout the school year.

Each section has different uses. The understanding of one is not dependent upon knowledge of the others. The section on general background information is designed for teachers with no previous experience in teaching students with visual impairments. It briefly discusses the differences in learning styles and educational considerations. This section also offers general recommendations for the classroom.

Contained in the section on adaptations are suggestions for modifying laboratory tools and skills. These suggestions include descriptions of specific adaptations for commonly used equipment. This section also presents devices designed specifically for use by blind and visually impaired students. General guidelines are presented for creating additional adaptations.

The final section is a collection of redesigned experiments, which highlight some of the adaptations from the previous section. These experiments are designed for use by the whole class, not as separate experiments for the blind or visually impaired student.

The intent of this manual is to improve the accessibility of laboratory experiments. The manual is a compilation of information and experience from many different sources, in the hope that this knowledge will be made easily accessible.
A Note on the Research

The background information provided in this manual has been compiled from various sources in Denmark and the United States. This research encompassed the learning styles of blind and visually impaired students, and the guidelines for teaching and devising adaptations. Sources included written materials such as books, journal articles, and Internet web sites, interviews with teachers and specialists, and classroom observations.

In the United States, research was conducted on the learning styles of the blind and visually impaired and on the integrated educational model. The primary sources of info were printed materials and interviews with teachers who are trained as specialists in the education of the blind and visually impaired. Contacts were also made with relevant organizations via email.

A study of the integrated educational model was also performed in Denmark through classroom observations and interviews with teachers who have had experience with blind and visually impaired students. Several schools were visited, and various science classes at different grade levels were observed. Teachers demonstrated some of the experiments that are commonly used in their science classes, and provided examples of standard laboratory equipment. Interviews were also conducted with an educational consultant, and regular contact was maintained with the Visual Impairment Knowledge Center.

Several lab manuals formed the basis of the analysis of existing experiments. Teachers identified the experiments and subjects that they considered to be most important. The experiments and their component skills and apparatus were analyzed for accessibility, based on the considerations suggested by the previous background research.
A more detailed version of this background research can be found in “Modifying Science Experiments For The Visually Impaired,” a project completed in conjunction with the Visual Impairment Knowledge Center in Hellerup, the Educational Consultants for Visual Impaired Students in Storstrøms Amt, and Worcester Polytechnic Institute in Massachusetts, USA. A copy of this document is available in the Visual Impairment Knowledge Center.
2 Teaching the Blind and Visually Impaired

Having a blind or visually impaired student in your classroom can be challenging, but it can be beneficial for both the students and you. With the right teaching methods and assistance, the student can fully participate in your classroom. To effectively instruct a visually impaired student in the classroom, you must be aware of the differences in their learning style.

2.1 How Blind and Visually Impaired Students Learn

Blind and visually impaired students have a specific learning style. This style stems from the student’s unique perception of the world. To better understand the learning style of blind and visually impaired students, consider the following situation.

Think about entering a room. Within seconds you have ascertained who is in the room and what activity they are doing. Also, you notice the surroundings: how the furniture is arranged, where there is an empty chair, and the food sitting on the table. In gaining all of this information you utilize very little verbal information and almost no tactual information. Yet you are able to construct a complete understanding of the situation, including the interrelationships of the different objects in the scene. Instead of visual information a blind or visually impaired person would rely on the auditory cues, verbal communication, or information gained from maneuvering around the room. By any of these methods they will have difficulty in constructing the entire scene because they do not have information about areas they are not in direct contact with.

The unique perception of the world is best exhibited in the difference between abstract and concrete conceptualization. Sighted people create abstract concepts by
putting many characteristics in a group. This abstract concept can be used to classify and understand objects not previously encountered. For instance, there are many types of birds that can be represented in a number of different shapes and positions. Yet, sighted people can classify them as birds because they have an abstract concept of a bird. This abstract concept is a model in our mind that can be manipulated, rotated, stretched or represented in a two dimensional form.

The blind student has a concrete concept of the world. The objects that are tactually explored and identified will have meaning but a picture of the same object will be difficult to identify. For instance, an outline of a bird is identifiable to a sighted person, but a blind person exploring a raised line diagram of the same picture may be unable to determine it to be a bird or define which points are its wingtips and which is its head.

There is also a concrete association between an object and the manner in which it is originally introduced. The initial characteristics such as its use or size are understood, but it is difficult to extend the concept of the object to having a different form or use. Because of this, there is difficulty in perceiving the inter-workings of a system, and how each object relates to and affects the others.

As with blind students, visually impaired students tend to conceptualize concretely. Since abstract concepts are based on visual information; a student's ability to form these concepts depends on their amount of residual vision.

Another consideration in the learning style of blind and visually impaired students is the time required to collect and process information. As discussed earlier, visual acquisition of information is very rapid. Conversely, tactual and audible methods can be time consuming and limited. When learning about something tactually the student must
be able to explore all parts of the object. When learning audibly a student must have an accurate description to obtain a clear understanding.

2.2 Basic Teaching Guidelines

The keys to creating a productive learning environment for a blind or visually impaired student are not extraordinary, and they are a benefit to the class as a whole. In fact, most teachers remark that having a blind or visually impaired student in class has made them a better teacher for all students. You do not have to, nor should you, alter your curriculum or standards when you have a blind or visually impaired person in your classroom. Modification is in the presentation of material.

Blind and visually impaired students need verbal descriptions of everything. This refers to reading and explaining what you put on the blackboard or what you hand out on paper. You should also refer to everyone and everything by name or description, rather than pointing or using vague terms such as "this" or "that." Whenever you are explaining, make sure you speak clearly and distinctly because the student may have a difficult time following you if they are also reading along, taking notes, etc.

Organization of the class and of material is very important for the blind or visually impaired student's understanding. To aid the student's mobility through the room, the furniture should maintain in its configuration. Also, the student needs to have a firm mental picture of where objects are in the laboratory so they are able to locate them independently. Therefore, every object should have a permanent location. For the blind or visually impaired student to accurately follow the material in class it must be presented in an organized fashion. Lesson plans prepared in advance will enable you to ensure a progression in a logical fashion that is easy to follow both orally and in text.
Using real examples provides concrete reinforcement for blind and visually impaired students. Two-dimensional representations and verbal descriptions do not convey as much information as real, three-dimensional objects. It is best to provide these objects whenever possible. To aid in the students understanding of the interactions between objects, demonstrations should relate to the student’s daily life or experiences.

The blind or visually impaired student often has suggestions regarding their learning methods, based on previous experience and personal preferences. You should consult with the student before and during the course to obtain feedback on their participation and comprehension.

The student’s peers can be useful resources as well. Not only should the student have a sighted lab partner, but they should also have help from their classmates during the lectures. The classmates can explain what is happening during a demonstration, or help the student find the correct place in the textbook or handout quickly. The assistance of a sighted peer is sometimes more beneficial than the minimal experience gained by performing the task unaided. You should determine which skills and experiences are important to the student’s understanding of the lesson material, and avoid spending too much time on adaptations that will not contribute significantly to the student’s education. For example, digital displays can be read by a lab partner without affecting the student’s participation in the experiment. This type of relationship is beneficial to both students, as both can still participate equally in the classroom.

These teaching methods not only make the classroom accessible to the blind or visually impaired student, but they also improve the learning experience for the rest of the students.
3 General Guidelines for Making Adaptations

Adaptations can be applied to activities, items, or environments. Their purpose is to maximize the visually impaired student’s participation in various functions without making drastic alterations. In general, adaptations can: alter the physical environment, change the rules, change the strategy, change the routine, reduce the complexity, provide cues, or offer personal assistance. This section also describes certain general principles that you should keep in mind when making adaptations.

3.1 Principles of Adaptation

The first rule for making adaptations for a blind or visually impaired student is ‘minimization of adaptation’. Adaptation emphasizes the disability of the student. This emphasis creates a gap between the blind or visually impaired student and their peers, which can hinder the student’s social interactions. Another reason for minimizing adaptation is because this simplifies the work for you, the teacher. If adapted materials are significantly different from the original materials, you will have to make special provisions when referencing the material in class. Also, if adaptations are too detailed, they will take too long to develop and will appear cluttered to the student. When designing a complex adaptation, consider the significance of the information compared to the effort involved in utilizing the adaptation.

The second rule for adaptations is the ‘avoidance of adaptation for basic skills’. Every student should be allowed to participate in every part of the classroom experience, which is why adaptations for some students are necessary. However, modifications can easily overcompensate and overlook the blind or visually impaired student’s ability to
perform basic skills. You must also be careful when adapting material because sometimes an adaptation will not portray the information that was intended.

3.2 Adaptations for Visually Impaired Students

When working with a student who has low vision, the goal is to optimize the use of their residual vision. This objective is accomplished differently for every student, depending on the specific condition. Because their vision is limited the student will not be able to collect information rapidly; therefore, less detail is optimal. Too much detail can create a confusing picture.

Increasing useful vision

There are four main considerations that can affect the function of the eye. They are illumination, contrast, size, and the presence of glare.

- **Illumination** - Items that are not well lit are harder to see. The illumination can be improved by changing the intensity or color of the light. These properties can be changed by using different types of bulbs, additional lights or lamps, or by increasing the wattage in existing lights.

- **Glare** - Glare is the reflection of light. This excess light interferes with the ability to focus on one area. A white piece of paper reflects a full spectrum of light, creating a lot of glare. Black paper with lines cut out of it reduces the glare from the rest of the sheet so the person can focus on the line they are reading. Glare can also be reduced by diffusing direct light through various filters.

- **Contrast** - Some color combinations contrast more sharply than others; for instance, it is difficult to see yellow writing on a white paper. To increase the contrast, use very dark blue or black on white boards, or white on black boards. For reading,
yellow filter will increase the contrast of black on white, so yellow sunglasses or a yellow filter can be used.

- **Size** – For many low vision students, size is a considerable problem. There are many ways to increase size. Simple methods include enlarging papers using a copier and obtaining large-print textbooks. Mechanical aids are available as well. These devices include telescopes, microscopes, telemicroscopes, electric-magnifiers, CCTV, and computers with magnification programs. Hand-held magnification devices are particularly useful in the laboratory. In choosing a device, you must consider how easy it will be to use.

**Specific low vision types**

Most adaptations are only useful for certain types of visual impairments. Adaptations that are beneficial to one student may actually limit another student’s useful vision.

- **General vision reduction** – Many students require information to be enlarged to an accessible size, and/or brought closer to them.

- **Distorted vision** – A student may have an area of the eye that has distorted vision. Therefore, information must be placed in a position that student can access it. This may mean that writing on the board is easier to read if it is concentrated around the periphery instead of the center. Always consult the student as to what is best for them.

- **Reduced field vision** – Reduced field vision covers various conditions in which you can see only what is in a certain section of your field of vision. Tunnel vision is the most common form of this condition, in which only the central section is visible. Students with this type of vision will not benefit from images being made larger
because they are unable to view the entire picture at once. The most effective strategy is to place all information close together.

- **Light Sensitive** – Some students with low vision are sensitive to light and will be hindered by excess light. These students will also be excessively affected by glare.

### 3.3 Adaptations for Blind Students

A major component of adaptations for blind students is texture. Texture can be used in a number of different ways. Braille, for example, conveys the most information, but it requires special equipment and an understanding of the system. It is primarily used for documents or labels that require written text. A low-tech method of texturing is simply using different types of materials, such as sandpaper and felt.

If the information is not easily portrayed through words, a common adaptation is raised line drawings. These drawings are often used in geometry, or any subject in which graphs are prevalent. They can be made on heavy-weight paper, plastic, or thin metal sheets, but require special devices to make them. You must be careful when using raised line drawings, however; this is one type of adaptation that is very prone to miscommunicating information.

Audible information can also be used for adaptations, and can be especially useful in a laboratory environment where an experiment is constantly changing and the student needs constant cues. Audible information is also useful for general studies in the form of talking books. While these books are useful as a complement to written text, they are not a replacement, and should not be used exclusively unless no other written material is available. Tape recorders can be used to record lectures and to take notes, which can be referenced at later times.
3.4 RNIB Questions

The Royal National Institute for the Blind, in London, has developed a set of questions designed to assist in the creation of adaptations for blind and visually impaired persons. They highlight the key features that an adapted device should have in order to be used successfully. Many of the questions also pertain to other types of materials, including text and other apparatus and instruments. The questions have been presented here in the most pertinent format for educational use.

30 Questions to Ask Yourself When Designing for the Visually Impaired

Visual information

1) Are printed characters legible and clearly visible?
2) Do the colors contrast enough?
3) Are electronic displays legible and clearly visible?
4) Are status and warning lights clearly visible?
5) Are different status and warning lights distinguishable from each other?
6) Are symbols large enough to be read by visually impaired people?

