CHAPTER I

INTRODUCTION

1.0 Introduction

The present study entitled **"Development of Science Lab Talking Device(SLTD) and its Effectiveness for Laboratory Experiment for Students with Visual Impairment"** is related to designing and development of Science Lab Talking Device using hardware and software to perform Science Experiments by the Visually Impaired students. Science Lab Talking Device has been developed using the hardware called Arduino Mega 2560 which is compatible with all sensor operations. In the present study, sensors such as load cell sensor, current sensor, voltage sensor, colour sensor and temperature sensor were used. Thus the device has both hardware and software system. The Embedded C program interface technology is used for real time data collection and converting the output in voice reading to enable visually impaired students to get the real time data in voice form. The voice output is read both in Tamil and English language. The output is heard through an ear phone/head phone connected with the device. The study had two stages: Designing and Developing the Science Lab Talking Device and Study the effectiveness of the Device by introducing the device to the students with visual impairment to perform various Physical Science Experiments. The effectiveness of the SLTD was found through intervention was given in four major components 1. Orientation to Basic Science Concepts, 2.Introduction of Existing/Adapted Science Lab Materials/Instruction, 3. Instruction for Using the Device for Various Experiments 4. Procedure for Introducing to Science Experiment using SLTD.

In this Chapter, the details in respect to Historical Perspectives of Education of People with Blindness & Low Vision, Evolution of Education of Persons with Visual Impairment in India, Inclusive Education for the People with Disabilities, Science Education for People with Disabilities, Science Education for Students with Visual Impairment, Method of Teaching of Science to Students with Visual Impairment, Global Standards on Science Education for the Students with Visual Impairment, Sensors & Software for Data collection of Science Experiments to the Students with Visual Impairment, Rationale of the Study, Statement of the Problem, Hypotheses, Scope of the Study, Delimitations of the Study and Organization of the Study are described.

1.1 Historical Perspectives of Education of People with Blindness & Low Vision

The people with visual impairment have passed through various stages of being treated as rejects of the society to being recognized as talented persons who were no inferior to their sighted counterparts the people with visual impairment have passed through the phases of getting social protection during the Judaic and Christian periods in the West, more for consideration of body than soul (Kirtley, 1975). Prior to the 80s blind people were mainly self-taught, often being given appropriate assistance. France was the cradle of new attitudes towards the blind and started the first school for blind children. The philosophical groundwork was laid by Diderot, an enlightened philosopher and physician to King Louis XV. In 1749, he published 'Letter on the Blind for the Use of Those Who See'. The next giant step was taken in Paris in 1784 by Valentin Hauy when he established the Institution des Jeunes Aveugles (Institution for Blind Youth). Admiration for their competence, not pity for their blindness, was what he hoped to engender for his students. The first school for blind children, which Hauy founded, was to become a model. Education of the children who are blind received a further boost by 1834 with the successful adaptation and development of the embossed dot code by Louis Braille, a Frenchman, himself blind. Until this time, people who are blind did not have an efficient system of reading and writing. Therefore the code which bears Braille's name, still taught around the world, ushered in an era of easier communication among the people who are blind themselves opening the doors for the acquisition of information and knowledge through the sense of touch (Punani & Rawal, 2000).

Hauy's success led to the establishment of similar institutions in Europe, including the first school for the students who are blind in Liverpool, England, in 1791. Almost half a century after the founding of Hauy's institution, the first school for the children who are blind was opened in the United States. Three private schools were then founded almost simultaneously. They are presently known as Perkins School for the Blind (1829), the New York Institute for the Blind (1831), and Overhrook School for the Blind (1833).

1.2 Evolution of Education of Persons with Visual Impairment in India

The residential model was rapidly replicated, not only in the USA but also beyond the shores of Europe and North America. The missionaries arrived in Asia and other parts of the world before the turn of the 19th Century to offer education and rehabilitation services to people who are blind. In India, Miss Annie Sharp, a Christian missionary from England, founded the first school for the blind in Amritsar in 1887. There were just four schools for the blind at the turn of the Century. But the efforts in this direction by the voluntary organizations and the Christian missionaries continued. By 1944, when the report on blindness in India was submitted, there were 32 schools in undivided India. Most of these schools were being managed by private agencies, with grants from some State Governments (NCERT, VI Educational Survey, 2006).

1.3 Inclusive Education for the People with Disabilities

Inclusive education is a new approach towards educating children with disability and learning difficulties with that of normal ones within the same roof. It seeks to address the learning needs of all children with a specific focus on those who are vulnerable to marginalization and exclusion. It implies all learners with or without disabilities being able to learn together through access to common pre-school provisions, schools, and community educational settings with an appropriate network of support services. This is possible only in the flexible education system that assimilates the needs of the diverse range of learners and adapts itself to meet these needs (Sanjeev & Kumar, 2007).

Inclusion is more than a method of educating students with disability. To meet the challenges, the involvement and cooperation of educators, parents, and community leaders are vital for the creation of better inclusive schools. Therefore, inclusion arose as a good solution to the question of how to educate these children more effectively (Singh, 2016).

To create equity of education to children with disability, is applied in different situations and contexts globally. It also indicated that both teachers and students with visual impairment were found to have a positive attitude towards the inclusive teaching-learning process (Bishaw, 2013).

Teacher training in special education is imparted through both face-to-face and distance mode(Sanjeev & Kumar, 2007). Different kind of teacher training programmes is implemented under Inclusive Education. The capabilities of teachers required to deal with children with special needs are out of mainstream schools. (Indumathi, 2002), stated that Inclusive education must respond to all pupils as individuals, recognizing individuality as something to be appreciated and respected.

1.4 Importance of Science of Education

Science education is the one of the core component of the basic education. It has a great importance in the development of children’s scientific thinking skills, in their ability to answer scientifically the problems they encounter in daily life, in the development of problem solving skills, and in the growth of their experience and skills in life. Science education has been identified as one of the most useful and valuable areas of content for students with special needs by some special educators (Mastropieri & Scruggs, 1994).

In addition, science education can contribute to students’ understanding of the world and their ability to form a scientific basis for the problems encountered in everyday life (Leong, 1993). In addition, science education has an important place in the development of problem-solving abilities and scientific attitudes, and in the enhancement of the experience and skills that recommended for the special educators, in the perception of the world, in making correct decisions in the direction of perceptions. It offers students the opportunity to experience rich experiences in order to understand the interrelationships of objects in the light of new ideas (National Research Council, 1996).

Science education provides great opportunities for students to develop high-level thinking skills and problem-solving strategies (De Boer, Pijl, & Minnaert, 2012) The efficiency of science education arises from well-prepared science activities.

1.5 Science Education for People with Disabilities

Science has been considered as one of the major subjects that can be taught to students with disabilities. Potential benefits of science education for students with disabilities are described by (Mastropieri & Scruggs, 1992) as (i) expanding experiential background for students who have had limited experiences; (ii) covering skills and knowledge important for adult functioning; (iii) using concrete, hands-on learning activities; and (iv) developing, through science activities, problem-solving and reasoning skills. Science would be beneficial for students with visual impairments because it may allow them to develop compensatory skills for observing, manipulating, and classifying phenomena and related matters.

