

CHAPTER II

REVIEW OF LITERATURE

2.0 Introduction

In first chapter, Rationale along with Objectives and Hypotheses has been given. The present chapter is devoted to reviewing researches related to different aspects of Science Experiments for the students with visual impairment. For better understanding the researches have been classified under the captions as follows. This chapter presents an overview of the available technology for science teaching for the Students with Visual Impairment.

- 2.1 Education of Disabled in Digital Era
- 2.2 Inclusive Education in India
- 2.3 Teaching Learning of Science for Students with Visual Impairment
- 2.4 Adapted Tools and Techniques for Science Experiments of Students with Visual Impairment.
- 2.5 Adaptive of Technology in Teaching Science to the Students with Visual Impairment
- 2.6 Assistive Technology for Students with Visual Impairment in Conducting Experiments
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2.1 Education of Disabled in Digital Era

Bridging the Disability Divide through Digital Technologies, provided an overview of the opportunities presented by the internet and ICT for the full participation of persons with disabilities and stated that Digital technologies break traditional barriers to communication, interaction, and access to information for persons with disabilities. The confluence of increasing public and private service provision through Information and Communication Technology (ICT) and the growing number of mainstream, everyday ICTs that can be used as accessible devices is changing the paradigm of technology-enabled development for persons with disabilities (Raja, 2016).

ICT is being used to offer differentiated instructions and learning by adapting content and process to meet a student's readiness level (Bender, 2012).

Several special educators and assistive technology specialists that work with students with disabilities see a tremendous overlap between assistive solutions and general educational tools and software designed (Bocconi & Ott, 2014); (O'Connell, Freed, & Rothberg, 2010; Puckett, 2011).

Educators are using a range of ICT to enhance learning for students with disabilities including electronic whiteboards, recording and uploading lectures, task organization and categorization, memory tools and aids (O'Connell et al., 2010).

If a classroom has access to regular ICT tools, a platform for inclusion is already there. Both Windows and Mac OS have in-built accessibility features such as text-to-speech, using voice commands, non-use or improved use of a mouse or external keyboard, magnification, text alerts instead of voice alerts. Electronic interactive whiteboards can be used effectively as a means to engage students with different learning needs, actively include students with disabilities in sessions where students are called upon for an exercise on the board, and facilitate collaboration and group learning between peers with and without disabilities (Allsopp et al., 2012); (Gioia Daniels, and Mead 2012).

Accessible learning content is now easier to create and disseminate. Web-based bulletin boards and knowledge management platforms, electronic documents, e-books, and audio books offer important alternatives to the rigidity imposed by traditional print-based and handwritten forms of learning and expression. E-publishing formats such as the DAISY format have been specifically developed to ensure that e-books are accessible by users' assistive technology (Watkins & Milne, 2014),

Learning is also aided by presenting materials in various formats including video and graphics and this again facilitates the principle of differentiated instruction that benefits students with and without disabilities. Smart devices such as tablets are also important tools for inclusive education (O'Connell et al., 2010; Shah, 2011).

Beyond their embedded accessibility features, a large number of apps are available, and growing in number, to assist students with disabilities in accessing and understanding complex subjects such as math and science, aiding them in following lessons through audio recording, electronic note taking, and apps that work as memory tools and help with organization (Watkins & Milne, 2014).

2.2 Inclusive Education in India

The concept of inclusive education, challenges, and measures to implement inclusive education in India. The researcher has concluded that inclusive schools have to address the needs of all children in every community and the central and state governments have to manage inclusive classrooms (Singh, 2016).

Nearly about 10% of the world's population is affected by a disability, and a large amount of these people live in developing countries. Three basic models considered by Researcher i.e. segregated, integrated, and inclusive special education, have been differentiated between by international and local agencies including Government and NGOs, and overwhelming support is being shown by human rights activists, non-profit organizations, government organizations, and different agencies, which are all in favor of inclusive special education as the most beneficial type of education for people of all ability levels (Aruna. & Lal, 2016).

Children with special needs can be included in the general school system without any demarcation and differentiation. Many problems such as lack of well-educated teachers, curriculum, resources, good infrastructural facilities, awareness, positive attitude, plans, policies are creating hurdles for extending the concept of inclusive education in India (Sarao, 2016).

Inclusive Education is a process of strengthening the capacity of the education system to reach out to all learners. It involves restructuring the culture, policies, and practices in schools so that they can respond to the diversity of students in their locality and suggest compensating these gaps with an optimistic motion for successful inclusion (Mrunalini & Vijayan, 2014).

The guidelines in a generalized model that schools can follow to initiate such programmes. The guidelines were derived from an empirical study that entailed examining prevalent practices and introducing inclusion in a regular school setting. Further, it is suggested that schools can implement inclusive education programmes if they are adequately prepared, are able to garner the support of all stakeholders involved in the process, and have basic resources to run the programmes (Madan & Sharma, 2013).

2.3 Teaching Learning of Science for Students with Visual Impairment

The latest trend in special education policy is to teach students both with and without special needs in the same school system. In the case of students with visual impairment, one of the main problems they face, particularly in physics, is the lack of instructional material adapted for the experimental laboratory. This paper presented strategies, activities and resources for instructional use by physics teachers for students with visual impairment using laser devices. For the best results, the teachers use resources from the perspective of building models to stimulate the interest and active involvement of the students (de Azevedo, Vieira, Aguiar, & Santos, 2014).

A study on Adapting Advanced Inorganic Chemistry Lecture and Laboratory Instruction for a Legally Blind Student by (de Azevedo et al., 2014) described the strategies and techniques used to successfully teach advanced inorganic chemistry, in the lecture and laboratory, to a legally blind student are described. The study results

discussed general accommodations and specific approaches that were used. Student assistants were utilized for the laboratory course, problem sets, and exams. Specific examples and detailed explanations of approaches that were helpful to the legally students who are blind throughout the entire course are provided. The students who are blind benefited from extensive, verbal description of complexes, figures, and diagrams. In addition, the student benefited from tactile description of figures and models.