Tactual information

7) Is the Braille legible? Have you considered:
   • Achieving the correct standard Braille 3D profile.
   • Positioning Braille in uncluttered areas.
8) Is the Braille optimally positioned in its role as labeling?
   • Is it near enough to be identified with the feature for which it serves as a label?
   • Is it far enough from the feature such that it can be read in an uncluttered area?
9) Are the tactual markings distinguishable?

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1 "30 Questions to ask yourself when designing for the visually impaired"; RNIB; April 2000;
http://www.rnib.org.uk/wesupply/products/30q.htm
10) Are the tactual markings optimally positioned in their role as labeling?
   - Is it near enough to be identified with the feature for which it serves as a label?
   - Is it far enough from the feature such that it can be read in an uncluttered area?

11) Can contrasting textures be readily identified?

Instructions

12) Are the instructions available in all appropriate mediums?
   - Large print (A minimum of 14 point Helvetica or Arial font)
   - Good quality Braille
   - Audio tape

Handling

13) Is the device easy to orientate?
   - Can a visually impaired person easily locate the front, back, top, and bottom?

14) Does the device have any sharp edges or rough surfaces?

Controls/Indicators

15) Are the controls easily distinguishable by touch?

16) Are the controls easy to operate?

17) Have you considered the pressure required to operate buttons/controls?
   - Too light a pressure does not give adequate tactual feedback.
   - Too heavy a pressure may reduce tactual sensitivity of a Braille reader's fingers after prolonged use.

Auditory information

18) Are the audible tones readily distinguishable?

19) Is the speech quality suitable?

20) Is the volume range suitable?

Vibratory output

21) Are the vibration patterns emitted from the device readily detectable?

22) Are contrasting vibration signals distinguishable?

Physical dimensions and build

23) Is the device durable enough, given the anticipated everyday wear and tear?
24) Have you considered the weight of the device?

*Cleaning*

25) Is the product easy to clean and maintain?

*Packaging*

26) Does the packaging allow for easy access to the device, its instructions, and its component parts, by the visually impaired person?

*Power supply*

27) Could a visually impaired person replace batteries required for the device?

28) Could a visually impaired person charge batteries required for the device?

29) Are power leads and their respective sockets readily distinguishable and/or clearly labeled?

30) Are main power connections robust?
4 Laboratory Adaptations

There are many skills and tools that are common to any science laboratory, as well as many dangers. Thus safety precautions, skills, and tools should be the first considerations when modifying any experiment.

4.1 Safety Concerns

There are many safety hazards present in any lab. These are present for every student and are not specific to blind or visually impaired students. However, because the blind or visually impaired student cannot identify these hazards readily, special attention needs to be paid to the safety of this student. A sighted partner can assist in identifying safety concerns. All precautions will improve the general safety of the lab.

Chemicals

Proper identification and use of chemicals is one of the greatest safety concerns for all students. The initial step to correct use is to obtain the correct chemical. Therefore, chemicals should always be kept organized in the same place. They should also be labeled in a way accessible to the students in the class, which includes print, enlarged letters, and Braille. A syringe made for measuring chemicals can be very helpful. When pouring the chemical, a funnel can be used to create a larger target area. Also, a conductivity sensor can be used to identify the top of the object, so as not to overfill it.

Glass

Glass apparatus is used in most chemistry experiments and is both fragile and unstable. To make glass objects safely accessible, they should be consistently stored in a secure manner. When in use, the glass objects should be placed in stands or clamps so
they cannot be unintentionally knocked over. For low vision students, contrast can assist in identifying the objects and their size. A piece of black paper placed behind the apparatus will create contrast with surroundings.

**Heat sources**

The obvious danger with heat sources is the possibility for a student to be burned or for the heat source to come in contact with a flammable material. The most common heat sources in a lab are Bunsen burners and matches. For those with low vision, the Bunsen burner can be made safer by identifying the inlet and outlet with contrasting non-flammable paint. Another safety modification for low vision students is the use of wire gauze to identify the position of the flame. Wire gauze will glow brightly where it passes through the flame. The gauze can be held in a clamp attached to a stand or laid on a tripod placed around the Bunsen burner. The tripod configuration also has the added feature of providing extra protection around the burner. Another concern with Bunsen burners is the possibility of the fire going out. The student should be instructed how to listen for the sound of a lit burner and to recognize when it stops. Hot plates are an alternative to Bunsen burners that are more stable. The use of matches can be made safer by using long handled ones or long tapers to keep the student's hand away from the flame.

**Movement**

Many Newtonian physics experiments contain moving objects. A blind or visually impaired student may not be able to ascertain whether there are any obstacles in the eventual path of the object. For instance, a rolling cart's trajectory may lead off an edge or into an object that is fragile. Another example is a balloon or rocket released into
space that cannot be tactually observed. A sighted partner or instructor should check any setup arrangements before an experiment is conducted.

**Power cords and connecting wires**

Power cords are dangerous because they provide an unexpected obstacle for the blind or visually impaired. Cords can trip people, upset machines or other devices, and cause objects to move or fall. To avoid these situations, power cords should be kept out of the way. Some options are to keep the equipment as close as possible to the outlet and the cord gathered and secured in place. If the cord must cover a distance then it can be run along the ceiling or taped down on the floor.

The dangers of electrical devices with connecting wires are the same as those with power cords. Wires should be kept as short as possible, especially because they can complicate the student's mobility around the devices.

**4.2 Skill Modification**

Below is a list of suggestions for modifying basic laboratory skills. Some modifications involve simple devices or are designed for more specific situations, but most are meant to be as general as possible. Many of the modifications, while not necessary for partially sighted students, make laboratory procedures easier, quicker, and safer for all students with visual impairments. Because most of these skills involve minimal adaptation, the student will need to practice in order to perform the skills quickly and effectively.

- **Balances:** Double and single pan manual balances can usually be used without much adaptation, as long as the pointer is able to be touched. The student will need to practice how to read the position of the pointer without moving it.
• **Building circuits:** The identification of components is the most difficult part of this procedure, so the student will most likely need a sighted partner to choose the appropriate resistors, capacitors, transistors, etc. Raised line diagrams can be used to interpret circuit configurations. The students may be able to construct circuits without much assistance by stringing wire between metal pins previously arranged on a board. They should also be able to follow the path of the circuit by touch in order to check their work. They can either install small speakers in addition to or instead of light bulbs, or they can feel the light bulbs as they heat up. If the electrical device is more advanced, involving soldering or preprinted circuit boards, the student will more likely have significant difficulties with the process.

• **Building models:** The student should have little difficulty in constructing models using molecular modeling kits or other modeling systems such as LEGOs. Usually, the model components for such systems have distinctly different shapes. If the pieces are unfamiliar, the student should be allowed to explore a model before building their own, to understand how the components fit together. The use of three-dimensional models can be beneficial to the student’s understanding of certain scientific concepts. It should not be assumed, however, that these models are self-explanatory – the student may not make the connection automatically between the properties of the model and the properties of a real object.

• **Constructing apparatus with basic parts (test tubes, flasks, stands, clamps):** Once the student has identified the necessary apparatus, they should be able to set up an experiment without much assistance. They might need extra time, however,
because much of the positioning cannot be gauged quickly by touch. If a sighted partner is assisting with a complex setup, the student should work on one section of the apparatus. The process may become confusing if the sighted partner moves components around on the lab bench.

- **Estimating units:** Students need to have a clear understanding of the sizes of standard units, so they can choose appropriately sized apparatus. Length is typically a familiar concept to them, but area and volume are more difficult concepts. Full-scale models of such units as cm², cm³, and L should be available for the students to explore and reference.

- **Handling flames (matches, splints, candles):** Some blind or visually impaired students may be able to light matches without any assistance. Alternatively, a partner or assistant teacher can light a long wooden splint or wax taper for them. Once the match or splint is lit, either the student can employ the flame in the experiment, or the partner or assistant teacher can guide the student’s hand to the appropriate place. The student should take part in this procedure whenever possible, instead of always relying on the sighted person. When using a Bunsen burner, the student must learn to check the gas line very carefully to make sure it is attached securely. The match should always be lit before the gas is turned on. It should be possible for the student to position a lit match near the top of the burner, resting a finger lower on the barrel if necessary, and then turn on the gas. The student should be able to hear the sound of the gas igniting. While the burner is lit, the student should be consciously aware of the sound it makes, in case the flame goes out. In a loud classroom, it is important for
the sighted partner to also keep a close watch on the burner, in case the student is unable to hear the sound of the flame. While a burner is lit, the student should learn to only search for objects (particularly the burner itself) by running their hands on the surface of the lab bench, in order to avoid touching or knocking over the hot barrel.

- **Identifying and locating apparatus:** Most apparatus can be easily identified by touch or with limited sight. Once the apparatus is in use, it may become more difficult to identify and locate if it is being heated, is placed inside another object, is full of a substance that could be knocked out, etc. It is therefore important for the apparatus to remain in the same place while in use, so the sighted partner must be conscientious when moving objects around.

- **Identifying containers and labels:** All students should be taught to place containers in specific locations. Blind and visually impaired students should not be taught to rely on the position of a container to identify it, however, as this is only meant to make identification quicker. The student must check the label carefully every time, especially for warning indicators.

- **Identifying gas evolution:** Because most gases are usually invisible, all students should be able to identify the evolution of a gas from solution in an experiment by sound and sometimes by smell. Blind and visually impaired students can also use matches and splints with the rest of the class to identify gases, because usually a whooshing or poofing sound (often loud) accompanies the extinguishing or lighting of the match.
• **Identifying light patterns and paths:** Students with residual sight should be able to participate in experiments regarding the nature of light, especially if a bright light bulb or laser is used. If the contrast is strong enough, the student should be able to see phenomena such as reflection, refraction, and diffraction patterns. If the student cannot adequately perceive light patterns, raised line drawings illustrating the phenomena are the best adaptation for understanding the concepts. An audible light sensor can also help to determine interference patterns, indicate refraction paths, etc.

**Measuring with and reading instruments:**

- **Rulers:** Students should have rulers with tactual markings at various units, and need to practice with them to be able to read them quickly and accurately.

- **Graduated cylinders, beakers, flasks, etc.:** For nontoxic, non-staining liquids, using a finger to measure the depth of the liquid should be safe. Tactual lines or scratches on the inside of the apparatus would be adequate in this case for determining liquid level. It is a good idea, however, to invest in a conductivity device for use with all liquids. The height of the device's electrodes would be determined by laying the electrodes against the outside of the apparatus along the scale, positioning the ends of the electrodes at the proper volume reading, and noting the position of the top of the apparatus on the electrodes. The electrodes would then be placed inside the apparatus, keeping the same positioning relative to the top, and the liquid would be poured in until the sound was heard. This technique can be used with most types of volume measuring apparatus, depending on the length of the electrodes.
• **Meters in general**: If the pointer on the meter can be touched, then the student can learn to read the scale by touch with practice. Often, it might be adequate for the student to feel that the pointer moves a relative distance, while the sighted partner records the actual reading. If the meter is behind plastic or glass, a sighted partner or assistant teacher will have to obtain the reading.

• **Perceiving motion (falling, rolling, flying, etc.):** It is difficult for a student to follow a moving object by touch. In order to collect measurements of horizontal motion, the student should be able to mark the starting and finishing positions. By lightly touching a cart or other object as it is set into motion, the student can get a sense of its initial speed. If the experiment does not involve the object coming to rest by itself, the student can get a sense of instantaneous speeds by stopping the object with their hand. Objects in slow horizontal or vertical motion can be followed by touch in some situations. When studying vertical motion, objects should be dropped onto a surface that will make distinct sounds, such as a thin sheet of metal. If the students are exploring rockets, a long, lightweight string can be tied to the rocket that the student can let run lightly through their hands to convey a sense of speed and direction. If an air track is used, the student should be allowed to experiment with it, pushing the slider with and without air to see how far it travels and how many times it rebounds at the ends of the track. Often, an air track is used to illustrate constant velocity by taking long-exposure photographs of a slider with a blinking light bulb on it. The student can measure between the light bulb images if a pin or other marker is placed in the same position on each one, preferably by a classmate.
• **Spring scales:** Properly modified, spring scales should be relatively easy for the student to read using tactual markings. They can be more difficult to use if the scale is being used to pull an object and the pointer is moving fairly rapidly, or if the scale is being moved by another student.

• **Stopwatches:** The student can use a stopwatch without modification, although they will need a partner to read the output.

• **Thermometers:** Students with residual vision can often use an alcohol thermometer, which is available in several colors. The student would have to try several thermometers to see if any were readable, depending on the color and degree of magnification that the casing provides. Even if students cannot see well enough to read a thermometer, they should learn how to properly place thermometers to illustrate the theory of heat transfer in various substances (beakers of water, distillation apparatus, solids, etc.).

