



**Addis Ababa University**  
**College of Natural and Computational Sciences**  
**Department of Zoological Sciences**

**Prevalence of Visual Deficiency and Color Blindness among High School  
Students - the Case of Menelik II Preparatory School, Addis Ababa**

*MSc Thesis Submitted in Partial Fulfillment of the Requirements for the  
Degree of Master Science in Biology*

**By**  
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**December, 2021**  
**Addis Ababa**

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## Declaration

I declare that this thesis is my original work. It has not been presented for a degree in any university and that all sources of materials used for this thesis have been duly acknowledged.

Name -----

Signature -----

Date -----

This thesis has been submitted for examination with my approval as university advisor.

Advisor.....

Signature.....

Date.....

Examiners

1. Name ..... Signature ..... Date .....

2. Name ..... Signature ..... Date .....

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## **Acronyms and Abbreviations**

**AMA:** American Medical Association

**CVD:** Color Vision Deficiency

**ETDRS** Early Treatment Diabetic Retinopathy Study

**MAR:** Minimum Angle of Resolution

**VA:** Visual Acuity

**VAS:** Visual Acuity Score

**WHO:** World Health Organization

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## **Abstract**

*Acuity of vision is the ability of the eye to determine the precise shape and details of an object. Normal vision refers to a state in which parallel light rays entering the eye form images on the retina when the eye is in a completely unregulated state. Refractive errors affect a large proportion of the population worldwide, irrespective of age, sex and ethnic group. They can easily be diagnosed, measured and corrected with spectacles or other refractive corrections to attain normal vision. The eye is very important to perceive colors using photo receptors found in the retina. Color deficiency describes the inability or decreased ability to identify colors or perceive color differences under normal lighting conditions. The cause of color vision deficiency can be acquired or inherited. Certain diseases, drugs and chemicals may cause color blindness. It can also be caused by accidents or trauma which produces swelling of the brain in the occipital lobe. Most of the inherited color vision deficiencies are due to the inheritance of mutated gene on the X-chromosome. The purpose of this study was to assess the prevalence of visual deficiency and color blindness among high school students. Regular students of 824 Menelik II Preparatory School participated in the study. Visual acuity was tested by using Snellen chart and that of color vision test by using Ishihara 24 plates. The result shows that 92 percent of the students had a normal visual acuity. On the other hand, a small percentage i.e. nearly eight percent had mild visual deficiency where they were unable to discriminate all the letters in Snellens chart. More males showed the mild visual deficiency compared to females (39 vs 28), However, this difference was not statistically significant ( $p=0.179$ ). Regarding color vision, 32(3.88%) males and 29(3.51%) females were found to be color deficient. The difference between male and female students with color deficiency was not statistically significant ( $p=0.701$ ). Of the total subjects found to have color deficiency, 24(2.91%) males and 18(2.18%) females were deutans; whereas, 8(0.97%) and 11(1.33%) males and females were protans respectively. These data imply that 42(5.09%) of the subjects were deutans and 19(2.30%) were protans. Out of the 61 students who showed color vision deficiency 69% had the Deutran type while 31% had the Protan type. None of the students were Protanopon. Deutranopia was more common among males while the reverse was true for protan. The overall difference between deutans and protans was statistically significant ( $p=0.003$ ). Therefore, the result of the present study showed that visual deficiency should be given importance.*

*Key words: color blindness, visual acuity, visual deficiency, school children*

# 1. Introduction

## 1.1. Background of the Study

Visual acuity is the ability of the eye to determine the precise shape and details of an object. The chart for testing visual acuity usually consists of letters of different sizes placed 6m away from the person being tested. If the person can see well the letters of all sizes that he or she should be able to see at 20 feet, the person is said to have 20/20 vision (normal vision). If a person can't see all letters from the chart with best correction glasses that are seen by a normal person from 200 feet then this person will have a visual acuity designated as 20/200 vision. Such individuals with visual acuity 20/200 are said to be visually impaired or legally blind. Color vision deficiency (CVD) or color blindness, is the inability or decreased ability to distinguish different colors under normal lighting conditions. It is one of the commonest disorders of vision and the incidence of CVD varies between races and locations. However, most color blind cases remain undetected due to absence of proper screening (Hall, 2016).