Science learning should be accessible by all learners (Holbrook, 2010) including the student with special educational needs. Science Education for All is one of the manifestations of Education for All (EFA, 2000). However, science education typically has received little emphasis in classrooms with visual impairments (Supalo, 2012). There might be several different reasons for this such as special education teachers may have little training in science, they may have difficulty obtaining relevant materials, or because they may find little time left for science after extensive allocations of time for basic skills instruction (Mastropieri & Scruggs, 1992). Regarding the upper grades, subject teachers such as science teachers although they know the subject may not have any kind of training for teaching students with visual impairment, they may not be able to adapt the current curriculum to the needs of those students or may not be able to access to the tactile materials or equipment to produce these materials.

1.6 Science Education for Students with Visual Impairment

Traditionally science teaching mostly depends on visual instruction (Sözbilir, 2016; Supalo & Kennedy, 2014). However, the distinction must be made between compensatory skills and functional skills so that students with visual impairments can access the expanded core curriculum in addition to the core academic curriculum of general education. Compensatory skills are those skills needed by students who are blind or visually impaired to access all areas of the general curriculum. Compensatory and functional skills include concept development, spatial awareness, keyboarding skills, listening skills, organizational skills, use of the abacus, or tactile discrimination skills (Holahan, McFarland, & Piccillo, 1994).

The curriculum framework sets out what a student with visual impairment should be able to do and the experiences that contribute to their learning needs of them. The curriculum should be balanced with due consideration given to the student's physical, social, emotional, linguistic, and cognitive needs. To teach children visual impairment, the teacher should adopt a consistent, realistic, and flexible approach in curriculum planning and implementation (Lohmeier, Blankenship, & Hatlen, 2009).

Many concepts in science and mathematics have been found inaccessible to students with visual impairment due to the use of figures, equations, and graphs (Annable, Goggin, & Stienstra, 2007; Kizilaslan & Sözbilir, 2018; Sleeuwenhoek, Boter, & Vermeer, 1995). Teachers can make the world of science more accessible to students with visual impairments through collaboration and specific adaptations in both the science classroom and laboratory by providing students with a variety of opportunities to explore and examine real materials closely or use models (Hadary, Cohen, Hadary, & Cohen, 1978).

A student with visual impairment is one of the types of students with Special Educational Needs who have limitations to obtain information through their eyesight sense. Besides being accessible to all learners, science learning also should be prepared for further education, employment, and independent living and should help students in developing an understanding and habits of thinking, which is needed to solve the problems in life (Mundilarto, 2002) for students who have visual impairment. Students with VI have the same cognitive abilities range as sighted students (Kumar, Ramasamy, & Stefanich, 2001) and the students with good accommodations help can master higher-order science concepts as well as sighted students (Jones, Minogue, Oppewal, Cook, & Broadwell, 2006)

Most of the science teachers and college science educators in (Stefanich, Norman, & Egelston-Dodd, 1996) study believed that students with visual impairment could become scientists such as chemists. Indeed, most students who have visual impairments have cognitive abilities equivalent to their peers but there seems to be a large gap between teachers' beliefs about students' capabilities and instructional resources available to help these students realize their full potential. There is evidence that students with disabilities are often not given the same opportunities to experience science as students without disabilities. Special education teachers often lack knowledge about the science curriculum, science content, and science pedagogy (McCarthy, 2005).

Student who is blind from birth could deal successfully with a college-level pre-med physics course if provided with appropriate faculty and student support. They emphasized the necessity for a one-on-one tutorial as the primary mechanism for learning. Including students with disabilities in regular classrooms requires some adjustments in the learning environments and in the instructional techniques. In general, successful classroom teachers have the skills to teach students with disabilities. The instructional units should be designed in such a way that it must emphasize that every student has potential that appear at different levels with different teaching methods(Parry, Brazier, & Fischbach, 1997).

Science and mathematics education is less accessible to children who are blind and partially sighted children since many of its concepts are presented graphically, and there are many concepts that cannot be explored by touch and are put across through visual observation (Kalra, Lauwers, Dewey, Stepleton, & Dias, 2009; Maguvhe, 2006; Sahin & Yorek, 2009).

For several reasons, the chances are slim for children who are blind and partially sighted to pursue a science education (Schleppenbach, 1996). Many people fear sight loss more than they do other impairments (Dickerson, Smith, & Moore, 1997) and tend to think that without sight, one would not be able to do any of the most taxing mental activities that sighted people are typically able to do.

Teacher motivation and mentorship in science learning are lacking (Maguvhe, 2006). Students with visual impairment need more instructional and environmental accommodations like an audio experience than visual instruction to learn science(Sahin & Yorek, 2009). Students with visual impairment do have an impact on academic performance, i.e., the students with visual impairment are more likely to have poor academic performance (Kovarski, Faucher, Orssaud, Carlu, & Portalier, 2015).

1.7 Method of Teaching of Science to Students with Visual Impairment

General information about standards-based content delivery, inquiry-based instruction, laboratory experiments, physical and biological science participation, astronomy participation, pedagogy, assessment, length of time spent in general education, and support by the teacher of students with visual impairments were assessed. And the majority of students with visual impairments are being educated according to state science standards of US, in the general education science classroom, and are participating in experiments with their sighted peers(Tiffany Ann Wild & Paul, 2012).

Much of the research on science instructional strategies for students who are visually impaired is related to making accommodations to existing science curricula and science materials, in order to provide access for those students (Jones et al., 2006; Kumar et al., 2001; Rule, 2011).

The students with visual impairment expressed very positive attitudes during the space science camp conducted due to the access to these hands-on accessible materials, and expressed less positive attitudes about their experiences in the general education classroom(Rule, 2011).

There is little research to show if these accessible instructional strategies are actually being used in the science classrooms in which students with visual impairments are being educated.

The teachers do not feel equipped to adequately teach students with visual impairments in the general education science classroom and are receiving very little training, prior to on the job training(Kahn & Lewis, 2014). The role of a teacher of the Students with Visual Impairment is an important one that helps to ensure that general education teachers understand the unique needs of these students. This study sought to understand what science education for students with visual impairments looks like in the classroom, from the unique perspective of Teachers of Students with Visual Impairment.

In mainstream science classrooms, as well as in non-formal environments, an effective approach for teaching science is the Inquiry-Based Learning (Minner, Levy, & Century, 2010). As a pedagogical strategy, inquiry-based learning in students and helps develop generic skills by playing different roles during a science session. This constructivist strategy is based in questioning, observing, researching, analyzing and applying. All inquiry-based learning experiences have four essential stages: focalization, exploration, reflection and application; and students plat specific roles to foster and assure collaborative work; these roles are secretary, reporter, leader and materials manager. At the beginning of the session, the teacher/facilitator will focus the group towards the learning objective in mind by making question(s) that the students will have to answer by exploration and experimentation. While the students explore and collect the evidence, they will have to organize to play the role assigned and to function as a team using their different abilities.

1.8 Global Standards on Science Education for the Visually Impaired

In the United States of America, The Individuals with Disabilities Education Act of 1990 (IDEA, 1990) and its reauthorization Individuals with Disabilities Education Improvement Act of 2004 (IDEIA, 2004) mandate that students with disabilities have access to educational experiences in the least restrictive environment (LRE).

The No Child Left Behind Act of 2001 (NCLB, 2002) requires that they have access to general education content taught by highly qualified instructors. Additionally, NCLB requires that students with disabilities be held to rigorous standards and participate in standardized testing based upon those standards.