• **Using liquids:** If liquid is in a large bottle, some liquid should be first poured into a smaller container, especially if small, exact volumes are to be used. The smaller container should preferably be wide-mouthed. If a narrower neck must be used, a funnel is very important, particularly if the liquid is caustic. The student should always hold both the bottle and the receiving container. It should be easier for the student to rest the mouth of the bottle on the edge of the container to ensure that both stay properly oriented. If, however, the student tends to let the bottle slip when pouring, then they should adopt the technique of touching the mouth of the bottle to
the edge of the container to orient it, then moving the mouth further over the opening of the container and supporting the bottle entirely with their hand while pouring.

- **Using pendulums:** It would be difficult for a student to continually follow the motion of a pendulum bob by touch. They should still explore the motion as much as possible by: holding a hand at each end of the pendulum’s swing and feeling how it strikes each hand alternately, using their own arm as a pendulum and feeling it strike a partner’s hands, suspending a pendulum from their hand and feeling the amplitude decrease over time (possibly suspending it between their knees while sitting, so they can feel the bob continuing to swing after it stops hitting their knees), and feeling the frequencies of different lengths suspended from their hand. If a device is set up which will emit a sound or click when the pendulum passes through it, the student can participate in most experiments that require the counting of swings or the measuring of frequency. Some experiments might also be feasible using an analog metronome.

- **Using solids:** Students can remove small portions of powdered solids in wide mouthed jars with metal spatulas, which is preferable. If the solid is in a narrow necked jar, it should be poured out carefully into a beaker or onto a piece of paper that can be folded to dispense the solid into another apparatus. The amount can be more easily adjusted this way, and it is more reliable than pouring directly from the bottle. Large solids should not pose problems, although shaking them out onto a piece of paper first is still a good precautionary measure.
4.3 Basic Tool Modification

No Modification

For low vision students the addition of bright colors can be useful in identifying any of the tools listed below.

- **Carts:** Carts are large objects that can be brightly colored so that students with residual vision can follow their motion. Many carts make sound ordinarily as they move which can help the severely visually impaired or blind student identify its position or state of motion.

- **Clamps and stands:** Clamps and stands, as used in chemistry, should be tactually familiar. The student with visual impairment is able to use these without any modification.

- **Cranks:** A crank handle is used in Newtonian physics experiments usually to move objects attached by a string. After the student has explored the apparatus, it can be used without modification. Be certain that you guide the student to understand the connection between the crank, string and object. Severely visually impaired or blind students will not be able to crank and perceive the object's motion at the same time, but can lightly touch the object as someone else cranks as well as taking a turn cranking.
• **Electrical Components** - resistors, capacitors, transistors, integrated circuits, batteries, wires, clips, wire coils: Electrical components do not need to be modified for use by the student. However, many components are color coded, such as resistors, and require identification by sighted students.

• **Funnels**: Funnels can be used to create a greater accuracy when transferring a liquid or solid from one container to another.

• **LEGOs and modeling kits**: Both LEGO and modeling kits require no modification because their components are brightly colored and entirely identifiable tactually.

• **Microphones**: Microphones are audible input devices and can be used easily by students with any level of visual impairment.

• **Pulleys**: Pulleys are often used in a series. Because there are many connections, the student will need to be given enough time to understand how they are all connected. Remember that creating a whole picture from tactually gathered information takes longer.

• **Springs**: Springs are often used in studies of mechanics. The student can obtain a strong understanding of the properties of springs by experimenting with them.

• **Tuning forks**: Tuning forks are audible and tactual devices that give no visual output. The one consideration is their placement in experiments in relation to other objects.
Labeling

• **Beakers, Flasks, Test Tubes, and Graduated Cylinders:** To make these glass objects more accessible to those with low vision they can be marked. The markings can be made with either colored paint or colored tape. To further emphasize the container, placing a black piece of paper behind it can increase the contrast. Tactual marking can be also be added to the container. These can be raised lines at intervals or Braille numbers indicating the level. Since all of the objects are glass, they pose the risk of being dropped or inadvertently knocked over. This risk exists for all students and can be helped by careful placement of containers away from the edges of counters, placement in sturdy stands, and an uncluttered workspace.

• **Bottles (liquids):** Whenever possible, plastic bottles with nozzles should be used. Otherwise, bottles containing liquids should be of a type that does not leak when being poured. Having a lip on the mouth of the bottle usually helps in orienting the bottle to another container for pouring, although some lips cause the bottle to drip.

• **Distance measures:** General distance measures, such as rulers, meter sticks, or tape measures, can be easily adapted. They can have tactual markings made by placing various sizes of pins, etchings, or bumps to demarcate the fundamental units on the scale. For long distances meter wheels are useful because they click audibly with every revolution. Strings with regularly spaced knots can also be used to measure distances. Protractors only need tactual markings. Compasses can be used in
conjunction with adapted rulers to produce the desired radii. Highly contrasting lines or enlarged number markings can aid the low vision student.

- **Gas sources:** In most labs the gas source is located at each lab station. Since there are many configurations of the sources, you will need to make modifications that suit the lab you work in. If there are other nozzles or handles nearby, they should be identified tactually and associated with their particular nozzles by tactually identifying the nozzles as well. When connecting hoses the student should have a tactual measure of the amount that the hose needs to be pushed on.

- **Labeling containers:** Plastic labeling tape printed with Braille and/or tactual markers can be used to label containers. Tactual markers can be used either to label a particular substance or to indicate the type of material or associated safety risk (acid, base, flammable, poison, etc.). Large, distinctly colored warning labels can be used with partially sighted students. Containers should be organized and students should be taught to return them to a specific location, but this does not replace labeling the container itself. If possible, the shape of a particular container should be some indication of the substance inside (screw lid = solid, glass stopper = acid, plastic stopper = non-caustic liquid, etc.)

**Analog dials and labeling**

- **Air pumps:** Air pumps are used when filling balloons or rockets for force experiments. The students with visual impairment need no modification for the use of this device. Some air pumps have analog air pressure meters that can be seen with magnification or read by the lab partner.
• Devices With Digital Readouts: At present the following devices have a digital readout that is inaccessible to students with severe visual impairment. Some companies currently make synthetic speech components, and it is possible that they will be included in other devices in the near future. As with other products, all dials and connections should be labeled in a way accessible to the students in the class. Although the devices’ outputs are inaccessible, the student will be able to use them in a laboratory provided that their partner will read the digital readout.

- Low-volt power source
- Signal generator
- Sound activated timer
- Thermometers
- Stopwatches
- Voltmeter
- Ammeter

• Geiger counters and radioactive sources: The Geiger counter has an audible output. The blind or visually impaired student should be able to independently complete experiments using this apparatus with the exception of reading the numerical output, provided that the dials on the Geiger counter and the radioactive material are labeled.

Tactual or Audible Modifications

• Balances: Manual single or double pan balances with pointers that can be touched (i.e. are not inside a casing) should be used. The pointer should be close enough to the scale to be able to touch both with one finger. Use narrow tactual markings to denote the various angles on the scale, and make sure that the height of the marking makes it either flush with or higher than the pointer. This will help the student to use
the least amount of pressure to feel the pointer, reducing the problem of accidentally moving it from rest or preventing it from coming to rest accurately.

- **Light sources such as flashlights, bulbs, and LEDs:** Bulbs and LEDs are most commonly used in electricity experiments to identify when there is current following through a circuit. This can easily be adapted by adding a sound source. A small speaker, piezo buzzer, or motor will emit a sound when a current is run through them, and like a light, the sound will get stronger with a stronger current. Flashlights that produce a greater amount of light should be used by students with low vision.

**Special Equipment**

- **Circuit diagrams:** Circuit diagrams can be represented as raised line diagrams. Difficult circuits can be very confusing as raised line diagrams. Also, the elements of the circuit will need to have distinct tactual differences in shape to be distinguished.

- **Matches, splints, and tapers:** Always get long handled matches, splints and tapers. This way the student’s hands are away from the flame. Butane gun lighters are another alternative to matches, which keep the flame far from the student’s hands and extinguish automatically.

- **Periodic table:** The periodic table is used frequently in all chemistry classes. It is available in a Braille version.

- **Prisms, mirrors, and lenses:** These objects are for the manipulation of light and its qualities. The objects themselves have no modifications, but their effects can be measured with a light probe. The light probe will beep when it is directed at light. Thus the student can identify where the light beam is before the prism or mirror and
after. Another way to make these more accessible is to produce raised line drawings of phenomena.

- **Syringe**: A syringe that is made for measuring chemicals can be of great use. For a visually impaired student to use such a device it is helpful to put tactual markings on the plunger indicating how much liquid is contained in the device. Tactual markings can be notches with Braille numbers as labels. Once a student learns to use this, it is a safe way to measure and transfer liquids of all kinds.

4.4 **Advanced Tool Modification**

In some cases, more advanced devices and more complicated adaptations can be useful in particular types of experiments. These require more time and/or more funds than simple adaptations. Most of them do not exclude use by sighted students, and in fact sighted students may enjoy using them.

- **Air Tracks**: Air tracks can be very easily adapted for use by students with some residual vision, by using brightly colored sliders and/or sliders with light bulbs attached. Sliders with light bulbs are very common because they are very useful for experiments demonstrating constant and changing velocity and acceleration. It is much more difficult for severely visually impaired and blind students to fully utilize an air track, but they can explore it through touch and gain an understanding of the nearly frictionless surface.

- **Bunsen burners**: Bunsen burners are one of the highest safety risks in a chemical laboratory. Therefore, extra precautions should be taken to prevent accidents. It is
always a good idea to place a tripod around the burner to prevent hands from getting too close. The ring of the tripod also helps the student to locate the flame when heating test tubes or placing other small objects in the flame. If the student has residual sight, a piece of plain wire gauze placed on the tripod will glow bright orange in the flame. The student may need assistance from a sighted person to adjust the flame properly. If the burner has a valve at the bottom for adjusting airflow, the handle should be painted a bright color to make it easy to locate, but even students with residual sight may not be able to see the flame adequately to adjust it themselves. Techniques for lighting burners are described in the "Skills Modification" section, but self-igniting burners are also available. These are triggered by various stimuli including the flow of gas, activation of a motion sensor, or depression of a foot pedal. These can be expensive but they are the safest type of burner, especially because some models turn off automatically after the stimulus stops.

- **Light Sensors:** Any sort of light sensor that is connected to a sound source is useful for severely visually impaired and blind students when performing experiments dealing with light. Light sensors can be used with the super-sensitive switch described in the "New Devices" section. The apparatus can be arranged so that the sound intensity is relative to the amount of light being sensed. The sensor can also be set up such that a sound is produced when a minimum amount of light is sensed, which is useful in illustrating interference patterns with dark and light bands or the diffraction pattern from a grating.
- **Multivibrator**: The multivibrator is described in the "New Devices" section, and is an adaptation for use with liquids. It emits a sound when its electrodes are placed in ionic solutions, and is useful for qualitatively determining the concentration of solutions and for titrating acids and bases when precipitates are formed.

- **Oscilloscopes**: Oscilloscopes cannot be directly adapted, because they are designed specifically for a visual output. Some oscilloscopes may have limited audible outputs, usually for indicating the frequency of the waves. In order to give the student an understanding of the frequency and amplitude of the source wave, a vibrator can be connected. The vibrator has a piston that moves vertically depending on the frequency and amplitude of the source wave. A long piece of fabric elastic stretched between the piston and another stationary object will generate a wave that can be felt, especially if a standing wave is generated.

- **Pendulums**: Pendulums, if possible, can be replaced with analog metronomes, as these are designed to emit clicks with every swing and have adjustable lengths. If the student will be using hanging pendulums, then it may be a good idea to use lightweight wire instead of string to suspend the bob. This will allow the student to touch the pendulum lightly at the top to sense the motion, without affecting the swing of the pendulum too severely. Wire will also keep the bob swinging in the proper plane better than string when set in motion by the student, because it will be difficult for the bob to be displaced sideways.

- **pH Meters**: pH meters are very useful tools in chemistry laboratories, because the paper indicators are based entirely on color changes. Low vision students may be
able to distinguish between very simple red and blue indicators, but the more versatile paper indicators have much more subtle color changes that may be impossible to distinguish for most visually impaired students. On the other hand, electronic pH meters may be easier for visually impaired students to use than paper indicators, and are much more accurate. Some electronic pH meters are available with voice synthesis, but the current models are too inaccurate for use in a laboratory setting, so it is recommended that you use regular electronic pH meters with blind and visually impaired students as well and have a sighted assistant read the output.

- **Raised Line Drawings:** Raised line drawing kits and heat-sensitive paper are infinitely useful in the lab. These products are usually used by the teacher or other adapter for preparing materials for the lab such as diagrams and graphs. During the lab, however, the student can draw their own diagrams of their equipment or other results with a manual kit. Graphing is a very important skill and tool for conveying experimental data, and should be accessible to the student. They can either graph manually with a kit, or they could input their data points into a computer program that produces graphs. The computer graphs can then be printed out and transferred onto heat-sensitive paper that will produce raised line graphs of the student's data. The lab partner's results can also be transferred into raised line drawings, if the results from an experiment are visual (magnetic field lines, free body diagrams, etc.), so that the student can interpret the results themselves.