The adaptive instructional aids assisted the student in writing and balancing chemical reactions, calculating unit conversions and concentrations, drawing Lewis dot structures, understanding structural representations of molecules with three-dimensional models, and identifying organic functional groups (Boyd-Kimball, 2012).

Students with Visual Impairment need instructional and environmental accommodations to learn science. They need more tactual and audio experiences than visual instruction. Suggestions and implications about teaching science to students with visual impairment are discussed (Sahin & Yorek, 2009).

An orbit molecular model kit from Indigo Instruments was the most beneficial method. This kit provided conveniently sized pieces that were easily transportable and manipulable by the instructor and the student, and was used to augment the student's understanding of organic chemistry concepts (Poon & Ovadia, 2008).

A low-tech way of using a transparency system to reproduce a meter stick and using a staple gun to make raised lines to serve as tactile indicators for students with visual impairment. Such techniques were important for measurement because they could be transferred to skills in everyday life (D. Kumar, Ramasamy, & Stefanich, 2001).

The creation of an olfactory acid/base indicator to assist students in a multisensory learning experience. This type of olfactory response can assist persons with blindness and visual impairment as well as other special-needs learners requiring a multisensory approach, but has limitations. Although this work was found to be beneficial to the subjects in question, olfactory detection can vary from person to person, based on the general health of each person at the time of the test. Also, with extended exposure to odors, olfactory sensitivity can degrade over the period of a

laboratory session, thus making it difficult to reproduce the same measurement consistently (Flair & Setzer, 1990).

Teaching of general science to students who are blind to aid their development into adult about scientific matters are important in everyday life. And also recommended natural specimens for study such as soil samples and plants, and that teacher make the study of science “alive and dynamic”. Importantly, students with blindness were capable of going on to more advanced learning in the sciences and that education in general science could help guide them toward fulfillment of their intellectual potential. The study of general science prepares the foundation for the later study of the special sciences. It determines the student’s aptitude for the science electives and guides to an intelligent choice (Coville, 1932).

The most important aspect of teaching science to the blind, and in fact, of teaching science to anyone, was that the teacher strives to establish within students the belief that learning science was possible, pleasurable, and important to having a disciplined and thoughtful mind. Botts emphasized that science education should be customized to the needs of individual students and classes, and that it should include active participation in experiments and demonstrations, models, field trips, class discussions, readings, and individual reports and evaluations (Botts 1934).

Students with blindness were welcome to enroll in a range of science classes and were regarded as equals at a mainstream public high school in Baltimore, Maryland. Classes included general science, chemistry, physics, and biology. Students with Visual Impairment participated in the same laboratory experiments as did their classmates, were expected to set up laboratory equipment and observe experimental results, and often assumed leadership roles in classes and lab groups. Traditional instruction in chemistry was supplemented with the use of tactile models and all senses other than sight (Bryan, 1941).

Insightful presentations by (Heisler, 1946; Overbeay, 1946; Riddle, 1946), and many others resulted from the 38th Meeting of the American Association of Instructors of the Blind. Heisler “The Need for Three Dimensional Instruction in Science Curricula” discussed several types of multisensory instructional aids, including verbal

descriptions, embossed diagrams, tactile models, auditory recordings, preserved animal specimens, natural specimens of minerals and soil, and live specimens of plants and animals.

Like many before her, (Pease, 1946) pointed out that the selection and purchase of indoor laboratory equipment for experimentation must be carefully based on its appropriateness for use by the blind. Pease did not, however, offer any specific suggestions on such equipment, but said that teachers must use their ingenuity to offer meaningful science instruction.

Simple experiments that high school students with visual impairment could perform in general science courses (Bryan, 1957). This program adapted science instruction to allow students to use senses other than sight for making observations. This work stressed the use of tactile models and diagrams and encouraged educators to require students to record experiments in a Braille notebook. Several suggested experiments were those involving air, water, convection currents, dew point, thermometry, weather, biology, zoology, and human physiology. Tactile observation of all demonstration apparatus was, according to Bryan, the “one general pedagogical rule for blind science instruction.

The use of tactile models made specifically for the learning needs of students with Blind or Low vision, but preferred the use of actual materials when practical and available. That models could spare students lengthy verbal explanations of dubious value, and that learning would be better retained by having students assemble models of complex objects to gain an understanding of how the parts fit together (Waterhouse, 1940).

2.4 Adapted Tools and Techniques for Science Experiments of Students with Visual Impairment

A series of practices used during undergraduate studies at Purdue University on how students with BLV could take notes and the techniques. To access overhead transparencies and other graphical concepts from lecture presentations and textbooks. These methodologies included utilizing a standard tracing wheel along with a piece of Braille paper in conjunction with a rubber mouse pad to make images on the paper.

The paper was then flipped over to access the image as it was meant to be presented from left to right. The challenges associated with access to textbook materials were described, and he explained that flexibility in textbook choice could be helpful, in case the course text is not available in Braille or audio format. Further the proper use of the directed laboratory assistant approach to working in the chemistry lab, along with techniques for taking quizzes and exams, and the importance of working with course instructors to determine appropriate locations and circumstances for exams were described. The role played by the institution's disabled student services office regarding the education of students with BLV was discussed and explained as being a supportive or ancillary resource to provide assistance in working out course-related accommodations between instructors and students (Supalo's, 2005).