Moreover, the Next Generation Science Standards (NGSS) advocate for excellence and equity for all students including those with disabilities (Achieve, 2013). The Next Generation Science Standards were developed to provide a consistent science education framework for ALL students based upon practices, core ideas and crosscutting concepts. (Achieve, 2013) and were subjected to a full review by the diversity and equity team (Miller & Januszyk, 2014). The NGSS draw about how students learn science and attempt to reduce the disparities in student outcomes across diverse groups (Miller & Januszyk, 2014).

"All Standards, All Students" (NGSS Lead States, 2013) provides teachers with case studies demonstrating how the standards can be implemented in classrooms with diverse populations. At the heart of the case study addressing students with disabilities are the principles of Universal Design for Learning (CAST, 2012) and differentiated instruction.

In Universal Design for Learning (UDL), barriers to learning are removed to improve and optimize teaching and learning for all people based on scientific insights into how humans learn. The use of Universal Design for Learning (UDL) frameworks provides multiple modes of access and engagement with content, as well as, multimodal means for student expression (CAST, 2012). Through the use of multimodal representations, students with disabilities can be supported in their understanding of complex science concepts and have options for demonstrating science understanding, aligning well with UDL.

The framework of NGSS stresses the importance of teaching science through inquiry based methods which has been shown to be an effective instructional strategy for students with visual impairments (Hilson, Hobson, & Wild, 2016; Koehler, 2017; T. Wild, 2010; Tiffany A Wild, Hilson, & Farrand, 2013; Tiffany A Wild, Hilson, & Hobson, 2013; Tiffany A Wild & Trundle, 2010). In an inquiry-based classroom, students engage in the actual work of scientific investigation of the natural world through scientifically oriented questioning and discovery (Koehler & Wild, 2019).

Students with visual impairments can participate in inquiry based methods of exploration in a similar manner as their sighted peers, but require accommodations and access to modified equipment (Koehler & Wild, 2019). For example, a student who is blind may need access to modified lab equipment such as a talking thermometer, braille metric ruler or a braille periodic table in order to be a full participant in a scientific investigation. While this equipment is readily available in the marketplace, general education teachers and administrators may not know of its existence.

Students with Visual Impairments can access and participate in the Science Curriculum on the use on both high tech and low tech equipment for students with visual impairments. Therefore, the role of the teacher of students with visual impairments, as a collaborator, becomes critical for ensuring access to the modified equipment and other accommodations that students with visual impairments require to be successful in today's science classroom.

Approximately 60,000 children, ages three through twenty-one, in the United States, have a documented visual impairment, which may affect their educational functioning (American Printing House, 2014). According to the U.S. Department of Education, ("NCERT, VI Educational Survey," 2006) National Center for Education Statistics (2017), approximately 90% of students with visual impairments receive instruction in the general education classroom for at least a portion of their school day.

Instruction in the general education science classroom typically relies on highly visual content and instructional practices that must be made accessible for students with visual impairments (Koehler, 2017; Koehler & Wild, 2019; Ross & Robinson, 2000; Sahin & Yorek, 2009). Students with visual impairments, educated in the general education science classroom, require accommodations in order to access this highly visual science content and often receive services from a Certified Teacher of the Students with Visual Impairment, who can assist the content area teacher in making the necessary accommodations to the science curriculum.

Little research exists that evaluates whether students with visual impairments are receiving the necessary accommodations to the curriculum in the science room and whether science content is truly made accessible for these students (Tiffany Ann Wild & Paul, 2012). This study expands upon a research study by Wild & Paul (2012) that sought to examine the types of practices that were in use in general education science classrooms to make science accessible to students with visual impairments. It expands the previous study by examining specific science pedagogy, equipment, accommodations, modifications, and assistive technology used in the science classroom by students with visual impairments, as reported by Teachers of Students with Visual Impairment. Additionally, it helps inform if the goals of the NCLB and IDEA legislation are being realized by students who are visually impaired.

1.9 Challenges in Teaching STEM subject to Students with Visual Impairment

It is a long held belief that technical subjects such as Science, Technology, Engineering and Maths (STEM) can be particularly challenging for learners who are blind or partially sighted. For example, Beal and Shaw (2008) reported that achievements in maths by learners who are blind and partially sighted tend to be below their performance in other academic subjects.

Similar findings for science were reported by (Dunkerton, 1997). Despite this supposed difficulty, there is evidence that learners who are blind and partially sighted can perform well in STEM subjects, and even excel at them. A student who is blind views his disability as an advantage in his studies of organic chemistry (Fletcher, 2011).

Teachers for the Students with Visual Impairment on how instructional practices are delivered to students with visual impairment in general Science classrooms. He concluded that of these students were physically in the same environment as their non-disabled peers, participation in Science experiments was low (Koehler, 2017).

Some aspects of engagement with classroom practice in science can be difficult for students who are blind/partially sighted without appropriate resources and instruction According to(Jones, Forrester, Robertson, Gardner, & Taylor, 2012), learning to estimate measurements is an important skill in science and in life. Making measurements tends to rely on visual perception, therefore this is an area which can be difficult for students who are blind/partially sighted.

The estimation skills of students who are blind/partially sighted were assessed and tasks involved the students showing with their hands how long they thought various measurements were e.g. millimeter, centimeter, meter, and feeling wooden rods and estimating their length. Results showed that whilst students who are blind/partially sighted were reasonably good at estimating measurements related to their real-world experience e.g pacing the length of a hallway, they were less able to estimate small distances e.g. millimeters and centimeters (Jones et al., 2012).

According to (Erwin, Perkins, Ayala, Fine, & Rubin, 2001) a key part of scientific discovery involves taking risks, something which children with visual impairments may be discouraged from doing.

The development of a science curriculum for children which aims to demonstrate the connection between children's play and scientific investigation. Observation of children taking part in the activities outlined by this curriculum showed that children were enthusiastic, persistent in their investigations, developed positive relationships with peers, used scientific language and made connections between their studies and the real world. This study demonstrates the importance of engaging children in science at an early age, and shows that children with visual impairments can be involved just like their peers (Erwin et al., 2001).

Another area which may be inaccessible to students who are blind/partially sighted without appropriate support is the way in which STEM subjects are taught. (E. J. Rowlett & Rowlett, 2009) highlight the fact that maths is often taught using the 'chalk and talk' method of teaching, focusing primarily on what the teacher is saying, and worked examples on a board. This can be difficult for learners who are blind/partially sighted as they are not able to see these worked examples and concept development on the board, but need the practice just like any other student (Rowlett, 2008). Whilst perhaps a simple conclusion would be to use a more accessible teaching method, the Quality Assurance Agency (QAA) for Higher Education has found chalk and talk methods to have substantial merit in mathematics teaching (QAA, 2007).

Another problem is that it is difficult to take in a lot of spoken information, and trying to take in large amounts of spoken mathematics without reference to what is happening on the board, or written notes can place high demands on memory (Cliffe, 2009). Spoken instruction can also be ambiguous, with teachers using gestures and referring to 'this equation' for example (Rowlett and Rowlett, 2009; Cliffe, 2009).

Some students have someone to help them such as a notetaker/class aide, which can be of use. However, a notetaker cannot explain what is happening on the board whilst the teacher is talking, and working through examples with a notetaker reading them aloud is a slow process, and can be difficult to concentrate on whilst the rest of the class are discussing the work as well (E. Rowlett, 2008). Furthermore, the presence of a notetaker/assistant may be a barrier to interaction with peers, potentially isolating the students who are blind/partially sighted and preventing true integration.