- **Spring Balances:** Spring balances are easy to adapt to be read by the student, although they require some time investment. Usually, the scale and pointer are
enclosed inside a plastic or metal case. The section of casing above the pointer must be removed. Depending on how deeply the scale is recessed, it may be possible to directly adapt it to be read by touch. More likely, though, the student will not be able to accurately read the original scale, so a tactual scale will have to be etched or added on the side of the casing.

- **Supersensitive Switch**: The supersensitive switch is also described in the "New Devices" section, but it can be used with a number of types of experiments. It has two contacts that can be connected to electrodes, sensors, or other electrical components, and will emit a sound when the circuit is closed. It cannot be used for titrations, however, as it will continue to emit sound when the solution is neutral because it is more sensitive than the multivibrator. A much simpler version of the super-sensitive switch will work with any conductive solution (including tap water), and is described in the "New Devices" section.

- **Timers**: Timers should be relatively simple to adapt. Because the timer already uses a pin to make dots with carbon paper, it can make indentations in the paper tape as well. A piece of plastic with a small depression would be placed under the paper tape so that the pin can press the paper into the depression. The timer cannot simultaneously use carbon paper, as the carbon paper would be deformed as well, but this adaptation is not permanent so the timer can be used for both sighted and visually impaired students.
4.5 New Devices

Multivibrator

A multivibrator is an electronic device that measures the strength of an electrical connection. This model uses both visual and auditory outputs, which helps a visually impaired student participate in the laboratory and understand the concepts behind the experiment.

List of Supplies and Components

1 x Circuit board, approximately 6 x 8 cm
3 x Transistor, BC547B
2 x Resistor, 1 kΩ
2 x Resistor, 10 kΩ
1 x Resistor, 33 kΩ
2 x Capacitor, 100 micro-Farads
2 x LED’s
1 x Small speaker, 8Ω impedance
1 x Female socket, red
1 x Female socket, black
2 x Wire, 6 cm in length
1 x Small box, approximately 7 x 9 x 5 cm (length, width, height)
1 x Soldering iron
1 x Solder, 25 cm in length
1 x Drill with 7mm drill bit

Building Instructions

1) Use the soldering iron to fix the resistors, LED’s, capacitors, and transistors to the circuit board in the manner depicted in Figure 1. Make sure that the transistors are connected in the proper fashion, with the base, collector, and emitter (b, c, & e)
positioned appropriately. Also, be sure that the LED’s are soldered in such a way that they can be bent to reach the same edge of the circuit board.

2) Solder one wire into each point labeled with a capital letter.

3) Drill 2 x 7mm holes into a side of the box where you want the two connector ports to be located.

4) Drill 2 x 7mm holes into a side of the box where the LED’s can reach.

5) Attach female connector ports to the circuit board in the following fashion: red port to A, black port to B.

6) Insert the circuit board into the box, bend the LED’s to protrude from their holes, and fasten the ports through their holes.

7) Cut a hole in the lid of the box large enough for the speaker and affix the speaker to the lid.

8) Attach the speaker to the circuit board using the soldering iron and solder.

9) Close the box.
Implementation Instructions

The multivibrator has a very simple setup. It needs a 9 Volt, direct current power source. The black port can be connected directly to the negative connection. The red port is connected to the experiment, which is in turn connected to the positive connection of the power source. This setup is extremely useful in qualitatively measuring the electric conductivity of a solution.
Supersensitive Switch

A supersensitive switch is an electronic device in which one electrical connection triggers another electrical connection to occur. This device can be used to inform the user with light, motion, or sound, when an electrical connection is made.

List of Supplies and Components

1 x Circuit board, approximately 5 x 7 cm
2 x Transistor, BC547B
1 x Resistor, 200Ω
1 x Small speaker, 8Ω impedance
1 x Female connector port, red
2 x Female connector port, black
3 x Female connector port, blue
6 x Wire, 6 cm in length
1 x Small box with lid, approximately 6 x 8 x 5 cm (length, width, height)
1 x Soldering iron
1 x Solder, 15 cm in length
1 x Drill with 7mm drill bit

Building Instructions

1) Use the soldering iron and solder to fix the resistor and transistors to the circuit board in the manner depicted in Figure 2. Make sure that the transistors are connected in the proper fashion, with the base, collector, and emitter (b, c, & e) positioned appropriately.

2) Solder one wire to each point labeled with a capital letter.

3) Drill 6 x 7mm holes into the sides of the box, in sets of three on opposite sides.
4) Attach female connector ports to the wires connected to the circuit board in the following fashion: red port to A, blue ports to B, C, and D, and black ports to E and F.

5) Insert the circuit board into the box, and fasten the ports through the holes in a fashion similar to the layout in the circuit board diagram.

6) Cut a hole in the lid of the box large enough for the speaker and affix the speaker to the lid.

7) Attach the speaker to the circuit board using the soldering iron and solder.

8) Label the connection ports with the letters used in the circuit diagram.

9) Close the box.

Figure 2: Supersensitive Switch

![Circuit Diagram]

**Implementation Instructions**

To use the supersensitive switch, it must first be attached to a power source. A 4.5 Volt, direct current source should be used, the positive to the red connector (A), and the negative to one of the two black connectors (E or F). Ports B and C are used to connect to the rest of the experiment. When a connection between B and C is made electrically,
the speaker will make a noise. This can be useful for anything from testing electrical connections on electromagnetic experiments to finding chemical solutions that are electrically conductive.

**Simple Conductivity Device**

This device is very simple to construct, but limited in use. When the “electrodes” are placed in contact with a conductive material, the device will emit a noise. The intensity of the noise is qualitatively proportional to the level of conductivity of the material.

**List of Supplies and Components**

- 2 x Wooden pencil, sharpened
- 2 x Wire, 10-12 cm in length
- 1 x Wire, 5 cm in length
- 2 x Small alligator clip
- 1 x Small speaker or piezo-buzzer
- 1 x 9 Volt battery
- 1 x 35mm film canister or similar container (optional)

**Building Instructions**

1) Carefully cut away a section of the wooden pencils, about 8 cm from the eraser (depending on the sizes of the battery and speaker). The 1-2 cm section should expose the graphite center only on one side of the pencil.

2) Tape the two pencils together with the exposed sections facing the same direction.

3) Solder an alligator clip to each long wire. Attach one wire to a terminus of the 9 Volt battery. Attach the other wire to the small speaker or piezo-buzzer.
4) Connect the battery to the speaker with the short wire. The battery may be placed in a container, such as a 35mm film canister, to protect the connections. Cut a hole in the lid for the wires.

5) Tape the battery and the speaker to the pencils, above the exposed sections. Attach an alligator clip to each exposed section. This should create an electrical circuit that is broken between the two pencils.

Implementation Instructions

This device is small and self-contained, and therefore is simple to use. The intensity of the noise emitted by the speaker will be proportional to the amount of electricity conducted through a material. This device can therefore be used to demonstrate the relative conductivities of various substances. Depending on the speaker, the device may emit a sound when placed in tap water, so it would not be an accurate device for indicating neutral solutions. It can, however, be used as a measuring device for the height of liquids, as described in section 4.2 "Skill Modification: Measuring with and reading instruments."

Figure 3: Simple Conductivity Device
5 Specific Experiments

The following experiments are provided in regular laboratory manual format. They are for use with the entire classroom and contain small modifications that make them accessible to the blind or visually impaired student.
5.1 Pendulums

The focus of this experiment is to explore periodic motion through pendulum measurements.

Materials:
- Stand with rods
- String 70cm
- 2 Washers or Nuts of different weights
- Ruler
- Scale with audible output
- Photodetector with electronic counter (optional)¹

Instructions:
- Weigh nuts or washers, record data.
- Attach rod to stand 75 cm above the table level.
- Attach the string so that it is 70 cm long and attach the washer or nut.
- Using the ruler pull the pendulum out to a height of 10 cm and release.
- Measure the period. To count the cycles leave the ruler in place to hear when the pendulum returns. Use an audible stopwatch to count the time it takes for ten cycles. Alternatively, use the electronic counter to count the time for ten cycles.
- Record data.
- Repeat for amplitude of 15 and 20 cm.
- Change fulcrum length, lower rod to 40 cm above the table level, and retie the string at 35 cm long.
- Take data for all three amplitudes.
- Repeat for second nut or washer.

¹ Available from Søren Frederiksen a/s Ølgod, Jutland. Can be connected to an amplifier and loudspeaker to produce audible output.
### Data Collection:

Nut One Weight_______ grams  

Nut Two Weight_______ grams  

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<th>Nut one</th>
<th>Time 10 cycles</th>
<th>Time for one period</th>
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</tr>
<tr>
<td>Amplitude 10 cm</td>
<td></td>
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</tr>
<tr>
<td>Amplitude 15 cm</td>
<td>Time/10</td>
<td></td>
</tr>
<tr>
<td>Amplitude 20 cm</td>
<td>Time/10</td>
<td></td>
</tr>
<tr>
<td>Fulcrum length 35 cm</td>
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<td>Amplitude 10 cm</td>
<td>Time/10</td>
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<table>
<thead>
<tr>
<th>Nut two</th>
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<tbody>
<tr>
<td>Fulcrum length 70 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude 10 cm</td>
<td></td>
<td>Time/10</td>
</tr>
<tr>
<td>Amplitude 15 cm</td>
<td>Time/10</td>
<td></td>
</tr>
<tr>
<td>Amplitude 20 cm</td>
<td>Time/10</td>
<td></td>
</tr>
<tr>
<td>Fulcrum length 35 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude 10 cm</td>
<td>Time/10</td>
<td></td>
</tr>
<tr>
<td>Amplitude 15 cm</td>
<td>Time/10</td>
<td></td>
</tr>
<tr>
<td>Amplitude 20 cm</td>
<td>Time/10</td>
<td></td>
</tr>
</tbody>
</table>
5.2 Evolution of Gases

The reaction of certain metals with other chemicals, such as acids, produces gas that escapes from the solution. Hydrogen, oxygen, and carbon dioxide can be produced in this way. A simple flame test can help to identify these gases.

A. Evolution of Hydrogen

Materials:
- Stand
- Test tube clamp
- Large test tube
- Funnel (optional)
- Hydrochloric acid (HCl)
  (in the range of 2N - 6N)
- Magnesium ribbon
- Matches
- Wooden splints

Instructions:

- Clamp the test tube vertically to the stand.
- Carefully pour 3-4 milliliters of HCl into the test tube, using a funnel if necessary. The test tube should have liquid in it to a depth of about 2 finger widths.
- Drop a piece of magnesium ribbon into the test tube. What do you see in the liquid? What do you hear?
- Wait about a minute for the gas to collect. Light a splint from a match. Place the flame above the mouth of the test tube. What happens?
B. Evolution of Carbon Dioxide

Materials:
- Stand
- Test tube clamp
- Large test tube
- Funnel (optional)
- Hydrochloric acid (HCl),
  (in the range of 2N - 6N)
- Marble chips
- CO₂ indicator (optional)
- Matches
- Wooden splints

Instructions:

- Clamp the test tube vertically to the stand.
- Carefully pour 3-4 milliliters of HCl into the test tube, using a funnel if necessary. The test tube should have liquid in it to a depth of about 2 finger widths. Place 1 drop of CO₂ indicator into the acid, if desired. What color is the liquid?
- Drop a marble chip into the test tube. What do you see in the liquid? What do you hear?
- Wait about a minute for the gas to collect. Light a splint from a match. Place the flame above the mouth of the test tube. What happens?
C. Evolution of Oxygen

Materials:
- Stand
- Test tube clamp
- Large test tube
- Syringe, 10 ml
- 3% Hydrogen peroxide solution
- Potassium Iodide (KI) or Manganese Dioxide (MnO₂)
- Matches
- Wooden splints

Instructions:
- Clamp the test tube vertically to the stand.
- Use the syringe to transfer 3-4 milliliters of hydrogen peroxide solution into the test tube (the test tube should have liquid in it to a depth of about 2 finger widths).
- Put a small amount of KI or MnO₂ into the test tube (just enough to cover the bottom). What do you see in the liquid? What do you hear?
- Wait about a minute for the gas to collect. Light a splint from a match, then blow out the flame gently. The end of the splint should be glowing red. Hold the splint well away from the end, and place the end about 2-3 cm inside the test tube. What happens? If nothing happens, try placing a lit splint above the mouth of the test tube. What happens?
5.3 Distillation of Salt Water

The focus of this experiment is to discover the properties of distillation, boiling, and condensation.