In "A Project to Make the Laboratory More Accessible to Students with Disabilities," (Lunsford & Bargerhuff, 2006) discussed a workshop program at Wright State University called Creating Laboratory Access for Science Students (CLASS), which was developed to train science teachers on methods of adapting laboratory curricula to be more universally designed. These laboratory modifications covered biology, physics, and chemistry. Among the chemistry topics discussed were physical properties, chemical properties, the periodic table, balancing chemical reactions, acids and bases, and water monitoring. One important modification the authors proposed was the use of plastic ware in place of regular glassware to prevent possible breakage. The CLASS project actively incorporated science educators along with persons of varying disabilities in the workshops. The workshops were designed to give science teachers the opportunity to have hands-on laboratory experiences while working with persons having a range of disabilities.

Teaching Chemistry to Students with Disabilities: A Manual for High Schools, Colleges, and Graduate Programs, edited by (Miner, Nieman, Swanson, & Woods, 2001) discussed a number of techniques for teaching persons with disabilities in high school and college chemistry classes. The book's contributors found that many of the suggestions for laboratory participation would also work in other sciences. Tips on assessment related to test taking and lab report writing were also suggested. For example, students with low vision could simply be given large-print exams and

textbooks. Persons with blindness could work with a reader - a person assigned to read printed text materials and, in many cases, record them in audio format for later reference.

Interlocking toy building blocks (e.g., Lego) as chemistry learning modules for blind and students with visual impairment (BVI) students in high school and undergraduate introductory or general chemistry courses (Melaku, Schreck, Griffin, & Dabke, 2016). Building blocks were assembled on a baseplate to depict the relative changes in the periodic properties of elements. Modules depicting the electron configuration of an element and molecular orbital theory were also constructed. Modules were presented as a hands-on training experience for a group of students with visual impairment followed by a survey. Also, module for classroom demonstration for an undergraduate general chemistry class of sighted students was presented.

A series of low-cost ways to illustrate chemistry and physics concepts for middle school and high school students with visual impairment. They discussed utilizing a set of substitute characters to represent chemical symbols in Microsoft Word files. These shortcuts included adaptations such as -> to indicate “goes to” in a chemical reaction, ^- to indicate a negative superscript, and to indicate a subscript. These techniques were employed to facilitate the reading of chemical equations because the JAWS screen reader does not correctly read some mathematical symbols. The use of laptop computers was discussed for recording data and reading electronic files regarding laboratory procedures and class assignments (Winograd & Rankel, 2007).

Technologies and techniques that could be implemented when teaching an entire class of students with BLV were reported. Several ILAB tools were prominently featured in the chemistry segment of this event, demonstrating that these tools are appropriate for teaching students with BLV. Other science segments at the event included biology, air science, engineering, and physics. Some of the SAVI/SELPH tools were also used, such as notched syringes. Cafeteria trays were utilized as workspaces for students conducting experiments, minimizing spills both on the benchtop and on expensive computer equipment. The laboratory procedures used in the chemistry experiments (Cary A Supalo et al., 2009).

The special methods, techniques, tactile demonstrations, and Braille-labeled models are useful in teaching the principles of physics to high school students with visual impairment. A wide range of topics including matter, sound, measurement, pressure, motion and energy, heat, mechanics, magnetism, electricity, and electronics were used. The students were allowed to investigate demonstration apparatus by touch. Bryan often used simple hands on classroom activities to demonstrate theoretical concepts and gave several examples, such as throwing, catching, and holding a ball to illustrate the concepts of kinetic and potential energy (Bryan, 1957).

A class developed for students with BLV at East Central State University in Oklahoma. The purpose of this course was to ensure that students with visual impairment had the same opportunities to experience science as did sighted students through the provision of total participation in all of the science activities. Science laboratory activities performed by students with visual impairment were similar to those required of sighted students. Special laboratory devices were used to adapt the activities to the needs of the students with visual impairment (Weems, 1977).

To make physics activities regarding the concept of equilibrium more accessible to students who are blind. The technique utilized a few low-tech laboratory tools specifically developed to teach spatial concepts in physics to students who are blinds through tactile means (Sevilla, Ortega, Blanco, & Sanchez, 1991).

The computerized arrangement allowed for the interface of laboratory probes through a serial port and text-to-speech output, and was used in conjunction with a talking voltmeter. The PSL was tested with a general chemistry course curriculum and allowed blind students to conduct a large percentage of the laboratory activities without a sighted assistant. It was the expectation that the PSL would become commercially available (Lunney, 1994).

Numerous techniques were involved to teach scientific concepts to young children by means of simple experiments and art representations. They cited the importance of the use of tactile art in the teaching of scientific concepts by having the students create models as illustrations. Numerous concepts were covered, including electric circuits, plant biology, greenhouses, pulleys, magnetism, liquids and solutions,

solids/liquids/gases, mass, density, light, sound, and many more (Hadary, Cohen, Hadary, & Cohen, 1978).

Careful verbal descriptions of lecture materials and the use of models are the two techniques used to teach general biology to college students with visual impairment. Although standard commercial models helped demonstrate the relative positions of major organs within the human body, their overall usefulness to students with blindness was limited due to inadequate tactile distinctions. Commercially available models were intended for sighted students, and many physical details were distinguished by color. As an alternative, sighted students prepared clay models of organs for their classmates with visual impairment. These models were designed to fulfill the expressed needs of the users with visual impairment and proved to be much more beneficial than the commercial versions (Dawson, 1958).

Typical class activities in which these students could participate, and stressed that student who are blind generally need not be exempted from activities required of the class as a whole. The BLV students usually possessed the skills necessary for taking notes, preparing assignments, and taking tests. Students with visual impairment in this setting were successful in performing laboratory experiments involving the dissection of plants and animals, and tactile examinations of models, specimens, and relief diagrams. In many instances, the BLV students were encouraged to touch plant and animal specimens, which provided them with a hands-on science experience (Bunner & Bunner, 1968).