Color blindness is a genetic condition caused by a difference in how one or more of the light-sensitive cells found in the retina of the eye respond to certain colors. These cells, called cones, sense wavelengths of light, and enable the retina to distinguish between colors. This difference in sensitivity in one or more cones can make a person color blind. The most common types of color blindness are inherited. They are the result of defects in the genes that contain the instructions for making the photo pigments found in cones. Depending on the type of defect and the cone that is affected, problems can arise with red, green, or blue color vision (Nathan et al. 2011).

Low vision and blindness are recognized as one of the major public health problems worldwide, especially in developing countries where 90% of the blind live. Ethiopia is believed to have one of the world's highest rates of blindness and low vision. Although the prevalence of blindness is high as people age, it is also a major problem in children in developing countries. The estimated number of visually impaired people in the world is 285 million; 39 million are blind and 246 million having low vision (WHO, 2012).

Color blindness is not physically debilitating, but it can have a major impact on one's day-to-day life. Individuals suffering from it may not be able to differentiate between red and green traffic signals. They may face difficulties at work as seen for technicians working in color industries. In children, visual impairment can affect school performance like inability to read and write in school. These can have a serious impact on children's participation in class and negatively affect their education (Wedner et.al., 2000).

Testing for colorblindness is usually done with pseudo isochromatic plates that display certain patterns or numbers. People with colorblindness are unable to see the number or pattern as those without colorblindness do.

In the Ethiopian education context, the Ministry of Education has got the learners' textbooks printed in colors so as to make the books be attractive for students. In the students' learning materials, diagrams, pictures, graphs, etc are printed in colors to help them enhance their understanding and do tasks without difficulty. However, students who are color deficient suffer a lot to identify and understand what is there in the colored pictures, diagrams and charts. As a result, most of them fail to perform well in their education as those who are not color deficient (Spalding, 1999).

Few studies are available in Ethiopia that addressed color blindness prevalence. Studies conducted by Tsega (2017) and Mengistu (2017) could be taken as evidences of few of the studies that addressed the prevalence of color blindness in Ethiopia. However, much was not studied in this regard. This resulted in limited knowledge and understanding of the extent of the problem. The current study is an attempt to contribute towards enriching the data volume on color blindness and visual deficiency by taking high school students as study samples.

## **1. 2. Objectives of the Study**

### **1.2.1. General objective**

The general objective of the study was to determine the prevalence of visual problems and color blindness among students in Menelik II Preparatory School.

### **1.2.2. Specific objectives**

The specific objectives of the study were to:

- Assess the frequency of visual deficiency among Grade 11 and 12 students in Menelik II Preparatory School.
- Assess the frequency of color blindness among Grade 11 and 12 students in Menelik II Preparatory School.
- Assess the correlation of age and sex with color blindness and visual problems.
- Identify the types of color blindness among the students.
- Investigate the difference in frequency between both sexes regarding color vision deficiency.

## **2. Review of Related Literature**

### **2.1. Visual Acuity (VA)**

Acuity of vision is the ability of the eye to determine the precise shape and details of an object. Cones of retina are responsible for high acuity of vision. VA is highly exhibited in fovea centralis, which contains only cones. VA is greatly reduced during refractive errors (Sembulingam, 2012).

Acuity depends on several factors but especially on the spacing of photoreceptors in the retina and the precision of the eye's refraction (Bear *et al.*, 2016). The normal VA of the human eye for discriminating between point sources of light is about 25 seconds of arc. That is, when light rays from two separate points strike the eye with an angle of at least 25 seconds between them, they can usually be recognized as two points instead of one. This means that a person with normal VA looking at two bright pinpoint spots of light 10 meters away can barely distinguish the spots as separate entities when they are 1.5 to 2 mm apart (Hall, 2016).

Acuity of vision is tested for distant as well as near vision. If there is any difficulty in seeing the distant object or the near object, the defect is known as error of refraction. Snellen's chart is used to test the acuity of vision for distant vision in the diagnosis of refractive errors of the eye; and Jaeger chart is used to test the visual acuity for near vision (Sembulingam, 2012).