Materials:

- Laboratory Stand
- Clamp
- 2 Test tubes
- Thermometer
- Right-angled glass tube
- Two-holed Rubber Stopper
- 2 Beakers, 250 mL
- Graduated cylinder, 100 mL
- Tripod
- Wire Gauze
- Water
- Salt
- Multivibrator (optional)

Instructions:

- In one of the beakers, add about 100 mL of water, add approximately 2 grams of salt, and stir. Place the electrodes of the multivibrator (if available) in the salt solution, and take note of the intensity of the sound.
- Once stirred, put approximately half of the salt water into one of the test tubes.
- Set up the apparatus as shown. Clamp the test tube with the salt water to the laboratory stand. Place the beaker with cold, fresh water onto the tripod, using the wire gauze to balance the beaker on top.
- Light the Bunsen burner. Allow the water to heat to a boil. After a few moments, there should be water collecting in the second test tube.
• Once approximately half of the water has gone from one test tube to the other, turn off the Bunsen burner.
• Test the water in the distilling and collecting tubes with the multivibrator. Compare these sounds to the sound of the original salt solution.

**Data Collection:**

Taste the salt water still in the beaker. How salty is it? ___________________________

Place the bottom of the first test tube into cold water. Once cooled enough to touch, taste the water in the test tube. How does the saltiness relate to the water in the beaker?

________________________

Taste the water in the second test tube. How does the saltiness relate to the water in the beaker? __________________________

Is the sound of the multivibrator in the remaining salt solution louder, softer, or the same as in the original solution? ________________

Is the sound of the multivibrator in the distilled water louder, softer, or the same as in the original solution? ________________ Did you expect to hear a sound? Why?

________________________

What conclusions can you make from these observations? __________________________

________________________

________________________

________________________
5.4 Conductivity of Acids

The focus of this experiment is to discover which acids are conductive and which acids are not.

Materials:
- Low voltage power source
- Multivibrator
- 3 Electrical cords
- 2 Alligator clips
- Electrode beaker
- Graduated cylinder, 100 mL
- Hydrochloric Acid, HCl, 1M
- Sulfuric Acid, H₂SO₄, 1M
- Acetic Acid, 1M
- Citric Acid, 1M
- Oxalic Acid, 1M

Instructions:
- Attach the power source’s positive direct current connection to an electrode in the electrode beaker using an electrical cord and an alligator clip.
- Attach the power source’s negative direct current connection to the negative connection of the multi-vibrator using an electrical cord.
- Attach the positive multi-vibrator connection to the unoccupied electrode in the electrode beaker.
- Measure out 25 mL of hydrochloric acid in the graduated cylinder, and pour into the electrode beaker.
- Turn on the low voltage power source to 6 Volts.
- After making observations, turn off the power source, properly dispose of the hydrochloric acid, rinse the electrode beaker with distilled water, and repeat, using sulfuric acid, acetic acid, citric acid, and oxalic acid.
Data Collection:

For each acid, did you hear a sound from the multi-vibrator? If so, how loud was it?

<table>
<thead>
<tr>
<th>HCl</th>
<th>H₂SO₄</th>
<th>Acetic Acid</th>
<th>Citric Acid</th>
<th>Oxalic Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How is electricity conducted through the acid? Why do some acids conduct better than others do?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
5.5 Conversion of Energy

Electrical energy can be converted into heat energy.

Materials:
- Thermometer
- Beaker with lid and heating element
- Water
- Ammeter
- Voltmeter
- Power source
- Switch
- Stopwatch

Instructions:
- Fill the beaker with 100g of water.
- Construct a circuit connecting the power source to the switch to the beaker’s electrodes to the ammeter in series. Connect the voltmeter to the ammeter and the switch in parallel with the beaker.
- Place the thermometer through the lid of the beaker into the water and read the initial temperature. Place your hand(s) around the beaker before the temperature is read.
- Set the power source to 5 volts. Close the switch for 5 minutes. Keep your hand(s) on the beaker during this time.
- Write down the reading on the ammeter during the warming period in the chart below.
- Write the final temperature after the 5 minutes have passed in the chart below.
- Did you feel any temperature change?
- Calculate the number of joules of energy absorbed by the water and the joules of energy that the power source produced.
- Repeat the experiment with 10, 20, and 30 volts. If the beaker becomes too hot for you, let go – you only need to record whether you could feel a temperature difference.
Data Collection:

<table>
<thead>
<tr>
<th>Energy Absorbed</th>
<th>Volume of water in kg</th>
<th>Temperature change °C</th>
<th>Energy in J</th>
</tr>
</thead>
<tbody>
<tr>
<td>E (J)</td>
<td>0.001 * 100g</td>
<td>10°C</td>
<td></td>
</tr>
<tr>
<td>E (J)</td>
<td>0.001 * 100g</td>
<td>20°C</td>
<td></td>
</tr>
<tr>
<td>E (J)</td>
<td>0.001 * 100g</td>
<td>30°C</td>
<td></td>
</tr>
<tr>
<td>E (J)</td>
<td>0.001 * 100g</td>
<td>40°C</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Produced</th>
<th>Voltage * Amps * Time 5s = Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E (J)</td>
<td>10 * 5V * A * 5 * 60s =</td>
</tr>
<tr>
<td>E (J)</td>
<td>10 * 10V * A * 5 * 60s =</td>
</tr>
<tr>
<td>E (J)</td>
<td>10 * 20V * A * 5 * 60s =</td>
</tr>
<tr>
<td>E (J)</td>
<td>10 * 30V * A * 5 * 60s =</td>
</tr>
</tbody>
</table>
5.6 Wave Generation

The focus of this experiment is to explore waves and resonance frequencies.

Materials:
- Sound tube with speaker and microphone
- Signal generator with tactual labels
- Oscilloscope with tactual labels
- Connecting wires

![Diagram of Sound Tube Setup](image)

Instructions:
- Connect the signal generator to the speaker in the sound tube.
- Connect the oscilloscope to the microphone in the sound tube.
- Turn the signal generator to 2000 hertz and listen to the noise given by the sound tube.
- Extend the sound tube until the noise reaches a maximum level.
- Record the length of the tube at this point.
- Students with sight can note the change in wave pattern on the oscilloscope.
- Continue to extend until the noise reaches another maximum.
- Record the length of the tube at this point.
- Repeat for the length of the tube.
- Change the frequency to 3000 Hz and repeat the process. Then change to 4000 Hz and repeat the process.
Data Collection:

<table>
<thead>
<tr>
<th>2000 Hertz</th>
<th>3000 Hertz</th>
<th>4000 Hertz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of tube:</td>
<td>Difference of lengths</td>
<td>Length of tube:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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6 Resource List

Organizations for the Blind and Visually Impaired

Closing the Gap
Specializes in use of technology for those with disabilities.
www.closingthegap.com

Comprehensive company listings for producers of adaptive equipment
http://www.hicom.net/~oedipus/blind.html#alpha/
http://www.nyise.org/speech/vendors.htm
www.abledata.com

Databases for general blindness and visual impairment sites
www.trace.wisc.edu
http://edtech.sandi.net/epd/VIResources.html
http://www.rdcbraille.com/webdis.html

Emerging technology sites
http://www.ece.udel.edu/InfoAccess/
http://www.touchgraphics.com/

Remedia Publications
www.rempub.com
Provide teaching materials for blind and visually impaired students, as well as teacher
information and idea exchange

Resources for Parents and Teachers of Blind Kids
Members.home.net//ddays/blindkids.html
Provides links to many sites with information or materials for education of blind and
visually impaired students.

Science and Experimental Resources

Barrier Free Education
http://rush.arch.gatech.edu/index.html
Offers complete laboratory experiments modified for various disabilities, as well as
general teaching suggestions and information.

CAST: Center for Applied Special Technology
http://www.cast.org/
Provides guidelines for teaching, tools, and further resources.
Disability Books
http://www.manasota.com/books/
Source of literature about various disabilities and assistive technologies, as well as audio books.

DO-IT Program, University of Washington
http://www.washington.edu/doit/
Offers resources and presentation materials for K-12, science, and mathematics teachers, as well as suggestions regarding the use of technology in the classroom and related links to other web sites.

EASI : Equal Access to Software and Information
http://www.rit.edu/~easi/index.htm
Gives explanations of common tactile graphics and lab equipment, as well as suggestions for teaching math.

Inclusion in Science Education for Students with Disabilities:
http://www.as.wvu.edu/~scidis/sitemap.html
Suggests strategies, organizations, resources, books, and videos about a variety of disabilities.

National Center to Improve Practice in Special Education through Technology, Media and Materials (NCIP) – Spotlight on Voice Recognition
http://www2.edc.org/NCIP/vr/toc.html
A newsgroup regarding voice recognition technology.

The Science Access Project (SAP) University of Oregon
http://dots.physics.orst.edu/
Offers downloadable scientific tool software with audio output, such as graphing calculators, for the computer.

Science and Disability Web Sites
http://people.delphi.com/LUNNEY/RELSITES.HTM
Consists of a list of web sites that contain information regarding disabilities and science (several of the links on this site are outdated). Many of the sites below are also listed on this site.

Science Education for Students with Disabilities
http://www.as.wvu.edu/~scidis/organizations/sepd_main.html
An online newsletter about science education.
Danish Organizations for the Blind and Visually Impaired

The Institute for the Blind
Rymarksvej 1
DK-2900 Hellerup
Tel +45 39 45 25 45,
ibos@ibos.dk
www.ibos.dk

Refsnæsskolen
Kystvejen 112
DK-4400 Kalundborg
Tel +45 59 57 01 00

Synskonsulenternes Samråd

Individual Contacts

Bendt Nygaard Jensen
Dorte Silver
Videncenter for Synshandicap
Rymarksvej 1
DK-2900 Hellerup
Tel +45 39 46 01 01
Fax +45 39 61 94 14

Hans Nørgaard
Syencentralen
Institut for Synshæmmede
Kuskevej 3
DK-4760 Vordingborg
Tel +45 53 77 33 33
Fax +45 53 77 39 09

Eric Brown
Poul Gaardhøje
Lindebjergskolen
Store Valbyvej 248 B
Gundsølille
DK-4000 Roskilde

Bendt Gjfler
Lindebjergskolen
Nygårdsvej 62
DK-4700 Næstved
Conclusions

Although science is one of the more difficult subjects to teach to blind and visually impaired students, these students can participate fully in a class or laboratory. It is clearly beneficial to both the teacher and the students to include the blind or visually impaired student in all class activities. Laboratory experiments are almost always performed in pairs, so the blind or visually impaired student will not be singled out by having a sighted peer to assist them. Some adaptations are required to make the materials and experiments more understandable or safer, but neither the curriculum nor classroom needs to be changed drastically. Most teachers and experts prefer to use the existing framework and develop innovative ways of including all students.

Laboratories can be complicated environments with unfamiliar equipment and procedures for all students. By identifying common, basic tools and skills that are useful on a general basis, the task of adaptation becomes more reasonable. These tools and skills often require only minimal alteration in appearance or use to enable the blind or visually impaired student to utilize them. These adaptations can be applied to numerous subjects and experiments. Not only does this broad application reduce the number of adaptations that need to be developed, but also simplifies the student’s experience in the laboratory.

In some situations, a technologically advanced device may be necessary or desirable for adapting certain types of experiments. Various useful electronic or computerized devices are commercially available from companies that supply products for disabled persons. Devices have also been designed by non-commercial sources specifically for use in certain experiments, when a need has been identified. These devices are
sometimes necessary in order for blind or visually impaired students to perform a particular task. If the devices are not available, however, these tasks can be performed by a sighted partner without significantly diminishing the value of the experiment for the blind or visually impaired student. For instance, devices that require a computer for non-visual output are often unusable in the classroom. In the near future, technology for speech synthesis will probably enable self-contained laboratory instruments to give accurate, timely audible output.

Considerable effort has been put into adapting science and other materials for blind and visually impaired students, and many organizations offer relevant information in the public domain. This experience and advice is not disseminated in an organized fashion, unfortunately. Since teachers often have limited time for producing classroom adaptations, they do not have much time to browse for suggestions or to develop their own adaptations. In addition, teachers often do not have the opportunity to share their experiences and solutions with other teachers who are beginning the process of adapting a classroom. This teacher's manual is designed to be a compilation of the most universal adaptations, as well as a directory of primary sources of information beyond the scope of the general recommendations.

To a large extent, suggestions that are broad in their applications are typically the most constructive. Thus, instead of producing an entire laboratory manual with new experiments, fundamental adaptations are described with examples of their inclusion in existing experiments. In Denmark this format is particularly important, because without a standardized curriculum, teachers have the freedom to incorporate unique elements into their classes which are not shared by other schools. A manual could not cover all of the
subjects and all of the experiments used in all classrooms. Teachers are also more willing to adapt the experiments that already have a place in their curriculum, rather than trying to find appropriate places for new experiments. By focusing on fundamental adaptations, the applications of this manual are less limited.