To teach a university student with blindness in two biology classes special techniques to be followed. Perhaps most significantly, they utilized a spirometer interfaced with a computer to measure the flow of air and other gases from human lungs. Simply reading the numbers on a computer screen was not found to be sufficient to provide the student with a tactile feedback representation of the volume transferred. Therefore, they attached a balloon to the output valve of the spirometer to allow it to fill with the gases and thus created a tactile representation of the gas output. The size of the balloon was then measured and volume was calculated (Womble & Walker, 2001).

2.5 Adaptive of Technology in Teaching Science to the Students with Visual Impairment

A novel methodology in Deriving Accessible Science Books for the Students who are blind of Physics for the development and production of accessible physics and science books from the elementary up to tertiary educational levels was derived. This language independent approach adopts the Design for All principles, the available international standards for alternative formats and the Universal Design for Learning (UDL) Guidelines. Moreover it supports both static (embossed and refreshable tactile) and dynamic (based on synthetic speech and other sounds) accessibility. It can produce Tactile Books (Embossed Braille and Tactile Graphics), Digital Talking Books (or Digital Audio Books), Large Print Books as well as Acoustic Tactile Books for the blind and students with visual impairment as well as but for the print disabled. This methodology has been successfully applied in the case of students who are blind of the Physics, Mathematics and Informatics Departments in the University of Athens (Kouroupetroglou & Kacorri, 2010).

A research was conducted on laboratory tools for students with BLV, and developed speech-accessible sensors and probes using the Vernier Logger Pro software and Lab Pro hardware. These probes included a pH meter, thermometer probe, conductivity detector, and many others. Milchus and Goldthwaite employed a JAWS scripiter to write scripts allowing the JAWS text-to-speech screen reader to speak data values as they were collected. Although these scripts proved to be useful at the time, they were not updated as new versions of Logger Pro and JAWS became available (Milchus & Goldthwaite, 2000).

The panorama of Strategies and Technology Aids for Teaching Science to Blind and Students with visual impairment presented the foundations for designing inclusive learning materials based on the user-centered design and universal design for learning (UDL) frameworks, using as example the development of technology-based tactile three-dimensional prototypes for teaching biology. An example of low-technology adaptations for making accessible instruments for the chemistry lab, using recycled materials will also be described, as well as adaptations for laboratory safety. Finally, there is also a section elaborating on the educational strategy to create inclusive

and engaging environments in science laboratories (Reynaga-Peña & del Carmen López-Suero, 2020).

The use of computer interfaces in the science laboratory was also described, based on work done by (Lunney, Gemperline, Sonnesso, & Wohlers, 1996). The importance of raised-line drawings and how they could assist in conveying scientific concepts was also discussed. Techniques regarding taking notes by means of a tape recorder and a careful review of safety aspects in the laboratory were also included. The use of volunteers to assist in laboratory orientation was mentioned. These suggestions and others described in this paper can easily be used by science teachers for their students with BLV. Teaching Chemistry to BLV Students This section summarizes various published works describing teaching adaptations developed by educators for use in their chemistry curricula. These methods range from a low-tech tactile periodic table to the high-tech use of computer interfaces in collecting laboratory data.

Using Technology and Other Assistive Strategies To Aid Students with Disabilities in Performing Chemistry Lab Tasks was conducted by (Neely, 2007) investigated the use and success of assistive technology devices as well as other equipment modifications in an attempt to transform science laboratories into environments where students with disabilities can function independently. The methods were developed and tested for entry-level science courses in chemistry, biology, geology, and physics, and could also be applied to other disciplines. Equipment evaluated ranged from high-end computerized magnification systems to glassware easily modified by the lab instructor. Results of the study emphasized the importance of identifying each student's type and degree of disability in order to effectively determine the equipment requirements and methods used to try to provide a valuable experience for students with visual impairment in a general education or an introductory chemistry class is discussed. Modifications that can be made cheaply and with little time commitment which will allow students with visual impairment to participate productively in the laboratory are examined. A conductivity tester that cost less than \$4.00 to construct, is easy to assemble, very rugged, and provides a great deal of entertainment for sighted and non-sighted students is described.

Creating an Adaptive Technology Using a Cheminformatics System To Read Aloud Chemical Compound Names for People with Visual Disabilities was conducted by (Kamijo et al., 2016). The study established the essential requirements for the prototype Chemical Literature Extraction and Aloud-reading System (CLeArS) that enables students with visual impairment people to recognize a depicted chemical structure after hearing its name, which complies with the nomenclature adopted by the International Union of Pure and Applied Chemistry. Details of the methods employed in CLeArS and its execution are presented, in addition to the fundamental requirements for recognizing chemical structures using CLeArS. Experimental results on 450 images comprising both simple and complex chemical structures show a high recognition rate of 90% among subjects with visual disabilities. Thus, concluded that reading aloud the names of chemical compounds is an effective method enabling students with impaired vision to recognize chemical structures.

A panorama of suitable teaching resources and strategies for science education of blind and students with visual impairment was provided the examples of what is possible to do specifically for experimental sciences i.e Biology, Chemistry, and Physics. This presented the foundations for designing inclusive learning materials based on the user-centered design and universal design for learning (UDL) frameworks, using as example the development of technology-based tactile three-dimensional prototypes for teaching biology. An example of low-technology adaptations for making accessible instruments for the chemistry lab, using recycled materials will also be described, as well as adaptations for laboratory safety. It concluded with the educational strategy to create inclusive and engaging environments in science laboratories (Reynaga-Peña & del Carmen López-Suero, 2020).

A survey to teachers of the students with visual impairment through a visual impairment was conducted to help determine what pedagogical practices, accommodations, modifications, adaptive equipment and instructional practices are being used to educate students with visual impairment in the United States and Canada. This study determined whether appropriate accommodations and modifications are being made in classrooms to meet the specialized needs of these students (Koehler & Wild, 2019).