#### **2.1.1. Emmetropy**

Normal vision, or emmetropy, refers to a state in which parallel light rays entering the eye form images on the retina when the eye is in a completely unregulated state (when staring off into the distance, for example). People with "good vision" are categorized as having normal vision.

However, because people suffering from hypermetropia, or farsightedness can also use the regulatory function so that parallel light rays from the distance form images on the

retina, it cannot simply be stated that "people able to see distant objects automatically have normal vision"(Cumberland et al., 2008).

According to WHO, the estimated number of people visually impaired in the world is 285 million, (WHO 2012 in Courtright and West, 2004).Unless marked improvements are made in numbers of healthcare personnel, infrastructure and use of services,75 million cases of blindness will likely occur by 2020 (Courtright and West, 2004).

Blindness is defined either in terms of best-corrected distance VA (the most appropriate refractive correction) or in terms of presenting distance VA (the individual's current refractive correction) in the better eye (Salomão *et al.*, 2009). Many population-based surveys from less developed countries have reported blindness rates using visual acuity level less than 10/200.The more developed countries have often used visual acuity less than 20/200 to define blindness (Salomão *et al.*, 2009).

The major causes of blindness in children vary widely from region to region, being largely determined by socioeconomic development, and the availability of primary health care and eye care services (Gilbert and Foster, 2001). In high-income countries, lesions of the optic nerve and higher visual pathways predominate as the cause of blindness, while corneal scarring from measles, vitamin A deficiency and the use of harmful traditional eye remedies are the major causes in low-income countries (Gilbert and Foster, 2001).

A prevalence of 0.25% in the general population is expected in communities with good economy and health services, rising to 1.0% or more in communities with very poor economy and health services (Salomão *et al.*, 2009).The difference in prevalence is mainly because blindness from cataract, refractive errors and corneal scarring (trachoma, corneal infections, and Vitamin A deficiency) has been eliminated in communities with good economy and eye health care (Salomão *et al.*, 2009).

Globally, the prevalence of blindness among children is estimated to be approximately one tenth of that in adults, at around 0.7 per 1000 (Rahi *et al.*, 1999). However, blindness in childhood has far-reaching implications for the affected child and family, and

throughout their life profoundly influences educational, employment, personal, and social prospects.

### **2.1.2. Types of visual problems**

#### ***Refractive Error (RE)***

Refractive errors affect a large proportion of the population worldwide, irrespective of age, sex and ethnic group. They can be easily diagnosed, measured and corrected with spectacles or other refractive corrections to attain normal vision (Salomao, Mitsuhiro and Belfort, 2009). It has been estimated that 2.3 billion people worldwide have RE, but only 1.8 billion people have access to eye examinations and affordable correction (Mabaso, Oduntan and Mpolokeng, 2006). This leaves approximately 500 million people (including children), mostly in developing countries (about 1/3 in Africa), with uncorrected RE causing avoidable blindness and impaired vision. Undetected or under corrected RE, particularly myopia, is a problem among school children (Mabaso, Oduntan and Mpolokeng, 2006).

#### ***Myopia***

This is a defect characterized by the inability to see distant objects. In myopia when the ciliary muscle is completely relaxed, the light rays coming from distant objects are focused in front of the retina. This condition is usually due to too long eyeball, but it also can result from too much refractive power in the lens system of the eye (Hall, 2016). In order to form a clear image on the retina, the light rays entering the eye must be divergent and not parallel. Thus, the myopic eye is corrected by using a biconcave lens. Light rays are diverged by the concave lens before entering the eye (Sembulingam, 2012).

#### ***Hypermetropia***

This is a defect characterized by the inability to see near object. In hypermetropia, the light rays are brought to a focus behind the retina (Sembulingam, 2012). It is usually due to either an eyeball that is too short or, occasionally, a lens system that is too weak. In this condition, parallel light rays are not bent sufficiently by the relaxed lens system to come to focus by the time they reach the retina. To overcome this abnormality, the ciliary

muscle must contract to increase the strength of the lens (Hall, 2016). Hypermetropia occurs in childhood, if the eyeballs fail to develop the correct size. It is common in old age also. Hypermetropia is corrected by using biconvex lens. Light rays are converged by convex lens before entering the eye (Sembulingam, 2012).