The principle of inclusion within the educational setting implies that all students should be allowed to participate in all aspects of their class, regardless of the difficulties involved with certain subjects. Adapting the classroom to achieve this goal is a rewarding task. Not only are all students guaranteed the same level of education, but also the quality of instruction is often improved by careful attention to details and a new perspective on the teaching technique. Every effort should therefore be made to assist in the process of adaptation for blind and visually impaired students.
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Damgaard, Bo; Lütken, Hans; Krog, Marianne; Sønderup, Anette; Thorsen, Peter Anker; Prisma Fysik og Kemi 7; Forlag Malling Beck; Albertslund, Denmark; 1999.

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11. Appendices – Table of Contents

Appendix A – United States Interviews

Questions for Interview Guide, United States
Contact: Keefe Bangert
Contact: David Banigan-White and Kathryn Summ
Contact: Kim Charleston
Contact: Cheryl Dougherty
Contact: Michael Gorse
Contact: Lenore Martin
Contact: Maggie Terrio Lawler

Appendix B – Denmark Interviews and Observations

Questions for interview guide, Denmark
Contact: Klavs Bisgaard
Contact: Kristina Eskelund Nielsen
Contact: Bent Gufler
Contact: Hans Nørgaard
Observation (Contact: Poul Gaarhøje)
Observation (Contact: Eric Brown)

Appendix C – Available Product List
Appendix A

Questions for Interview Guide, United States

Name, Subjects taught, number of years teaching?

What are your methods of teaching (i.e. how much homework, project work, in-class work, lectures, handouts)?

Have you ever had a visually impaired child in your classroom?

Do you know where you can find resources or information to aid in teaching a visually impaired student?

What are the obstacles you have come across?

Have you come up with any decent solutions to these obstacles?

Have you noticed a different learning style with visually impaired students?

Have you needed to change your teaching methods or curriculum, for a visually impaired student?

Did you have a teaching assistant in the classroom to help with the learning process of the visually impaired student?

Did you have any special products in the classroom to help with the learning process of the visually impaired student?

Are you aware of any disability legislature surrounding the education of visually impaired people?

Did you need to change anything in the classroom to conform to any sort of regulations set forth for the education of visually impaired people?

What is your opinion on computer simulations of some experiments?

Are there science materials readily available?
**Contact: Keefe Bangert**  
Position: Teacher of the Visually Impaired, Worcester School District  
Organization: South High School, Worcester, MA  
Phone: 508-799-3341  
Personal Interview  
Date of Interview: 17 Feb, 2000  
Interviewed by: Matthew Dion, Karen Hoffman, Amy Matter

**BACKGROUND**

Keefe Bangert started his career in 1992, working summers at Perkins as a program aide. During these summers he taught daily living skills. In 1996, Mr. Bangert earned his Master's degree from Boston College in the fields of elementary and vision education. Mr. Bangert then went on to work at Perkins full time, teaching history, Braille, and functional reading. During this time, he also accompanied a Perkins student to a local high school, where the student was taking classes. After a semester at Perkins, Mr. Bangert decided that he would rather work in public schools. In September of 1997, Mr. Bangert accepted a position in the Worcester School System as a Teacher of Visually Impaired (VI) Students. His current students include a few elementary school children, and one student who is in the total service life skills program. Mr. Bangert works with both totally blind and borderline legally blind students.

**OBSTACLES**

Mr. Bangert stated that the largest hurdle to overcome for a VI student is the concreteness of being blind, and the abstractness of sight. As much as 90% of what we learn is through vision. If a person is blind, they do not get that 90%. A sighted person can look at a table, for example, and know it is a table. A blind person would need to examine the object thoroughly to come to the same conclusion. If the blind person just felt the table top, he/she would not know if four legs on the corners supported it, a center post, chains from the ceiling, or nothing at all. Mr. Bangert stressed that in the case of a blind individual, a great deal of time and trial and error is needed to come to a conclusion a sighted person can make in an instant.

Two of the hardest things to teach a VI student are the sciences and maps. The sciences are difficult mainly because they are abstract, but also because the course material includes many diagrams and models to represent things. Maps are difficult because of the very nature of maps: they are a visual representation of an area.

The most typical way to adapt a map is through raising the lines. Mr. Bangert cautioned that this is not always the best way of adapting things however. Raising something does not give as much information as we think it does. A raised square, for example, does not convey the idea of area or shape. It will more often than not be perceived as arbitrary lines going off in different directions.
Another problem is teaching a VI student social skills. An example of this is sarcasm. Sarcasm relies heavily on facial expression. This poses a serious problem for a person who can’t see the person’s face. Inappropriate behavior is also difficult to deal with. A VI person cannot see that they are being ignored or snickered at. They must be told directly what is right and wrong.

An additional obstacle is that adults are not ‘cool’. The last thing a VI child or teenager wants to do is to have an adult hanging around them all the time. This poses a problem to the vision teacher, because they need to balance between trying to stay on the student’s good side, while making sure they learn what they need to learn.

Mr. Bangert stated that the legislative structure makes paperwork complicated and constant.

APPROACH

Mr. Bangert advocates as much inclusion as possible. The VI student studies the same material and follows the same curriculum as sighted students. Mr. Bangert is a support to the teacher, being in class if needed, and modifying the media used to teach. The most important ideas to keep in mind while modifying the media are tactile differences, less attention to detail, and concrete ideas. Tactile differences can come in the form of different raised surfaces, such as puff paint, glue, and felt. Mr. Bangert stated that recycling centers are great for finding supplies to create tactile differences.

As far as low vision adaptations, contrast is important. Having something black on white is much more effective than say, blue on green.

Another key factor in the adaptation process is the relationship between the teacher of VI students and the general education teacher. The vision teacher needs to come across as a resource and helper, not as an added burden. A general education teacher should be able to come to the vision teacher for help if they are feeling overwhelmed. Mr. Bangert has a checklist used to train the teachers to deal with a VI student. This checklist includes explaining drawings, saying what is being written on the board, and calling names when a student has his/her hand raised. There is also the issue of the teacher’s curriculum. The vision specialist is not supposed to make judgments on the curriculum, but Mr. Bangert thinks that offering an alternative plan usually works better than simply disagreeing with the teacher.

Mr. Bangert thinks that having disabled students integrated in public schools helps to give the public an understanding of disabilities and a certain level of comfort that would not be otherwise reached. A sighted student needs to learn what to do around a VI student to help them out. In a lab, the VI student’s partner needs to explain what is going on and incorporate the VI student as much as possible. As far as other areas, sighted
students need to learn how to describe things and places, set up meeting times and places, how to give directions using sounds, and what not to help with.

Mr. Bangert does not have any students who justify the purchase of a computer.

RESIDENTIAL SCHOOLS

Mr. Bangert has had the opportunity to work in both residential and public schools. Mr. Bangert believes that residential schools are needed because some students cannot attend public schools and need the one-on-one education a residential school can supply. Residential schools also have a wealth of knowledge and can deal with multiple handicaps.

Mr. Bangert also has issues with the social implications that residential schools have. People with disabilities need to learn how to cope with society, especially the area in which they live. Peers with inappropriate social behavior surround them, and it is difficult to teach a disabled person that their behavior is not acceptable when everyone else is doing it.

ADDITIONAL INFORMATION

- If a vision teacher only has an elementary education degree, they are only allowed to work with grades 1-6. Mr. Bangert has a Masters in vision education, and therefore is authorized to work with grades K-12.
- Lions Clubs are great sources for funding.
- Apples are better than PC's for VI students. Apples have speech recognition incorporated into the system, and have fewer glitches.

If this project were taking place in America, Mr. Bangert would have to protest. The law says that trained professionals should be developing this area.
BACKGROUND

Both Mr. Banigan-White and Ms. Summ are vision specialists working for the state of Connecticut. Neither has a scientific background, although both have worked extensively with visually impaired and blind students. Ms. Summ has also taught visually impaired and blind students in Sweden for several months.

RECOMMENDATIONS

The regular curriculum does not have to be modified for the inclusion of a visually impaired or blind student. Certain modifications of the teaching style and of materials used in class are required, though. When possible, topics and examples that are relevant to daily experiences of the student should be chosen. One-on-one aides are immensely useful in the classroom to facilitate the adaptation of material, but peers should also be included in the process. In labs, particularly, peers should be used as partners instead of adult aides.

In regards to adapting visual aid materials, there are two options: seek out preexisting material or construct new adaptations. There seems to be a significant amount of technological and scientific material available for the blind and visually impaired, especially in terms of textbooks and diagrams. Raised line drawings are the most common adaptation of visual materials, but the real object is unquestionably preferred whenever it is obtainable.

Visually impaired and blind students have really enjoyed science, despite the difficulty in teaching this subject. They rarely seem frustrated by the limitations of laboratory work. For chemistry, molecular modeling kits are very useful tactile models. Neither specialist has had much experience with computer simulations of experiments, so they were not able to offer an opinion as to their usefulness in teaching science.
The Talking Book Library is structured much the same as a regular public library, with the same genres of material. Therefore, the Library has a very limited selection of technical references. Often, these references are not up-to-date as well. The Library would not be an appropriate resource for students studying science or technology.
BACKGROUND

Cheryl Dougherty has been employed as a teacher of the visually impaired (VI) for 26 years in various schools in Worcester. Her main student is a sophomore named Lindsey. She also assists other VI students with other disabilities.

OBSTACLES

Ms. Dougherty stated that the ease or complexity of the program depends on the styles of the general education teachers involved with the VI student. The regular teacher needs to slow down, say everything that is written on the board, and be very organized. The teacher needs to lessons prepared a week in advance, to give Ms. Dougherty and her assistant time to prepare the materials needed. The attitude of the teacher can play a big role as well. The teacher may be fearful or unnerved of teaching a VI student. They may also be over-conscientious, making the student feel self-conscious. There may also be a problem of having Ms. Dougherty in the classroom. Some teachers do not like to have another teacher in the classroom, as it makes them feel like they are being critiqued.

Another obstacle may be the courses being taught. Geometry is a big problem for VI students. Being a very abstract subject, VI students in general have a difficult time comprehending the concepts. The course material also makes for a lot of preparation work for Ms. Dougherty.

The way material is presented nowadays has also created more preparation work for Ms. Dougherty than in the past. The classical lecture has taken a seat in most classes for a more visual aid based, hands on approach.

A few more problems deal with computers. Ms. Dougherty would like to see Worcester’s program receive more services for computer training for VI students. Currently there is no refreshable Braille display on the computers, which means that a VI user needs a speech program, which is currently unavailable, or a sighted guide. Ms. Dougherty would like to see VI students gain more independence in the field of computers.
APPROACH

The main goal of the program is to develop the VI student's confidence. In Worcester, VI services is a very individualized program. The amount and type of guidance and support needed is tailored to each VI student's needs. The amount of support is also dependent on the resources of the school's education board. Worcester's board of education has been very supportive.

Totally blind students require the most work in terms of getting material translated into Braille and explaining what is on the board. This is why a teacher can request to have Ms. Dougherty in the classroom as an assistant.

Most classroom material comes from the American Printing House. Ms. Dougherty prefers Braille books to talking books because talking books are not interactive, tend to be very dry, and do not explain diagrams too well.

Mr. Dougherty stated that Federal Law 94-142, IDEA, and the ADA all directly affect teachers and assistants of the VI.

CASE: LINDSEY

Ms. Dougherty often referred to her primary VI student, Lindsey. Lindsey is taking many honors courses, including Spanish III, English, and Geometry. Ms. Dougherty describes Lindsey as very intelligent, conscientious, honest, and organized.

Of particular interest was Lindsey's experience with Biology. She finds the course material less of a challenge than others, partly due to the large amount of memorization, and lower amounts of abstract thinking involved. In labs, Lindsey is paired up with a sighted partner. The sighted partner performs the experiment, and Lindsey takes notes. Lindsey's partner also explains diagrams and chart to her in class.

In general, Lindsey takes notes on a Braille & Speak, although not for Spanish or Geometry, as they require different codes the Braille & Speak cannot handle. Lindsey typically gets longer time for tests, and has Ms. Dougherty help her with charts and formulas written on the test. Lindsey's peers do not seem to think this situation is unfair, and do not complain.

Along with regular classwork, Lindsey needs to learn many other things from Ms. Dougherty, such as social skills and independence. Lindsey gets class credit for the time spent with Ms. Dougherty.
ADDITIONAL INFORMATION

- Computer simulations of experiments could be helpful
- Two good contacts regarding science experiments are Purdue University, and the Texas School for the Blind
- When a VI student goes to college, he/she
  - Needs to depend a lot more on state programs
  - Must purchase more equipment for home use
- Must find textbooks on their own
Contact: Michael Gorse  
Position: WPI student  
Personal Interview  
Date of Interview: 7 Feb 2000  
Interviewed by: Matthew Dion, Karen Hoffman, and Amy Matter  

BACKGROUND  

Michael Gorse is a junior Computer Science major at Worcester Polytechnic Institute (WPI). Mr. Gorse went to school in Dedham, MA until 6th grade, when he moved to Phoenix, AZ. During high school Mr. Gorse moved back to Dedham, MA. He has been totally blind his entire life.  