Teaching Enzyme Activity to the Visual Impaired and Students who are blind was reported by (De Oliveira, Nascimento, & Bianconi, 2017) developed experiments and graphical representations that enable students with visual impairment and students who are blind to understand enzyme properties. The experiments were done with pineapple bromelain, using reconstituted dry milk and gelatin as substrates. The “visualization” of the results were based on the sensation of the viscosity of the samples. The graphs were made with cold porcelain with all the labels (legends and numbers) written in Braille with a positive slate. From our experience with a blind student, both the experiments and the graphic representations were useful adaptations for teaching enzyme properties.

Four new modules for the scientific education of individuals with visual disabilities were designed for informal settings, the modules are safe and inexpensive and last 10-15 min each. The module entitled The Sound and Feel of Data represents axes and data points with pipe cleaners and coins, respectively, allowing for a discussion of data presentation and trends without reliance on visual signals. This work provides new ways to introduce science that are applicable to all learners, students with visual impairment or not (A. Kumar et al., 2018).

2.6 Assistive Technology for Students with Visual Impairment in Conducting Experiments

The various adaptive technology devices then on the market for students with BLV to utilize in the science classroom discussed contact information and approximate cost for each device was included in this work. For students with low vision, a magnification device known as the Clarity can be used in the laboratory. A camera attached to the device captures images that are then enlarged and viewed on a screen. The device can be attached via a clamp to a bench top to further assist in its laboratory use. Talking timers in the science classroom to assist students with low vision were also mentioned. An audible beaker with tone output to indicate to students with BLV when they are nearing the top was not found to be helpful. Other than the “talking” beaker, the devices were shown to be very useful in providing hands-on laboratory experiences (Neely, 2007).

The students with visual impairment were able to use inexpensive electronic equipment to build different types of detectors. Examples included a null detector with audio output, a probe connected to an electronic thermometer, and a colorimeter with an embossed dial. All of these devices could be made from locally available materials. The authors felt that the elimination of speech output devices and the Optacon was possible using tactile representations (Gupta & Singh, 1998).

A Braille 'n Speak note-taking device, produced by Blazie Engineering (which was later purchased by Freedom Scientific), with commonly available laboratory equipment including balances, pH meters, an ultraviolet-visible spectrometer, and a spectrophotometer," The Braille 'n Speak, in its "speech box" mode, can read ASCII input from lab devices through RS-232 connections. This interface was one of the first initiatives for accessible research-grade laboratory equipment, and could be used by students with blindness in science classes at the high school and university levels (Lunney et al., 1996).

An accessible setup that attempted to provide students with a feel for the changes in solution composition that accompanied the addition of titrant in a neutralization titration. The signal output from a pH meter was conditioned and detected by an audio-encoded Simpson multimeter. The Simpson multimeter was a standard device modified by replacing its meter movement with a potentiometer. The potentiometer had a tactile dial and was nulled aurally. The scale was calibrated by the multimeter to correspond to a pH range of 2 to 12. A 10 mL Metrohm piston buret with a Braille-labeled scale was used to dispense the titrant. A Perkins Braille Writer was used by the blind student to record the data. The setup allowed the blind student to perform most required laboratory operations, including pH calibration of the Simpson multimeter. The student was able to collect and record the titration data, and correctly identified an unknown (Tallman, 1978).

A number of commercially available high-tech devices for the students with visual impairment and described efforts to develop a general-purpose laboratory microcomputer system called the Universal Laboratory Training and Research Aid (ULTRA) for people interested in scientific and technical careers. This was a cutting-edge approach for its time. The ULTRA was designed to serve as both an educational

tool for college students and a research tool for professionals. It could function as a talking data acquisition and data analysis system, talking terminal, stand-alone talking computer, and stand-alone talking calculator. The system could be connected to many instruments with either an analog or digital output signal. Although this device was multifunctional and useful in the research chemistry laboratory environment, and thus carried over to classroom applications, it was limited in its practicality as a result of the high cost associated with the technology (Lunney & Morrison, 1981).

A General Purpose Talking Laboratory Instrument for the students with visual impairment is basically a 3 1/2-digit multimeter with speech output; however, it has added functions which extend its usefulness beyond the ability to measure the usual ranges of AC and DC voltage and current. The device can function as a thermometer, a pH meter, a 6-digit timer, and an events counter. Two voltage-to-frequency (V/F) converters make it useful as an audible comparator and peak detector. It is realized by using the counter to count the pulse train from a V/F converter which monitors the input signal. A low-level differential channel is provided for interfacing to instruments with recorder outputs, such as gas chromatographs. Spoken values of measured quantities are accompanied by sign, decimal point, and units. The instrument can also interface with other digital devices through 42 lines of parallel digital input-output. It can convert seven parallel BCD digits into speech or it can output BCD data from its counter or converter to a microcomputer (Salt, Lunney, & Hartness, 1980).

A low cost null detector an electronic thermometer and a colorimeter for enabling children with visually impairment children to do experiments in science that normally are accessible only to sighted children. The instruments are based on audio null detection in a balanced bridge and use a thermometer for sensing the temperature and an LDR for color change. The analog output can be tactually read by children with visually impairment. The equipment has been tested for suitability with children with visual impairment. The approach followed in developing these equipment would be generally appropriate to a wide variety of science equipment for students with visual impairment children by incorporating suitable sensors (Gupta & Singh, 1998).

In 1979 the Macrolab, an interdisciplinary center for science students with disabilities, was established at the New Jersey Institute of Technology and it produced

a number of adaptive laboratory devices for college students, which provided various tactile and auditory inputs for users. Length was measured by means of a Braille ruler and micrometer. Several instruments were used to measure time, including a stopwatch, an electric timer with raised dots, and a talking clock. A talking analytical balance was used for measuring mass. Instruments for making electrical and temperature measurements included a voltmeter, ammeter, ohm meter, Wheatstone bridge, impedance bridge, and thermometer. These devices were equipped with speech output capability and combined tactile scales with audio output.