In some cases, class notes are provided ahead of time and can be produced in accessible formats for students who are blind/partially sighted. Many students value this, to the extent that some are reported to think there is no point attending lectures without notes (Cliffe & White, 2012). Indeed, Cliffe and White suggest that access to full notes in the right format enables students to focus on engaging with the class rather than trying to write down information given. However, there remain problems even with pre-prepared notes. Firstly, if lecturers don't follow the notes or change the order without warning, this can confuse students (Cliffe and White, 2012). Secondly, where PowerPoint slides are provided, the print copies only show the full slide and don't give the opportunity to work out answers/fill in tables as is often done in class by revealing the slide a bit at a time (E. Rowlett, 2008).

Various researchers have highlighted the need for further training for teachers to better equip them to teach STEM subjects to students who are blind/partially sighted. (Fraser & Maguvhe, 2008) report that many teachers even some of those working in specialist schools for the students who are blind/partially sighted have only had general teacher training, and therefore lack the skills and ideas for adapting the curriculum for those without sight. This results in students missing out on participating in class with detrimental effects on their learning.

According to (Norman, Caseau, & Stefanich, 1998), science is widely seen as a subject suitable for disabled students to be included in mainstream classes, but few science teachers have specialist training in supporting students with disabilities. Furthermore, few 'special education' teachers have specific science knowledge, meaning some disabled students slip through the gaps and receive very little relevant science education.

An intensive programme aimed at improving science instruction, which involved both specialists in visual impairment and specialists in science coming together to explore the benefits of using the natural environment to teach science to students who are blind/partially sighted(Penrod, Haley, & Matheson, 2005).

Research evidence relating to teaching STEM subjects to students who are blind/partially sighted is difficult to come by. According to (Ferrell, Buettel, Sebald, & Pearson, 2006) it is difficult for studies in this field to meet strict criteria for 'scientifically based research' due to low prevalence of visual impairment which makes it difficult to recruit suitable samples of students to take part in studies.

General guidance such as providing accessible materials and offering orientation in the science lab as well as examples specific to physical, chemical and biological science teachers of students with visual impairments in science subjects to be followed. It also reported on implications for educational policy, in terms of educating teachers on accessibility issues, changes to science assessments and integration of educational technology(Kumar et al., 2001.

1.10 Science Lab Experiments for Students with Visual Impairment

Learning is effortful and means changing and challenging knowledge. To learn an abstract concept such as those in science requires as much hands-on activity as possible. We all know that science experiences depend mostly on visual data and we may not know how hard it can be for a student with visual impairment being in a science laboratory.

A person who is blind seriously lack the skills in taking notes and recording data, it is helpful if the student who is blind can work with a sighted peer in conducting experiments which most of the time require taking data. While the student who is blind is operating the equipment, the peer student can explain the results and record the data for the student who is blind. Students who are blind showed that they could actually perform many of the activities in experiments such as plotting graphs, measuring angles, classification of rocks and minerals, and solving mathematical problems. Chemical experiments cause problems since they require visual observations in most cases such as chemical reactions. If bubbles are emitted in a chemical reaction or if a chemical reaction involves a temperature change, the student who is blind can feel the reaction in progress by hearing or by touching. However, if a color change is involved in the reaction, the student who is blind will need his/her sighted partner to explain the reaction for him/her(Eichenberger, 1974).

Tactile measuring tools for students with visual impairment by photocopying sections of a meter scale onto transparencies, and pasting the cut sections into a meter long scale, and using staples or glue to emboss each centimeter marking(Wagner, 1995). The Students with Visual Impairment could use this tactile scale to practice measuring objects. According to Wagner (1995), such measurement activities should help students with visual impairments "gain self-confidence in a skill easily transferable to real life"

Most lab equipment requires visual confirmation for amounts and measures. Therefore, the majority of students with visual impairments have limited participation in labs. Without access to full participation in labs, students with visual impairments are hampered in their learning.

This problem has motivated the development of a number of computer-based assistive tools and most recently talking laboratory tools (Supalo et al., 2007) Assistive technologies and laboratory data collection aids can aid learning of STEM (Science Technology Engineering and Mathematics) subjects by the Students with Visual Impairment (Mulloy, Gevarter, Hopkins, Sutherland, & Ramdoss, 2014).

The recent reports evidenced that it is usual that students who are blind are not allowed to perform experiments in the laboratory, but instead, are paired with a sighted student who performs the tasks and shares the information on the experiment that is taking place (Pence, Workman, & Riecke, 2003). Opportunely, in the last few years, there have been organizations or groups that have offered science camps for youngsters who are blind and visually impaired (Wedler et al., 2012) where hands-on experiences are enforces.

1.11 Development of Science Laboratory Adaptations/Equipments

In science, hands-on activities are essential for a meaningful learning. Since the 1970's there have been reports on adaptations to make experiments accessible for the students who are blind (Malone & De Lucchi, 1979), and several of them focused on chemistry experiments, mainly titrations (Hiemenz & Pfeiffer, 1972). More recent examples of how researchers have shown that experiments on titration can be accessible by using olfactory cues, are the reports of (Neppel, Oliver-Hoyo, Queen, & Reed, 2005; Wood & Eddy, 1996), demonstrating the use of the odor of raw onion, garlic or vannillin to indicate the endpoint of the titration of solutions of sodium hydroxide with hydrochloric acid.

In those cases, odor is used instead of phenophthlein, the most used color indicator of pH. More recently, (Bandyopadhyay & Rathod, 2017) have developed a more sophisticated adaptation, which is an android app to detect the color change of phenolphthalein at the titration end point. Other authors have also suggested the use of acoustics to evidence electrochemical reactions (Cady, 2014), or proposed the use of a program for sonification of space physics data (Candey, Schertenleib, & Diaz Merced, 2006).

Students with visual impairment have the same needs in life science as their sighted peers. However, they lack the ability to observe the environment. In a college level study, (Baughman Jr & Zollman, 1977) reported their experiences including a student who is blind in a physics laboratory. They adopted all of the equipment for use by the blind student by using regular physics instructional materials which included a meter stick, timer, syringes, balance, graph board, and volume cubes. This study indicates that regular laboratory apparatus can be adapted to be used by the students with visual impairment.

Low cost adaptations of devices for the chemistry laboratories using recycled materials. For example, to detect conduction current in chemical substances, an adapted device analogous to that commonly used in regular chemistry labs was built. In this device, which regularly uses a bulb that turns in when there is conductivity in substances, the bulb was replaced by a buzzer 3-4kHz and 1.5-15 Vcc. The integrity of the user is protected by incorporating a recycled (old) cell phone charger to convert the output voltage of 110 V to 5 V. This way, the original device was easily converted to an accessible detection instrument, and thus, it became suitable for users with and without visual disabilities (Reynaga-Peña et al., 2018).

Tactile modifications of preserved specimens and humanely prepared living organisms could form excellent hands, on specimens in biology (Malone & De Lucchi, 1979). (Ricker & Rodgers, 1981) suggested modifying chromosome kits with “pop-it beads” using readily available tactile markers for teaching cell division. The suggested tactile markers include small plastic strips of various sizes and shapes to represent color codes, and holes to represent relative positions of chromosomes.