SCHOOL EXPERIENCE  

When Mr. Gorse went to school in Dedham, he was the only blind student in his class. He was in a heterogeneous classroom, where he learned with the rest of the students. During school, Mr. Gorse also met with a vision specialist, who taught him how to read Braille and use computers. This vision specialist also taught teachers different techniques on how to include Mr. Gorse in the classroom. Mr. Gorse also met with a building instructor after school once or twice a week. The purpose of this instructor was to learn life functions, including how to use a cane and navigate both in and out of school.  

When Mr. Gorse moved to Phoenix, he noted that the school system was much larger and had many other students with disabilities. He also found that the Phoenix school system was more organized in their approach towards disability programs, and had many more procedures than the Dedham school system.  

In Mr. Gorse’s first year at WPI, he took two Physics classes with labs. The professor for the first class, Mechanical Physics, exempted Mr. Gorse from all lab experiments, as they were only worth 5% of the total grade. Mr. Gorse participated in the experiments for the second class, Electricity and Magnetism. There were two experiments over the course of the term. For both experiments, Mr. Gorse’s sighted partner performed the experiment.  

Mr. Gorse could not remember any science experiments from high school.  

ADDITIONAL INFORMATION  

Mr. Gorse mentioned a visually impaired student’s online bulletin board that he was part of. He is posting a message asking if anyone else has any insight regarding the modification of physics or chemistry experiments.  

There was mention of a Tactile Graphics Kit, possibly made by American Printing House. This device can be used for raising a picture on a page so a visually impaired person can make use of it.
Contact: Lenore Martin  
Position: Teacher of the Visually Impaired, Worcester School District  
School: Forestgrove Jr. High, Worcester, MA  
Phone: 508-799-3420  
Personal Interview  
Date of Interview: 14 Feb, 2000  
Interviewed by: Matthew Dion, Karen Hoffman, and Amy Matter

BACKGROUND

Lenore Martin started out as a kindergarten teacher for 3 years. She then started a moderate special needs masters program. Before the program was completed, she found a job as a teacher of the visually impaired (VI). Ms. Martin then completed the masters program in vision at Boston College. She has been a teacher of the VI for 11 years.

OBSTACLES

- Every case is different. There are no common solutions.
- General education teachers cannot devote enough time to a VI student.
- General education teachers get a profile of the VI student, but too often it is not read or forgotten.
- Science and maps are the hardest topics to teach to a VI student.
- Ms. Martin has little time to develop classroom materials for VI students.
- Social skills and socialization are very difficult for a VI student, and very difficult to teach as well.
- 80% of all learning is through vision. A VI student must compensate.
- VI children tend to have lower dexterity and fine motor skills.
- Often a VI student has other mental or physical issues to contend with.

GENERALIZATIONS

- A VI student does not learn as much as a sighted student.
- VI students are very disorganized.

APPROACH

The first step in any classroom environment is to perform a functional visual evaluation. This determines where the VI student should sit for maximum socialization, learning, and comfort. Then the visual impairment teacher will meet with the general education teacher and go over proper teaching techniques, including saying everything written on the board. If the teacher needs cues in the classroom, Ms. Martin will be in the classroom advising the teacher and helping the VI student. One thing Ms. Martin touched on is that
she must always remember that she is a guest in the classroom, and should not critique the general education teacher at all.

As far as adaptations go, Ms. Martin stressed that things should be kept as simple as they can be. They must also not make the VI student stand out, as that would be detrimental to the student’s social progress.

Ms. Martin also spoke of different technologies available. A Braille & Speak can be very useful for a VI student. She also talked of computers. For mildly VI students, a simple fix such as a different input device and a larger mouse cursor is all that is needed. Mostly all VI students can use a computer with the help of a sighted facilitator who does most or all of the input. Ms. Martin also spoke of computer programs that exist for VI children, however could not think of any in particular.

ADDITIONAL INFORMATION

- Special Education Technology meeting meets at Worcester Polytechnic Institute.
- Nystagmus – rapid fluttering of the eye due to an inability to focus. Most legally blind people have it. There is no cure.
- At schools for the blind, mobility education is preferred over academic education, since most students are severely handicapped.
Contact: Maggie Terrio Lawler  
Position: Head of Special Education Services, Worcester School District  
Phone: 508-799-3056  
Personal Interview  
Date of Interview: 11 Feb 2000  
Interviewed by: Matthew Dion, Karen Hoffman

BACKGROUND

Maggie Lawler has had 20 years of experience in the field of special education, including 10 years in Worcester, MA, 6 on Cape Cod, and 4 in various programs in Southern Massachusetts.

INITIAL ENTRANCE

In the first three years of a visually impaired (VI) person’s life, early diagnosis and intervention takes place. Perkins outreach program reaches the child at his/her home as part of early intervention. After an eye exam is performed, a meeting is held to arrange the child’s education plans. This meeting typically takes place around the child’s third birthday. Also around this time, the child will receive a mobility evaluation, testing for special and body awareness. If the child is partially sighted, a functional visual evaluation is performed, testing to see how he/she uses residual eyesight in their surroundings. Also, an ophthalmologist or low vision specialist will review any available technology and make suggestions for any appropriate equipment.

GOALS OF PROGRAM

- Create a “least restrictive environment”
- Totally immerse the student in classroom, recess, and lunchroom activities
- Develop organizational skills
- Provide interaction with real people
- Prepare students for real jobs
- Use non-obtrusive organization and adaptations

WORCESTER’S APPROACH

Ms. Lawler stressed that there is no universal plan. Each student is different, and therefore requires a different approach. If at all possible, the student should go to the local school. This promotes friendships and acquaintances with people in the child’s neighborhood.

As far as human resources, Ms. Lawler stated that a trans-disciplinary team, consisting of occupational, physical, speech, and language therapists and vision specialists, analyzes the entire classroom environment, looking at the arrangement of furniture, the child’s coordination skills, etc. to assure a proper learning environment for the VI student. There
is also a Braille transcription staff Ms. Lawler deemed “excellent”. There are also full time vision specialists, who work as a teacher’s assistant in the classroom. These vision specialists work on modifying behaviors to help VI students to fit in with their peers. As the student grows, the vision specialist gradually lets go until their main task is to provide materials for the student.

Ms. Lawler also commented on typical classroom practices. Teachers are trained not to lower the standards for VI students. This gives the student a false idea of where they are at in their studies. The teachers are also trained that the student is their student, not the vision specialist’s. There is also extensive training regarding teaching techniques.

Materials used in the classroom are modified only as a last resort. The idea is to make the VI student’s material identical to the other student’s. This makes the student fit in better with other students. It also makes things easier on the teacher. If modified material must be used, textbooks would have raised line drawings, as well as follow the same page numbering pattern as the original textbook. Books on tape are can be used as a supplement, however these do not take the place of written textbooks. Real objects, as opposed to models or drawings are always preferred.

Once the student has turned 14, he/she is invited to meetings so they are able to give input to their programs. The services of the school cease after the student has completed high school.

ADDITIONAL INFORMATION

- Summer refresher courses are provided
- For low-vision cases magnifying equipment is available
- “Braille & Speak” device – produces both Braille and text printouts. Small, portable, user friendly
- Vision Resource Library in Canton, MA provides textbooks and other aids for Worcester’s VI students
Appendix B

Interview Questions, Denmark

Teachers

Experience with blind or visually impaired students
How many blind or visually impaired children have you had in your classes?
What was the severity of their visual impairment?
How much assistance did you receive in teaching these children?
How much assistance did the student receive?
How much assistance would be ample?
Did you restructure the curricula to meet the child’s needs?
Where were any activities that the child had trouble participating in?

Curricula
Which topics do you cover in physics and in chemistry?
Which do you consider most important?
Do you use in-class demonstrations? If so, for what topics?
Do you do in-class labs? If so, for what topics?
Have you made adaptations to labs to make them accessible?
If so, to which labs and what were the adaptations?
What labs would you like to have made accessible?
Which labs do you think would need the most work to adapt?

Teachers of the visually impaired

What is your job
How many students do you work with?
What are the most difficult subjects to work with?
What are the obstacles in integrating general classrooms in Denmark?
How well are the general education teachers trained?
What teaching assistance is available to the general education teacher?
How well is the curriculum adapted to meet the needs of the visually impaired student?
What technological assistance is available to the general education teacher and the student?
What are the laws concerning education of the visually impaired?

Consultants

What is your job
What is your role in the visually impaired student’s life?
Do you work directly with student, teacher, and administrators?
What are the statistics relating to visually impaired children in Denmark?
What are the laws concerning education of visually impaired students?
Does the curriculum get modified when a visually impaired child is in the class?
Contact: Klavs Bisgaard  
Position: General Education Teacher, Science  
Phone: (45)  
Personal Interview  
Date of Interview: 5 April, 2000  
Interviewed by: Matthew Dion, Karen Hoffman, Amy Matter

BACKGROUND

Klavls Bisgaard teaches science at Bjørnehøjskolen in Helsinge, and has Kristina Eskelund Nielsen in his ninth grade class. He seems very involved personally in her education, and Kristina has responded well to this attention. He did not, however, feel the need to alter his curriculum or teaching style in any way.

TRAINING

Klavls has not officially been instructed in teaching methods that are effective for blind and visually impaired students, as only the math and Danish teachers from Bjørnehøjskolen were sent to Refsnæsskolen for training. Although he seems to adequately convey the subject matter without this training, he would have preferred to have some prior information regarding the instruction of blind and visually impaired students.
Contact: Kristina Eskelund Nielsen  
Position: 9th grade student  
Personal Interview  
Date of Interview: 5 April, 2000  
Interviewed by: Matthew Dion, Karen Hoffman, Amy Matter

BACKGROUND

Kristina is a ninth grader in the Bjørnehøjskolen in Helsinge. She finds science to be a subject that is fairly difficult to understand, but she is highly appreciative of her teacher, Klavs Bisgaard. She feels that his is very helpful in explaining anything that is written on the blackboard, preparing her for the test material, and other classroom procedures.

LECTURE

In terms of lecture material, chemistry is easy because she has raised line drawings that are easy to feel and interpret. She considers physics to be harder to understand because there are more instances when the drawings are inadequate or unavailable, in which cases sight is necessary.

LABORATORY

Kristina participates in every experiment, working with a partner like all of the other students in the class. The same classmate assists Kristina in both science and math. Kristina also has another general education teacher to act as her eyes during lab, mostly reading the outputs of measurement devices. Experimentally, chemistry is a difficult subject because many of the labs involve color identification or change. Measuring pH is a common experiment that involves only the observation of color changes. Forces and Newton's laws are also difficult to experience in a lab, because moving objects cannot easily be followed by touch or hearing. Fortunately, many labs focus on electricity and magnetism, which are easy to understand, especially through use of raised line drawings.
Contact: Bendt Gufler  
Position: Educational Consultant  
Phone: (45) 55 54 65 24  
Personal Interview  
Date of Interview: 28 March, 2000, 30 March, 2000  
Interviewed by: Matthew Dion, Karen Hoffman, Amy Matter

BACKGROUND

From 1960 to 1970, Bendt Gufler was in the service of the Air Force, working as a meteorologist. Since then, he has been working as an educational consultant, as well as a teacher of physics, chemistry, and biochemistry. In his career, he has had one blind student. The student inspired him to work on developing course material and experiments for other teachers with blind students.

EXPERIMENTS – CHEMISTRY

Mr. Gufler reviewed and performed many chemistry experiments done in a typical Danish 7th or 8th grade fysik class. While performing these experiments, Mr. Gufler reviewed what the main point for the visually impaired student to understand in each one, as well as any difficulties regarding this understanding due to the visual impairment.

Topics reviewed in the field of chemistry included acids and bases, chemical reactivity, precipitation, and electrical conductivity of ionic solutions. Mr. Gufler thought that acids and bases were difficult to adapt because of the visual nature of all basic tests for pH. As long as the chemical reaction does not solely depend on color change, Mr. Gufler thought that the visually impaired could get the main point to the experiment. While the visually impaired student cannot see the precipitation take place, they could taste the chemical precipitated out of the solution provided that the precipitate is non-poisonous. Electrical conductivity of an ionic solution has sound and smell aspects that can appropriately display the main points of the experiment for the visually impaired student.

EXPERIMENTS – PHYSICS

As in chemistry, Mr. Gufler performed common experiments a 7th or 8th grade Danish student would perform. These experiments included electromagnetism, resistance, AC/DC differences, power production, nuclear physics, and light diffraction. Since the majority of these topics are not grounded in the sighted world, and have a bit of abstract nature to them, the visually impaired students are on a more level playing field. The only topic that is grounded in the sighted world is light diffraction. Mr. Gufler stated that this would be an especially abstract topic for a congenitally blind student.
SUGGESTED DEVICES

Mr. Gufler suggested a couple devices to construct or improve upon. The first is a multi-vibrator device with a speaker, which can help in many experiments, including electrical conductivity of an ionic solution. The second is an acid-base meter that is not as visually oriented as litmus paper is.