Laboratory microcomputers were quickly finding their place in curricula at all levels and in all fields of study. Technology developments had made computers accessible to persons with visual impairment. Computer programmers with BLV were being trained and employed as a result of the microcomputer. The advent of the computer also allowed for the development of input/output modules that included Braille terminals and voice synthesizers. The control of laboratory instrumentation by microprocessors and microcomputers was evolving to become a routine practice. Salt et al. stated that as microcomputers became more common in the classroom and in the laboratory, and as microcomputer technology became accessible to people with visual impairment, it was certain that microcomputers would become increasingly important as laboratory tools for students who were students with visual impairment (Salt et al., 1980).

2.7 Effect of Sensor Devices for Students with Visual Impairment to Perform Science Experiments

Persons with disabilities are commonly underrepresented in STEM fields of study and are not provided the same hands-on science education as their peers. Utilizing the Sci-Voice Lab Solution from Independence Science participants will complete an experiment with the Talking Lab Quest (TLQ) and Logger Pro science tools. Navigation and operation of the TLQ will be presented along with an overview of the 70 + sensors compatible with the device. Low-tech tools will be discussed and how science curricula can be adapted for biology, chemistry, earth science, and physics laboratory activities. This technology is empowering students with Visual impairment to be more fully integrated into laboratory groups with peers without visual

impairment. This integration has created a hands-on learning experience essential for building interest in science, technology, engineering, and mathematics (STEM) professions (Cary A Supalo, Hill, & Larrick, 2014).

The design and construction of a simple Arduino-based pH sensor using universal pH paper was discussed. This can be assembled for less than \$40 and is ideal for use in laboratory classrooms teaching students with visual disabilities. The device is simple to construct and suitable for adoption in school chemistry laboratories because of its miniature size, user-friendliness, and flexible coding. The Arduino-based pH sensor allows the students with visual impairment to use and interpret universal pH paper in measuring pH, which could not be previously attempted. A change in color of the indicator paper, as detected by the RGB color sensor, generates a distinctive audible tone that corresponds to the pH value being measured. This device can function as a helping hand in the learning process by facilitating a more exciting and meaningful laboratory exercise experience not only for the students with visual impairment but also for their peers without visual impairment (Qutieshat, Aouididi, & Arfaoui, 2019).

The construction and evaluation of a digital thermometer especially designed to be operated by people with visual disabilities. The accessibility thermometer can be used as an educational tool in practical activities in classes for sighted and students with visual impairment, with the aim of helping those with special needs gain better access to the scientific world. The thermometer measuring scale ranges from -15°C up to 115°C , and the temperature is informed through beeps and vibration pulses similar to Morse code. Two thermometers were used to calibrate the constructed instrument, a LM35 sensor and a 7mercury thermometer; good agreement between the measured temperatures was shown through a linear correlation of 0.9997 with the LM35 sensor. Tests carried out with students who are blind showed that this instrument could be an important tool in helping them to better understand the proper scientific concept of temperature. Besides being low cost, the device is user-friendly and provides quick response and good reproducibility (Vitoriano, Teles, Rizzatti, & de Lima, 2016).

A simple talking calorimeter for the people who are students with visual impairment based on the Arduino Uno without any shield. An electronic interface was designed using a Wheatstone bridge, a thermistor, or an operational amplifier. The

temperature values are communicated by a loudspeaker connected to pulse-width modulation (PWM) digital output pins 3 and 11 of the Arduino Uno. The system is based on the Talkie library for Arduino Uno. This library was developed using Linear Predictive Coding and includes about 1000 English words. Two new Talkie libraries were constructed, one for Portuguese and another for German. This device can be easily implemented in any teaching laboratory with extremely reduced costs (Gomes, Cavaco, Morgado, Aires-de-Sousa, & Fernandes, 2020).

Seeing Chemistry through Sound: A Submersible Audible Light Sensor for Observing Chemical Reactions for Students Who Are Blind or Students with visual impairment, (Cary A Supalo et al., 2006), designed a hand-held device to output light intensity as an audible tone and it helps the students with visual impairment to observe chemical changes in solutions. The submersible audible light sensor (SALS) creates an audio signal by which one can observe reactions in a solution in real time, using standard laboratory glassware such as test tubes or beakers. Because many observations in the chemistry laboratory are visual, the SALS device enables students who are blind and students with visual impairment to perform a broader range of experiments independently. It is believed that this active participation will inspire more of these students to pursue careers in the science, technology, engineering, and mathematics (STEM) professions. The SALS device can be further refined to provide vibratory and visual outputs for students with learning or physical disabilities.

The example of how the light sensor then available from the American Printing House for the Blind and originally developed at the Lawrence Hall of Science at the University of California, Berkeley, could be used in elementary science classes to detect the relative amounts of visible pollutants in four jars of water samples of different pollutant levels. The light sensor, when held against the exterior of each glass jar, produced varying tones depending on the light intensity due to higher or lower levels of pollutants found in each water sample. This paper also implied that the light sensor could be used in a wide variety of other elementary science activities but did not give specifics as to these other possible applications (Franks & Sanford, 1976).

2.8 Software Aided Science Experiments for Students with Visual Impairment

Augmentative titration used to educate students on basic theories and techniques through guided laboratory experiments. This study integrated several programmable instruments such as automated pumps for liquid transfer into an augmented titration setup that can be operated remotely. This system uses Siri as a speech recognition tool and Python programming language to develop action routines for titration uses. The application of Siri provides a smooth user-to instrument experience, and the use of Python allows coders to electively develop and maintain the work flow. Three chemistry professors positive feedback highlighted the promise of our system as a valuable addition to undergraduate chemistry teaching laboratories. Further, this tool introduces students to the type of automated experimentation that is emerging as the modern standard in chemistry research laboratories (Yang et al., 2021).