To enable students with visual impairments to observe fish in an aquarium: Place inside the aquarium a slightly smaller plastic aquarium with drilled in holes which functions like a sieve. As the student slowly lifts the inner aquarium and drains off the water into the larger aquarium, the fish will be trapped in the bottom of the inner aquarium. Now by the sense of touch the student can explore the fish. Supervision might be required in order to make sure fish are properly handled(Abruscato, 1988).

The same level of importance resides in the effective use of inclusive teaching strategies that promote active and autonomous learning by every student which should happen in parallel to being able to offer laboratory activities with an experimental design that facilitates spatial cues for safe manipulation in the science laboratory.

When the laboratory is accessible and safe for all by using the measures described above, the teacher or lab instructor can direct students to do, in the same session, the regular experiments and the ones with adapted devices. This could also be an opportunity to share results, discuss ideas and more importantly, to create in this way an environment inclusive for all students.

1.12 Laboratory Safety Issues for Students with Visual Impairment

A crucial part in laboratory practices is seeking accessibility without losing safety. First, to help Students with visual impairment to work independently in the experimental sessions, a piece of tape can be placed in the shape of a cross to divide sections as in a Cartesian plane in the laboratory table, so students can identify where the materials and solutions are strategically located for experiments. The instructions for the experiment could be written in Braille for Students to read, but also can be orally said at the time of the experiment. This strategy was used by our group in several workshops for teachers in Mexico. In these workshops, each student was completely independent and was able to conduct the experiments in the regular time. (Lopez Suero et al., 2017)

Issues of safety are often first-priority concerns for teachers of visually impaired science. Because the science laboratory can be a hazardous environment for all occupants, laboratory safety should be the first topic discussed in all science classes. Particular precautions should be in place in laboratories in which students with visual impairment are working. Science teachers arrange a time for students with visual impairment to "tour" the science laboratory. Ideally, this would be during the teacher's planning period or before or after school, when the lab is vacant and the teacher has the students' undivided attention. These students need to become familiar with the science lab environment so that they can move about the room with ease and locate necessary equipment and materials such as emergency showers, fire extinguishers, eye wash stations, and first aid kits (Kumar, Ramasamy, and Stefanich 2001).

Students with normal sight should also be prepared for the presence of a visually challenged student in the science laboratory. Establishing a rule that visually impaired students always have the right of way when they are moving about the class is recommended as well as cautioning students to keep aisles as barrier-free as possible. Students should also be warned about moving desks and other classroom furniture and materials from their regular placements without first warning students with visual impairment. Students with normal sight should also be briefed about the function of guide dogs and cautioned against treating them as pets. The teacher should ask the class for volunteers to work as a lab partner with the visually impaired student. This will prevent the assigning of a lab partner who may be unwilling or uncomfortable working with a visually impaired student.

1.13 Role of Technology for Education of Students with Visual Impairment

Students with visual impairments have historically used a wide variety of tools to assist them in their education (Turnbull, Turnbull, & Wehmeyer, 2007). Low technology aids such as handheld magnifiers and slate and stylus used to write Braille are found in schools along with high-technology devices such as computer screen magnifiers, Braille printers, and screen reading software.

An important policy consideration for high-technology approaches was the inclusion of the National Instructional Materials Accessibility Standard (NIMAS) in IDEA 04. NIMAS established technical specifications for electronic versions of print materials. These requirements increased the potential for greater access to literature because NIMAS provides digital text files that can render into appropriate formats for students. Because of this, there is a clear need to understand how students are accessing text and what ramifications such access has for large-scale assessment, especially in the area of English and language arts. The level at which students can access text through magnification equipment, Braille, or computerized equipment on large-scale assessments are all governed by Individualized Education Plan (IEP) team decisions and state testing accommodations policies. There are disagreement in some state policies about which accommodations are allowable and which are not (Thurlow, Thompson, & John- stone, 2006).

According to the American foundation for the blind (2014), assistive technology may remove many barriers related to education and employment for individuals with visual impairment. Students with visual impairment can complete homework, do research, take tests, and read books along with their sighted classmates, because of the use of computers and other devices. These include: Assistive technology programs that run on off-the-shelf computers can speak the text on the screen or magnify the text in a word processor, web browser, e-mail program or other application. Stand-alone products designed specifically for people who are blind or visually impaired, including Personal Digital Assistants and electronic book players provide portable access to books, phone numbers, appointment calendars, and more optical character recognition systems scan printed material and speak the text. Braille embossers turn text files into hard copy Braille. However this is not the case in African countries as AT remains out of reach in most educational systems (Belay, 2005).

1.14 Role of Technology in Teaching Science Experiments to Students with Visual Impairment

Wohlers (1994) has suggested that computer interfaced instrumentation provides tools for mass-volume measurements, and talking calculators facilitate calculations. Qualitative identifications of certain non hazardous materials could be made using the sense of smell (Keller, Jr., 1981).

Chemical reactions involving colors can be identified using a colorimeter interfaced with a computer programmed to convert color signals into Braille outputs. Also, light probes interfaced with Braille computers can be used as detectors for determining end-points in volumetric analyses. Similarly; modified ultra-violet and infrared spectrophotometers can be used for chemical characterization.

There are also devices designed to make accessible regular laboratory instruments via auditory information;, these instruments can output their readings of data as sound rather than graphics or numbers in a digital display, as it usually happens. One of those instruments is the Talking Lab Quest 2, a sensor interface for students who are blind or low-vision for use in science education, which uses Sci-Voice software. The Talking LabQuest 2 device couples to Vernier sensors (for pH, temperature, motion, conductivity, UV-Vis Spectrophotometer etc), making their use accessible in such way that students who are blind can easily follow in real time chemistry and physics experiments (Supalo, Isaacson, & Lombardi, 2014).

Using the Talking LabQuest 2, several experiments were adapted for the students who are blind and the results were documented; some examples are the relation pressure-volume in a gas, an acid-base titration using a drop counter, and the study of exothermic and endothermic reactions (Kroes, Lefler, Schmitt, & Supalo, 2016).

Those studies report that some limitations were detected when several Talking LabQuest 2 were used at the same time, since it was hard for the BVI students to identify the voice of their own terminal. However, they also reported that after students got used to it, the technology helped teachers and students to create more inclusive environments, and promoted the interest in science fields (Kroes et al., 2016).

With respect to educational materials for the classroom, our groups has developed tactile three-dimensional models to teach/learn biological concepts of microscopic nature (cell biology, microbiology, plant tissues), which are accessible to students who are blind and students with visual impairment (Reynaga-Peña, 2015). These models were conceptualized by scientists, so they have scientifically accurate information, and were developed by visual arts students, in order to be highly attractive to all learners. Because they were designed based on UDL principles, those 3D models hold adequate tactile resolution, contrasting colours and amicable tactile features for students who are blind, while being engaging for sighted users as well.

The first generation of 3D models was further improved by adding touch-response technology to provide auditory information and hence promote autonomous learning. Prototypes were made using polymer clay, and then covered with silver paint that connected to sensors. The hardware to transduce the signal generated by touch was bought from Touch Graphics. This way, the information reached a personal computer, triggering audio information through special software developed specifically for each prototype. A highlight of this system is that each part of the 3D model was individually wire, so the scientific auditory information related to each part was displayed as the user touched it. In the 3D prototypes created this way, users can hear one, or many times, the audio descriptions containing scientific information regarding the topic that is being represented herein. This second generation of prototypes is innovative and even more engaging, but their production cost was high due to the technology used, the software produced for each of them, and their artisanal fabrication.