ADDITIONAL INFORMATION

- In Denmark, schools are concerned with not only the student’s education, but also the development of social skills.

- Chemistry and Physics are taught in the same class, which on average meets two hours per week.

- Approximately 50% of the school year is spent studying electricity and electromagnetism. 40% is spent on chemistry. The final 10% is spent on Newtonian physics, nuclear physics, meteorology, or whatever other subjects the teacher is interested in.
Contact: Hans Nørgaard  
Position: County Consultant  
Organization: Synscentralen, Storstrøms Amt.  
Phone: (45) 55 37 33 33  
Personal Interview  
Date of Interview: 3 April, 2000  
Interviewed by: Matthew Dion, Karen Hoffman, Amy Matter  

DANISH SYSTEM

When a child below the age of 19 is diagnosed with a visual impairment, a doctor is required to make a claim to the state eye clinic. An announcement is then made to Refsnæsskolen, who provides for all of the child's material aids. Refsnæsskolen is a school for children with visual impairments and multiple disabilities. Another announcement is also made to the local/county advisor.

Before a child starts school, there are only a few things taught, such as Braille and mobility. Once the child is ready to start school, a psychologist evaluates the student to see if he/she is ready to start school. If the child is ready to start, then preferably they are enrolled in their local school. There, the local general education teachers take care of all issues dealing with the student. These teachers can be prepared via Refsnæsskolen, where they can take classes on teaching and dealing with totally blind and severely handicapped students.

To aid in the education of the visually impaired student, an assistant teacher may be added to the classroom. These assistant teachers are general education teachers already teaching classes at the local school. Each blind student has an assistant teacher who attends nearly half of the student's classes. The assistant teacher helps the blind student understand what is going on in class, and provide them with materials as they are needed through the class. Hans' personal opinion is that a team would work better, as opposed to an individual. Sometimes it's better to have an assistant teacher with background in a subject, and other times it's better to have an assistant teacher with no background.

PROBLEMS WITH THE DANISH SYSTEM

There are a few main focuses in the Danish system. The first is social skills. It is the teacher's responsibility to encourage the social development of the visually impaired student. The second is classroom management. There are a few levels to this, including physical materials and the amount of assistance given by the assistant teacher.

Typically textbooks are not a problem, since Refsnæsskolen can usually handle them, provided they have six month's notice. Additional material can be modified through Refsnæsskolen, however they need at least two week's notice. Otherwise, teachers need to modify day-to-day materials and handouts on their own. This becomes a strain on the teacher's time.
There are two streams of thought. The first is that the visually impaired student be exposed to everything, and get as much help as necessary along the way. The other is for the student to get no help, and cover what the student can cover. Typically real-life falls in between these two ideas. While assistant teachers are supposed to assist the visually impaired student, sometimes they need to give the student room to explore on their own.

MR. NØRGAARD’S ROLE

Mr. Nørgaard deals with children who only have visual impairments. He follows the children from the beginning of kindergarten to the end of the child’s schooling. Mr. Nørgaard describes his role as a mix between the American itinerant teacher model and general counselor.

LEGISLATION

In Denmark, legislation concerns all students. It tells what to do for all students in different cases. In Paragraph 20 of the education legislation, it details how all children have access to education. Piece 1 of this paragraph states that if the student has difficulties learning with the current education system due to disabilities, the local schools typically deal with it. If a student has a more sever handicap, the responsibility for the education is switched to the county. Typically the cutoff is around 60,000 Kr per year, per student, but this number varies from county to county. The municipality pays for basic supplies, while more advanced forms of support are paid for by the county. There is currently legislation being debated to raise the line of support from 60,000 to 100,000 Kr.

IDEAS FOR FINAL PROJECT

Mr. Nørgaard believes that a good idea for a final product for this project would be a traveling box that contains equipment for a science classroom, along with a teacher’s manual to describe how to use the equipment. In this box, adapted devices or explanations on how to measure pH, temperature, mass, and liquid volumes would be appreciated. Also, a list of web-based sources detailing suggestions on how to instruct visually impaired students, modified experiments, or science experiments in general would come in handy.

ADDITIONAL INFORMATION

• There are approximately 100 children attending Refnsæskolen at any given time.
• There are 16 counties in Denmark, who each have a separate support network for visually impaired students.
• There is a debate currently in progress regarding a centralized / decentralized system, and whether or not to put more emphasis on the local schools, counties, or state.
Classroom Observation – 9th grade science
Contact: Poul Gaarhoje
Position: General Education Teacher – English, Assistant Teacher -- Science
Address: Lindebjergskolen
Store Valbyvej 248 B
Grundsølille
DK 4000 Roskilde
Date of Observation: 5 April, 2000
Observed by: Matthew Dion, Karen Hoffman, Amy Matter

CLASSROOM ARRANGEMENT

The room was divided into a lecture section and a laboratory by a blackboard. Eleven students were present of the 12 registered. These students are half of a larger class that takes science and math in the same period. Whenever possible, the class is divided so that half takes science and the other takes math for half of the period and then they switch, but this is dependent on teacher availability. This particular science class took the entire period, for the benefit of our observation.

CLASS STRUCTURE

The topic of the lecture was radioactivity. A demonstration was performed throughout the lecture with some student participation, but no lab experiment was incorporated. The demonstration involved a Geiger counter, sources of $\alpha$, $\beta$, and $\gamma$ radiation, a timer, and shielding materials. The radioactive sources were passed around the room while the teacher was lecturing. A student helped with setting up the Geiger counter and positioning the radioactive sources. As the teacher was explaining the basics of the Geiger counter, the machine was emitting clicks for every count, and the frequency of the clicks was distinct depending on the source and its position relative to the counter.

Much of the demonstration involved shielding materials. A sighted student would position a source of radioactivity close to the counter and then manipulate the controls on the counter and timer to obtain a reading for one minute. After an average reading for the unshielded source was obtained, the student would insert various thicknesses of shielding materials (paper, aluminum, and lead) and obtain new readings. During most of these procedures, the sound of the counter was turned off and only the final reading was announced.

INTERACTION WITH THE SCIENCE TEACHER

The science teacher, Jørgen Petersen, mostly lectured towards the side of the room where the sighted students were sitting, although the grouped seating arrangement of the students was unusual due to the observers’ presence (usually the students are spread across the classroom). Since Anders was removed from the group in this arrangement, the teacher specifically handed to Anders the radioactive source that had been passed around the rest of the room.
While the teacher was pointing out parts of the equipment and writing on the board, he seemed to be explaining what he was pointing to or writing. When he drew a graph on the board, he mentioned the units on each axis, the location of each of the points, and the shape of the resulting graph. During the demonstration, the teacher relied on the students to announce the readings and explain to Anders what was being observed. On one occasion, the teacher prompted one of the students to explain something to Anders, and the student later spoke to Anders about the demonstration without prompting. Anders asked a few questions to the teacher, and also answered questions from the teacher correctly.

INTERACTION WITH THE ASSISTANT TEACHER

The assistant teacher for Anders in science class, Poul Gaardhøje, sat next to Anders at the front of the room. During the lecture, Anders and Poul had an almost constant dialogue. This did not appear to be a problem, as the atmosphere of the class was relaxed and the students were also talking among themselves and with the teacher. Poul was mostly explaining the lecture material as the teacher presented it, often in conjunction with the materials that Anders had available such as a Braille periodic table and raised line graphs from the textbook.

During the demonstration, Poul wrote down the readings on the regular worksheet for Anders. Poul also retrieved one of the metal shielding plates for Anders to feel, because the plates were not passed around the rest of the class. When Anders needed any special materials such as the raised line graphs, Poul retrieved them and found the correct item.
Classroom Observation — 7th grade science
Contact: Eric Brown
Position: General Education Teacher
Address: Lindebjergskolen
    Store Valbyvej 248 B
    Grundselille
    DK 4000 Roskilde
Date of Observation: 5 April, 2000
Observed by: Matthew Dion, Karen Hoffman, Amy Matter

CLASSROOM ARANGMENT

The room was divided into a lecture section and a laboratory by a blackboard. Thirteen students were in attendance, all of whom were sighted. This group of boys was half of a larger group, divided by gender to make smaller classes.

CLASS STRUCTURE

The first half of the class was spent in discussion in the lecture side of the room. The teacher, Eric Brown, first had the students identify pieces of safety equipment by showing the equipment and calling on students by name. Then Eric introduced the lab experiment and explained the procedure to the students, referring to the description in the students’ lab manuals.

The students then moved to the lab section of the classroom, divided themselves into pairs, and sat at their lab benches. The odd student worked alone. Upon prompting by Eric, the students set up a stand with a test tube clamp and large test tube from the equipment that was available at their lab stations. Eric checked their apparatus, then told them to retrieve the hydrochloric acid that was also part of the standard equipment, and fill the test tube to a depth approximately equal to two finger widths. When all of the students were finished with this step, Eric handed out pieces of magnesium ribbon. The students dropped the ribbon into the acid and observed the bubbling of the acid, the dissolving of the ribbon, and the sound of the escaping gas. Eric handed out another piece of ribbon to each pair and the observation was repeated. The students seemed surprised by the reaction and excited about repeating it.

Eric asked questions about the students’ observations, and wrote the chemical equation for the reaction on the blackboard. He then conducted a discussion with the students about the chemical process. The students had to answer questions in their lab manuals about the reasons for the phenomena that were observed, which they did at their benches without assistance from Eric. When they had finished answering the questions, they were allowed to perform the experiment again.
### Appendix C

<table>
<thead>
<tr>
<th>Company</th>
<th>Address</th>
<th>Website</th>
<th>Products</th>
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</thead>
<tbody>
<tr>
<td>Blazie Engineering</td>
<td>105 East Jarrettsville Road, Forest Hill, MD 21050</td>
<td><a href="http://www.blazie.com">www.blazie.com</a></td>
<td>Electronic Braille Devices, Computer Software</td>
</tr>
<tr>
<td>Lighthouse International</td>
<td>111 East 59th St., 12th Floor, New York, NY 10022-1202</td>
<td><a href="http://www.lighthouse.org">www.lighthouse.org</a></td>
<td>Low Vision Aides, Talking Devices</td>
</tr>
<tr>
<td>HumanWare, Inc.</td>
<td>6245 King Road, Loomis, CA 95650</td>
<td><a href="http://www.humanware.com">www.humanware.com</a></td>
<td>Electronic Braille Devices, Computer Software, Low Vision Aids</td>
</tr>
<tr>
<td>American Thermoform Corporation</td>
<td>2311 Travers Avenue, City of Commerce, CA 90040</td>
<td><a href="http://www.antarq.com.mx">www.antarq.com.mx</a></td>
<td>Braille Printer, Computer Software</td>
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<tr>
<td>Synapse</td>
<td></td>
<td><a href="http://www.synapseadaptive.com">www.synapseadaptive.com</a></td>
<td>Computer Software, Voice Recognition</td>
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<td>Arkenstone, Inc.</td>
<td>NASA Ames Moffett Complex, Building Field, California 94035-0215</td>
<td><a href="http://www.arkenstone.org">www.arkenstone.org</a></td>
<td>Reading Device</td>
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<tr>
<td>Seiko Instruments USA, Inc</td>
<td>Educational Products Division, 2990 W. Lomita Blvd, Torrance, CA 90505</td>
<td><a href="http://www.seiko-education.com">www.seiko-education.com</a></td>
<td>Reading Devices</td>
</tr>
<tr>
<td>Raised Dot Computing, Inc.</td>
<td>408 South Baldwin Street, Madison, WI 53703</td>
<td><a href="http://www.rdcbraille.com">www.rdcbraille.com</a></td>
<td>Computer Software</td>
</tr>
<tr>
<td>LS &amp; S Group</td>
<td>PO Box 673, Northbrook, IL 60065</td>
<td><a href="http://www.lssgroup.com">www.lssgroup.com</a></td>
<td>Low Vision Aids, Talking Devices, Braille Devices</td>
</tr>
<tr>
<td>Keyboard Alternatives &amp; Vision Solutions</td>
<td>537 College Avenue, Santa Rosa CA 95404-4102</td>
<td><a href="http://www.keyalt.com">www.keyalt.com</a></td>
<td>Computer Software, Reading Devices, Voice Recognition</td>
</tr>
<tr>
<td>Henter-Joyce, Inc.</td>
<td>11800 31st Court North, St. Petersburg, FL 33716</td>
<td><a href="http://www.rfbd.org">www.rfbd.org</a>.</td>
<td>Talking Books</td>
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<tr>
<td>Recording for the Blind and Dislexic</td>
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<td><a href="http://www.rfbd.org">www.rfbd.org</a>.</td>
<td>Talking Books</td>
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<td>Tactilog</td>
<td>Roskildevej 15, DK - 7441 Bording</td>
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<td>Electronic Braille Devices</td>
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