The Independent Laboratory Access for the Blind (ILAB) project developed and evaluated a suite of talking and audible hardware/software tools to empower students with BLV to have multisensory, hands-on laboratory learning experiences. The ILAB tools were designed to provide multisensory means for students with BLV to make observations and collect data during standard laboratory lessons on an equivalent basis with their sighted peers. Various qualitative and quantitative data collection instruments were used to determine the ILAB tools had led to increased involvement in laboratory-goal-directed actions, greater peer acceptance in the students' lab groups, improved attitudes toward science, and increased interest in science. Premier among the ILAB tools was the JAWS/Logger Pro software interface, which made audible all information gathered through standard Vernier laboratory probes and visually displayed through Logger Pro. ILAB tools also included a talking balance, a submersible audible light sensor, a scientific talking stopwatch, and a variety of other high-tech and low-tech devices and techniques. While results were mixed, all four participating BLV students seemed to have experienced at least some benefit, with the effect being stronger for some than for others. Not all of the data collection instruments were found to reveal improvements for all of the students, but each of the types of data provided evidence of benefit for varying subgroups of participants. It is the expectation of the ILAB team that continuing to implement adaptive technologies for BLV students in science

laboratory classrooms will foster enhanced opportunities in science classes and professions (Cary Alan Supalo, 2010).

Talking Tools were assisted Students Who are Blind in Laboratory Courses. A number of tools and techniques have been developed to assist students with blindness and visual impairment who are studying in secondary and post-secondary science laboratories. Commercial electronic probes and their associated software packages allow real-time viewing and collection of data using a personal computer; however, until now, these data have been inaccessible to students with blindness or visual impairment because of the incompatibility of the data acquisition software with screen-reading software, programming modifications allowed a new level of compatibility, which promotes a greater degree of independence and accessibility to laboratory science for people with visual impairment (Cary A Supalo et al., 2007).

2.9 Smart Phone Aided Science Experiments for Students with Visual Impairment

Open source physics education applications in terms of blind users in inclusive learning environments are available. All apps are categorized as partially, full or non-supported. The roles of blind learner's friend during the application are categorized as reader, describer or user. Mentioned apps in the study are compared with additional opportunities like size and downloading rates. Out of using apps it also get information via internet and some other extra information for different experiments in physics lab. Q-codes reading or augmented reality are two other opportunity provided by smart phones for users in physics labs. The study also summarized blind learner's smartphone experiences from literature and listed some suggestions for application designers about concepts in physics (Bülbül, Yiğit, & Garip, 2016).

An Android-based application to provide colorblind and students with visual impairment a multisensory perception of color change observed in a titration. This application records and converts the color information into beep sounds and vibration pulses, which are generated by the smartphone. It uses a range threshold of hue and saturation coordinates of the HSV (hue, saturation, value) color space for detecting a

color change specific to an indicator for, e.g., shades of pink for phenolphthalein-based titration, and informs the users before and upon attaining the end point. This approach can enable color-blind and students with visual impairment to actively perform a fairly routine laboratory activity of titration (Bandyopadhyay & Rathod, 2017).

2.10 Accessible Science Lab for the Students with Visual Impairment

Numerous low-cost methodologies assisting students with BLV in the chemistry classroom, including Braille-labeled magnets, Styrofoam balls, clay balls, straws cut to varying lengths, commercially available model kits, and more. Many ways are available to modify periodic trends, valence shell electron-pair repulsion (VSEPR) theory, basic laboratory methodologies for measuring volume, and the use of a two-dimensional felt board to illustrate organic chemistry mechanisms. The Submersible Audible Light Sensor (SALS) developed in the Chemistry Department at Pennsylvania State University was described, and how it could be used to indicate color changes to persons with blindness. Additionally, the paper included an overview of the uses of technology in the chemistry classroom as pertaining to learners with BLV (Graybill, Supalo, Mallouk, Amorosi, & Rankel, 2008).

The conventional biology laboratories without any assistive technologies for students with visual impairment are not able to provide wholesome learning environment to students with visual impairment. In conventional laboratories students with visual impairment face problems in performing practical of microscopy, anatomy, physiology, biochemistry, dissection, taxonomy and morphology. By making certain modifications and integrating assistive technologies, conventional laboratory can be used to indicate color changes to persons with blindness. Additionally, the paper included an overview of the uses of technology in the chemistry classroom as pertaining to learners with BLV.

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made accessible for students with visual impairment where both students with visual impairment and students without visual impairment can work together (Kamble, Bhole, & Jadav, 2013).

The most standard lab exercises have a strong visual orientation, and some processes (e.g. mitosis) that are mainly explained through diagrams are difficult to understand from a verbal description alone. To address this problem, the tactile models were developed for Braille-labeled “manipulables” that allow students who are blind to make their own observations with the help of “seeing-eye student” assistants. These models were used to accommodate the students with visual impairment at WVU (Caldwell & Teagarden, 2007).

Verbal descriptions were inadequate and while actual specimens of rocks, plants, and animals were often helpful, they were not sufficient in many circumstances. For example, the study of flowers, leaves, or roots were difficult because actual plant matter were often much too small for detailed tactile exploration (Burke, 1932).

Multisensory approaches were recommended to teaching laboratory science to students with BLV. The greatest challenge in teaching science to the blind was finding appropriate methods for laboratory work. The best technique was having the teacher conduct demonstrations using equipment that could be tactilely explored by the students and that produced experimental results involving noises such as small explosions or buzzers whenever possible. Commercial adaptations were few and the quality of improvisations relied on the creativity of individual teachers. The goal was to achieve high quality education equivalent to that offered in schools for the sighted (Hamilton, 1932).

Laboratory classrooms for the blind should have all the science equipment found in any fine school, but specifically adapted for students with BLV as much as possible (Long, 1940).