Commercial agencies, such as Touch Graphics, have also developed general touch-response materials and educational tool using technology, which can be the Tactile Talking Tablet (TTT) device (Landau & Wells, 2003), where materials can be created for any subject through the Authoring Tool Software, those can be created by the BVI users themselves; and the set if tactile graphics on STEM subjects, made on specially designed thermoformed vinyl, which hold auditory information. A highlight of the latter is a periodical table of the elements that contains colours and printed text, as well as Braille and Tactile features.

More recently, with the widespread use of 3D printing technology, there is a new trend to create and use 3D printed materials to substitute thermoformed graphics. Several examples in subjects such as Biology and Astronomy have been reported in the literature (Grice, Christian, Nota, & Greenfield, 2015; Horowitz & Schultz, 2014). The possibility of using 3D printed objects versus 2D tactile thermoformed graphics is an advancement; however, most objects printed this way lack tactile resolution, particularly in terms of richness of textures, given that common 3D printers use a single type of printing materials. In addition, most if not all 3D printed materials, lack of technology that allow providing auditory information and therefore, do not promote autonomous learning. Thus, it is necessary to take into consideration the design frameworks.

1.15 Devices for Laboratory Experiments to Students with Visual Impairment

A need for accessible tools, and felt that more active participation in school laboratory activities could lead to higher rates of retention in the areas of science, technology, engineering, and mathematics (STEM) (Swanson & Steere, 1981). Morrison and Lunney developed the first 3.5 digit multimeter, which was capable of speech output and could measure time, temperature, and pH. They developed software that allowed students with BVI to use pH electrodes, visible spectrophotometers (Spectronic 20), infrared spectrophotometers, and piston burettes.

In 1983, Cetera described the use of two high-tech devices: a talking calculator from Sharp, which aided students with basic mathematical calculations, and the Opticon, a small camera able to read digital displays on balances and other laboratory equipment and then produce raised-line images from the data. Speech accessible computers were also discussed, and the paper predicted an increasing role of text-to-speech PCs in providing access to collected data.

A talking spectrophotometer was introduced by Hinchliffe and Skawinski, both from the New Jersey Institute of Technology, in 1983. In a move towards more accessible classrooms, the authors graciously provided, upon request, complete construction details of this device. In 1984, Lunney and Morrison attempted to create a speech interface that could accommodate the use of still more probes. Known as the

Universal Laboratory Training Research Aid (ULTRA), the device served as an instructional aid and talking personal computer.

Another notable innovation was the incorporation of a personal computer into the data acquisition process. Work by Wohlers and others in 1994 combined a now-unavailable speech-capable note taking device, the Braille 'N Speak, with standard laboratory equipment. In its “speech box mode,” the note-taker was able to read aloud any data values received, via cable, from laboratory equipment capable of outputting ASCII data streams. While many of the low-tech adaptive tools developed in the1980’s and 1990’s are still available or easily duplicated with inexpensive materials, the computer-based tools have become outdated. Nevertheless, these early demonstrations provide solid examples of assistive technology for students who are BVI.

1.16 Sensors & Software for Data collection of Science Experiments to Students with Visual Impairment

High school curricula increasingly use personal computers in the data collection process. Logger Pro software from Vernier Software and Technology, created and designed with high school teachers and secondary-level students in mind, provides a software interface between laboratory probes and users. Vernier also publishes its own science curriculum and laboratory exercises for secondary students; the course developed by (Volt & Sapatka, 2000) covers the use of these probes in high school, and notes that the level of precision is sufficient for these target groups. The Vernier Software and Technology company markets a line of over 70 low-cost analog and digital laboratory probes that allow a user to view, record, and manipulate data by using a personal computer. Up to four analog probes may be connected to the Vernier Lab Pro, a device that connects to a PC via USB port and potentially allows the parallel recording of four separate data streams.

The computer program Logger Pro allows users to view data graphically, compare hypotheses, and conduct statistical analyses. While not precise enough for research or medical uses, these probes are priced low enough to maximize availability to high school-level laboratory classes.

Vernier also produces a line of tools named Go, aimed at schools with exceptionally limited funding. When used in conjunction with a “Go-link” device, all the available probes plug directly into a USB port; data is then accessed with a scaled-down program named Logger Lite.

Job Access with Speech (JAWS) is another computer program frequently used by students who are BVI. JAWS is a computer screen-reader, typically able to speak the information that a sighted student would visually read. However, in an unmodified form, JAWS and Logger Pro are incompatible.

A level of success was achieved, the scripts were not maintained, and are now incompatible with newer versions of both JAWS and Logger Pro. To address this problem, new scripts have been written for current versions of Logger Pro (version 3.5) and JAWS (7.0 and 8.0), making the Vernier probes and data fully accessible to students with BVI. These scripts are available for download, free of charge, on the Independent Laboratory Access for the Blind (ILAB) website(Milchus & Goldthwaite, 2000).

1.17 Rationale of the Study

The mission of science education, in terms of school establishments, is to prepare individuals who would develop a certain level of scientific understanding and basic scientific process skills. Developing basic scientific process skills requires practice in and out of school. Therefore, practical work is seen as a prominent feature of school science teaching in many countries, and it is acknowledged that good quality of practical work promotes the engagement interest and curiosity of students as well as developing a range of skills, science knowledge, and conceptual understanding. Learning science requires intensive use of the senses, particularly the eyes in order to be a good observer (Abrahams & Millar, 2008; Abrahams & Reiss, 2012).

Students with visual impairment are required to complete the same curriculum and examinations as sighted students. However, due to the nature of science and mathematics, the majority of the education resources and instructional methods are based on vision, which is partly or not accessible at all by students with visual impairment. There is a need for adaptation in the educational resources and methods for the needs of individuals with visual impairment. Although there are some guidelines how to adapt educational resources to the needs of students with visual impairment, there is still a huge gap in how to adapt educational resources and instructional methods to the needs of them as they are a heterogeneous group. Science education is less accessible to students with visual impairments due to the fact that it includes many abstract concepts. These students typically need a variety of opportunities to explore and examine real materials or models by touch or putting across through residual visual observation (Gast et al., 1992; Wright and Wright, 1998).

As it is the case for all disabilities, it is true for students with visual impairment that they have been discouraged from learning science, technology, engineering, and mathematics (STEM), and as a result they are underrepresented in the STEM workforce (Supalo & Bodner, 2012). students with visual impairment are coming to the science and related courses with misconceptions embedded in mind, from either themselves or their teachers, that science are difficult and not accessible for them. Moreover, parents and employers are having doubts as to whether a person who is visually impaired can manage STEM related careers. In order to overcome this problem, there is a trend in the world that all classrooms have to be barrier-free. With the encouragement and help from the science education research community, it is believed that major barriers will be addressed and students with visual impairment are able to access science classrooms and achieve as same with their sighted peers. A review by (Mastropieri and Scruggs,1992) documenting research in science education for all disability groups resulted with 14 reports out of 66 reports being investigated. Taking this figure into account (Sözbilir et al.2015) suggest the emergence of interest in science education research community is encouraging, although the number of research reports in teaching science to students with visual impairment is still quite low compared to the entire science education research literature. Therefore, there is a strong need for research in this area to produce evidence-based practices in large scales.

Current literature indicates that the majority of the studies are still at a very beginning stage and they focus on different topics in science such as motion, electricity, development of scientific process skills, and inclusion. On the other hand, although the numbers are not high, studies vary from teaching primary science concepts (Wild, Hilson, & Hobson, 2013), biology (Fraser & Maguvhe, 2008), chemistry

(Lewis & Bodner, 2013), physics (de Azevedo, Vieira, Aguiar, & Santos, 2015). Exposure to science education contributes to the development of an interest in the science subject. Young people with disabilities who lack exposure to science may never have the opportunity to develop this interest. A lack of teacher training around appropriate accommodations in the sciences, particularly in the laboratory environment, may create barriers for students with disabilities (Moon et al., 2012).

One of the primary reasons for the exclusion of students who are blind from the sciences is their inability to perform practical. In the case of students who are blind, the practical component of science proves to be rather impractical (Sam Taraporewala, 2013).

Science education is less accessible to students with visual impairments due to the fact that it includes many abstract concepts. These students typically need a variety of opportunities to explore and examine real materials or models by touch or putting them across through residual visual observation (Gast et al., 1992; Wright and Wright, 1998).

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There is a need for adaptation in the educational resources and methods for the needs of individuals with visual impairment. Although there are some guidelines (i.e. Dion, Hoffman, & Matter, 2000) how to adapt educational resources to the needs of students with visual impairment, there is still a huge gap in how to adapt educational resources and instructional methods to the needs of the students with visual impairment as they are a heterogeneous group. Students with visual impairments differ in intellectual ability, development rate, social competence, and other factors. In addition, they differ in terms of their impairments, the extent of their visual acuity, and their ability in using the vision if they have.

Labs do not have technology that enables access, or devices that convert visual material into audio or tactile formats. The teachers and laboratory assistants also have little inclination to extend their imagination beyond the existing practices that prove tedious even for sighted students. Instead, authorities should focus their attention on evolving science assessment beyond standard practical formats. This will allow for inclusive lab spaces where students can use different modes of access to study concepts and conduct experiments.

Retrofitting lessons might not always be the best way out. For students who are blind to be able to compete with their sighted counterparts on an equal footing, teachers need to extend the boundaries of their syllabus and classroom beyond heavily sight-dependent methods. They must be diligent about providing students study materials in accessible formats such as Braille, large print, digital, tactile, or audio.

Schools require is fresh and non-visual thinking. They need to incorporate experiential and immersive learning with planned visits to the field, museum, and factories into the curriculum. Adapting lessons for students who are blind also gives sighted students the opportunity to learn beyond sight. Current trends in pedagogy encourage practices that are student-centric. Teachers can no longer expect students to constantly adjust to classrooms. They too will have to make concerted efforts to understand and integrate the child's needs and modes of learning.

Around the globe, there is a growing awareness about the need to make science accessible to students with visual impairment. There is an attempt to shift away from purely visual ways of learning and studying science.

The National and International Policies and legislations reiterate equality of education to persons with disabilities on par with persons without disabilities. The Sarva Shiksha Abhiyaan attempts to uphold the Right to Education Act, 2009. It promises to supply accessible textbooks and teaching-learning resources to students who are blind and low-vision enrolled in schools.

The Indian RPWD Act 2016 prescribes to provide learning materials and appropriate assistive devices to students with benchmark disabilities, in addition, to making suitable modifications in the curriculum and examination system. It also suggests Institutions need to gear themselves to not only admit, but also adapt to the varying needs of diverse student bodies. But even after legal binding, students with visual impairments are deprived of many learning experiences particularly when the concept is visually oriented. In Western countries, students with visual impairment are exposed to many adapted devices and gadgets helping them get the desire to learn science subjects. In the Indian context, the survey of literature revealed that there is hardly any device available to help students with visual impairment to participate in the science laboratory experiment. Hence an attempt was made in the study to develop a quest which is named as Science Lab Talking Device. The device is designed with the support of Arduino Mega 2560 as hardware and five types of sensors namely Temperature, Colour, Current Measurement sensor with Light Detection, Volte Measurement, and a Weight sensor.

This device was developed mainly to perform physical science experiments which were in the Grade VI to X Science curriculum of Tamil Nadu Secondary Board. This device would help the students with visual impairment to be involved in the physical science laboratory experiments and also help them collect the live data and interpret it. Here, the effect of the device was examined with the help of students' participation and performance in doing the science experiment in this Experimental Study.

1.18 Statement of the Problem

The Statement of the Problem is worded as: ***Development of Science Lab Talking Device and its Effectiveness for Laboratory Experiment for Students with Visual Impairment.***

Terms used in the study

Science Laboratory Experiment

The Science Activities carried out with apparatus and tailored procedures for designed inquiry questions

Visual Impairment

Visually Impaired in the study means Students with Total absence of sight or Low Vision studying in Special Schools and Inclusive Schools from Grade VI to X.

Sensor

A sensor is a device that measures physical input from its environment and converts it into data that can be interpreted by either a human or a machine.

Arudino

It is an Open-source electronic prototyping platform enabling users to create interactive electronic objects.

1.19 Conceptual Frame Work

In recent years there has been growing diversity in the profile of the learner population across the global education system. Whilst this trend is positive, it generates challenges for everyone involved in education. Learners who have a disability were considered to be amongst the most marginalized within the education system. Despite legal obligations for inclusive education in almost all States, it is considered about more than simply placing a learner who has a disability in a mainstream setting and providing additional support (French & Swain, 2004) and is about more than simply "being" in a setting(Clough & Nutbrown, 2005). Rather, it is about valuing everyone for who they are, regardless of the nature or source of that diversity (Kinsella & Senior, 2008). Inclusive education represents part of a global agenda requiring national governments and their agencies to produce and implement policies that promote inclusion (K. Wright, 2010). The concept of inclusion has greatly contributed to learning and teaching (Suleymanov, 2015)

The UNCRPD asserts that state parties shall "ensure that persons with disabilities are able to access general tertiary education, vocational training, adult education and lifelong learning without discrimination and on an equal basis with others" (Shevlin et al., 2020). Universal Design for Learning(UDL) is based on the " concept of creating spaces where all students can be educated, to the greatest extent possible, without the need for adaptation" (Novak & Rose, 2016). Inclusion demands major changes within society itself and should not be viewed in a vacuum (French & Swain, 2004). It is, therefore, essential to recognize that what happens within all aspects of education and training is integral to achieving authentic inclusive education and practice. The concept of Universal Design for Learning (UDL) is vital to inclusion because it increases access to equal learning opportunities within the mainstream teaching environment, including for learners with disabilities. UDL is a framework, based on scientific insights into how humans learn, to improve and optimize teaching and learning for all. Students with disabilities are found to be frequently trapped in a vicious cycle of exclusion from education, society, and mainstream development programmes due to a lack of necessary support and the means for equal participation (Ahmad, 2015).