Appropriate instrumentation in the chemistry laboratory for students with BLV is important. The Optacon, a device that utilized a small handheld camera to take images of printed characters and produced vibrational outlines of those characters on a separate pin touch pad, could be utilized to read display screens on laboratory

equipment such as various amplifiers and, particularly, digital multimeters. Safety concerns in the laboratory, and how the laboratory could be hazardous for persons with BLV as well as their sighted counterparts should be addressed. This interface of the Optacon along with standard laboratory equipment provided great versatility of use for students with visual impairment (Anderson, 1982).

Adaptation of the Chemistry Laboratory Curriculum for Visually Handicapped Students, evaluated the feasibility of students who are blind' participation in a general chemistry laboratory course. They looked at a number of experiments and developed a few audible tools, and concluded that, from the perspective of 1980s technology, BLV students would always require some level of sighted assistance in carrying out experiments (Horowitz, Foulke, Shoemaker, Deck, & Taylor, 1987).

A small number of laboratory modifications were necessary to make participation easier in a general chemistry laboratory for students with BLV, and that these accommodations were relatively low cost. The major difficulty identified was the lack of a Braille textbook. Not having the concepts in Braille made it difficult for the students to track their data. This paper also described several demonstrations utilizing a buzzer connected to the LED display of a conductivity probe, which allowed students with BLV to respond along with their sighted counterparts (Ratliff, 1997).

The dependency of distance and time in pendulum experiment to the students who are blind was reduced using Arduino and ultrasonic sensor, the periodic oscillation of the pendulum is translated in a periodic variation of frequency in a speaker. The main advantage of this proposal is the possibility of understanding the movement without the necessity of touching it (Goncalves et al., 2017).

2.11 STEM Education for Students with Visual Impairment

Using Inclusive Design to Improve the Accessibility of Informal STEM Education, for Children with Visual Impairment was conducted by (Murgaski, 2020). STEM workshops are designed to provide experiences for twenty-five blind and students with visual impairment children at a summer camp, with STEM activities that are engaging and fun as well as educational. The workshop aimed that the participants should have equitable experiences to their peers without visual impairment, so that they

may get the same enjoyment from the STEM workshops as any other participants. The study investigated the accessibility features of various commercially available robots, and consider the stability of accessibility features as robots are updated and replaced over time.

The study on *Computer Haptics: A New Way of Increasing Access and Understanding of Math and Science for Students Who are Blind and students who are Visually Impaired* that visual information is used to present math and science content. This can take on many forms in the classroom from textbook pictures to computer simulations. These visual presentation methods are not readily accessible to students with visual impairment and this can lead to a lack of understanding and concept development. The students may not understand what they are missing and the teacher may not know how to easily convey that information. An innovative technology, computer haptics, provides a way to easily offer additional information through the sense of touch to supplement information being provided through auditory and visual means. Using a computer and a peripheral device called a haptic force-feedback controller students can virtually explore three-dimensional shapes and receive tactile and kinesthetic sensations (Darrah, 2013) .

Role of Teacher limit the participation of blind and partially sighted learners in mathematics and science education. Since the teacher, still remains one of the most crucial factors in any education system, the role of the teacher as understood by a blind technician in promoting the participation of blind and partially sighted learners in mathematics and science subjects. The study revealed that teacher motivation and mentorship in mathematics and science methodologies and the use of tools for learner empowerment are lacking. It further revealed that teachers lack the requisite skills in special education to harness learner potential in mathematics and science. This situation necessitates government action in teacher training and development (Maguvhe, 2015).

Hands-on summer enrichment programs held for BLV students. Also innovative technologies that were developed to provide spoken quantitative feedback for BLV students engaged in hands-on science learning activities. Some low-tech polymer synthesis activities that were designed to be very tactile and hands-on in scope are also discussed. These activities were presented in several recent workshops and can be

reproduced and implemented as part of a chemistry course in high school or used as hands-on demonstrations for all learners (Cary A Supalo et al., 2014).

Persons with BLV could conceptualize physics and mathematics graphs through sound. Alterations in pitch to indicate changes in the slopes of linear graphs were utilized. Incorporation of a dash tone feature to indicate negative slopes, and used continuous sounds with changing pitch to represent sine and cosine graphs. This work later served as the basis for View Plus Technologies' current product known as the Audio Graphing Calculator (AGC), now commercially available from various retailers of access products for persons with disabilities. The AGC is used by persons with BLV around the world, helping them to visualize graphics in an audible format (Sahyun, 1999).

Some students who are blind, like their sighted counterparts, have an interest in astronomy that could lead to greater enthusiasm for the sciences. However, students who are blind have difficulty accessing the graphical materials in STEM-related courses; educators tend to lack expertise in teaching scientific concepts to BLV students; and expectations by teachers, parents, and the students themselves impact the students' performance in science classes (Beck-Winchatz & Riccobono, 2008).

2.12 Conclusion

This research review purpose is to help the reader understand different aspects of education of students with visual impairment particularly focusing on science education. There has been much research and discussion conducted on teaching science to students with visual impairment including tactile models, low cost techniques to illustrate chemistry and physics concepts, adapted tools, environmental modifications, accessible labs for students who are blind and students who are visually impaired, assistive technology for conducting experiments and effect of sensor devices to perform science experiments. Most of the research found was on assistive technology and components but the effectiveness of such technology for science education of students with visual impairment needs to be established. More testing is required to gain better understanding of how technology is useful and why the students with visual impairment are struggling to identify themselves with their peer groups. Research on the Literature review revealed that in countries like the United States, common Science experiments

have been modified to the needs of students with visual impairment. But in Indian context, such modification/adaptation or development of new devices for science experiments is rarely noted. Hence the present research was planned to develop a tool and study its effectiveness by introducing to students with visual impairment