Effective technology integration can help provide all learners the ability to access the general education curriculum, offering them multiple means to complete their work with greater ease and independence in performing tasks that they were formerly unable to accomplish, or had great difficulty in accomplishing (Jones et al., 2012). Approaches in the use of assistive technology in inclusive education focus on using technology to train or rehearse and to assist and enable learning. A large population of ‘at at risk' students are seen to need assistance. Assistive technology serves in bridging this gap by 'assisting' in educating children in the same classroom, including children with physical, mental, and developmental disabilities helping them to learn the material in a way that they can understand, by eliminating barriers as their peers (Smith, Austin, & Kennedy, 1996). Students who are blind or students with visual impairment face a number of challenges in laboratory science courses because many observations and manipulations are visual in nature. It is often difficult for students with visual impairment to participate directly in the laboratory. Without special adaptive tools and techniques, they do not receive the educational benefit of the “hands-on” science experience, nor are they on equal footing with their sighted peers. Students with visual impairment are an underrepresented population in science education as a result of technological and attitudinal barriers to equal access in the science classroom. This lack of sufficient educational opportunities for students with blindness and low vision has led to low participation in the professional scientific community.

A report from the National Federation of the Blind Jernigan Institute (2006) stated that historically, academic and vocational expectations for students who are blind, with few exceptions, have neither elicited nor supported high academic performance. The majority of these students who are blind have received especially inadequate training in science and math concepts, particularly during the critical middle and high school years, when a passion for a subject and career interest is best sparked. In the review of the Indian education system as far as science education is concerned, traditional techniques have included pairing students with visual impairment with students without visual impairment counterparts in science laboratory classrooms, thus encouraging a passive approach to learning. Even more unfortunate, waivers have often been granted to students with visual impairment, exempting them from participating in science courses.

In 1984, Lunney and Morrison attempted to create a speech interface that could accommodate the use of still more probes. It is known as the Universal Laboratory Training Research Aid (ULTRA), the device that served as an instructional aid and talking personal computer. While many of the low-tech adaptive tools developed in the1980’s and 1990’s are still available or easily duplicated with inexpensive materials, the computer-based tools have become outdated. Nevertheless, these early demonstrations provide solid examples of assistive technology for students with visual impairment. One of the main problems for students with blindness or visual impairments who wish to participate independently in a laboratory curriculum is the lack of talking and/or accessible tools (Bach-y-Rita, Collins, Saunders, White, & Scadden, 1969). The most common adaptation is for the student to work with a sighted laboratory assistant. The assistant’s responsibility is not to do the experiment, but rather to carry out the student’s instructions. This is to be done even if the student gives incorrect instruction. (Burgstahler, 2008). In order to prevent discrimination against disabled individuals and uphold their equal participation in society, the Indian Government established a legal framework to make access possible to a full range of educational opportunities for persons with disabilities. With this premise, the research aimed at designing a simple and inexpensive device that would allow students with visual impairment to perform their laboratory experiments in the same independent manner as their sighted counterparts. Such tools may allow students with visual impairments to get involved in laboratory experiments at an early age.

1.20 Objectives

The Objectives of the Study were to

1. Develop a Science Lab Talking Device (SLTD) for students with visual impairment to participate and perform Physical Science Experiments.
2. Study the efficiency of the device based on power (energy) and time.
3. Analyze the efficiency of the device based on its error free software programme.
4. Examine the efficiency of the device on its time complexly and space complexity.
5. Analyze the level of acquisition of Physical Science concepts by the students with visual impairment before and after the introduction of Science Lab Talking Device.
6. Find out the effectiveness of the newly developed Science Lab Talking Device on the efficiency of the students with visual impairment in performing the Physical Science Experiments.
7. Identify the effectiveness of the newly developed Science Lab Talking Device on the efficiency of the students with visual impairment in performing the Temperature Measurement Experiment.
8. Identify the effectiveness of the newly developed Science Lab Talking Device on the efficiency of the students with visual impairment in performing the Acid and Base Experiment.

9. Identify the effectiveness of the newly developed science Lab Talking Device on the efficiency of the students with visual impairment in performing the Electricity Experiment.
10. Find out the effectiveness of newly developed Science Lab Talking Device in performing the overall procedure involved in the Experiments viz., Listing the items for Experiment, Identification of Items, Setting Apparatus and Conducting Experiment in the selected Experiments.

1.21 Hypothesis

The following null hypotheses were framed for the study

1. There is no significant difference in the level of acquisition of physical science concepts by the students with visual impairment before and after introduction of the newly developed Science Lab Talking Device.
2. There is no significant difference in the efficiency of the students with visual impairment in performing Physical Science experiments at the pretest, posttest and delayed posttest levels.
3. There is no significant difference in the efficiency of the students with visual impairment in performing the Temperature Measurement experiment at the pretest, posttest, and the delayed posttest levels.
4. There is no significant difference in the efficiency of the students with visual impairment in performing the Acid and Base experiment at the pretest, posttest, and the delayed posttest levels.
5. There is no significant difference in the efficiency of the students with visual impairment in performing the Electricity experiment at the pretest, posttest, and the delayed posttest levels.
6. There is no significant difference in the efficiency of students with visual impairment in performing the overall procedure involved in the Experiments viz., Listing the Items for Experiment, Identification of Items, Setting Apparatus and conducting Experiment in the selected Experiments at the pretest, posttest, and the delayed posttest levels.

1.22 Scope of the Study

1. Students who are blind or have low vision typically do not get the same experience while participating in the laboratory experiment due to accessibility. The Science Lab Talking Device may provide students with visual impairment with necessary skills and techniques for everyday science laboratory work in the realm of Physical Science up to High school level.
2. The developed device has a variety of testing/measurement tools/techniques and applications.
3. This SLTD may provide more equity to students with visual impairment in the physical science laboratory experiment.
4. The study results showed the effectiveness of the device for performing experiments and hence may have scope for production in the Industry and marketing.

1.23 Delimitations of the Study

1. Due to scarcity of sample, the study is restricted to only experimental group and no control group
2. The demographic variable used in the study is restated to Gender only due to non- availability of sample as stated in the inclusion and exclusion criteria
3. The SLTD device developed in this study mainly focuses on six sensor operations namely Temperature, Colour, and Light Detection, Current Measurement sensor, Volte Measurement and Weight sensor.
4. The Study only focused on three Physical Science Concepts namely Temperature, Acid & Base and Electricity
5. The study was conducted only in Coimbatore & Madurai Districts of Tamil Nadu

1.24 Organization of the Study

The present study on "**Development of Science Lab Talking Device and its Effectiveness for Laboratory Experiment for Students with Visual Impairment**" is organized and reported under the following chapters:

Chapter I : The first Chapter presents Introduction, Historical Perspectives of Education of People with Blindness & Low Vision, Evolution of Education of Persons with Visual Impairment in India, Inclusive Education for the People with Disabilities, Science Education for People with Disabilities, Science Education for Students with Visual Impairment, Method of Teaching of Science to Students with Visual Impairment, Global Standards on Science Education for the Students with Visual Impairment, Sensors & Software for Data collection of Science Experiments to the Students with Visual Impairment, Rationale of the Study, Statement of the Problem, Hypotheses, Scope of the Study, Delimitations of the Study and Organization of the Study are described.

Chapter II : The second chapter presents the review of literature related to the present study.

Chapter III : The third chapter explains the research procedure, which includes designing and development of SLTD, and its introduction among students with visual impairment, construction of tools, selection of samples, administration of the tools and data collection procedure.

Chapter IV : The fourth chapter deals with the tabulation, analysis and interpretation of data in detail.

Chapter V : The fifth chapter reports the findings, recommendations and suggestions. This is followed by bibliography and appendices.

The review of related literature is presented in the next chapter.