## **2.2. Measuring visual acuity**

### **2.2.1. Snellen eye test charts interpretation**

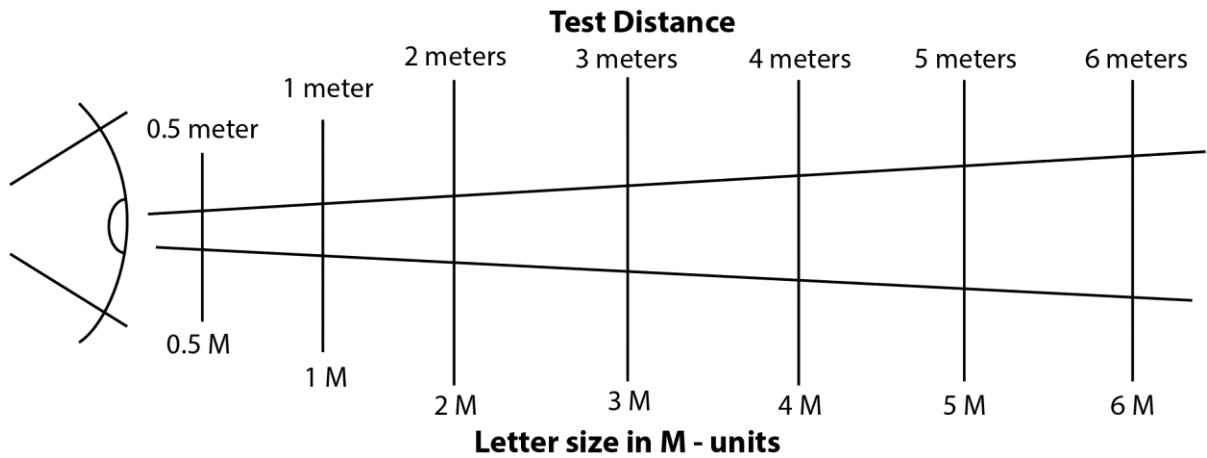
Snellen designed his optotypes on a 5×5 grid, on which the line thickness is one unit and the letter width and height are five units. This system is followed for most letter and number charts. For children's tests (such as Allen pictures and other test symbols), it is often abandoned and much thinner lines are used. Precision Vision offers stylized pictures, called Patti Pics, for which Snellen's 5×5 principle is followed. They result in less change in the measured acuity when children graduate from picture charts to letter charts. Alternative symbols that can be used for illiterate adults or in countries that are not familiar with the Roman alphabet are the tumbling E test and the Landolt C or broken ring.

Letter charts are not only used to measure visual acuity, they are also used as targets for subjective refraction. This is the main reason distance acuity is measured more often than near acuity. At a long distance, accommodation is relaxed, so that the refraction can be more accurate. At a longer test distance, the effect of small changes in the subject's position is less important and can be ignored.

#### ***Letter size***

Snellen used a rather verbose definition to indicate the letter size: "the distance in meters at which the letter subtends 5 min of arc." Louise Sloan simplified this by defining the M-unit as the size that subtends 5 min of arc at 1 meter. Thus, the verbose statement "this letter subtends 5 min of arc at 'x' meter" can be simplified to "this letter is 'x' M-units". Here the number denoting the M unit size is the viewing distance in meters for 20/20 acuity (Sembulingam, 2012).

$$\text{Visual acuity} = \frac{\text{Test distance}}{\text{Letter size}}$$



Snellen fraction	0.5/0.5	1/1	2/2	3/3	4/4	5/5	6/6
Decimal equivalent	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Snellen equivalent	20/20	20/20	20/20	20/20	20/20	20/20	20/20

Most Precision Vision eye charts carry the letter size designation in M-units. This makes it easy to calculate the visual acuity if the chart is used at any other distance than the one for which it was designed by inserting the new test distance (in meters) and the letter size (in M-units) directly into the above formula ([www.precision-vision.com/p](http://www.precision-vision.com/p)).

### ***Visual acuity scores interpretation***

Visual acuity, also known as clarity of vision or sharpness of vision, refers to a person's ability to see small details. A visual acuity score is the result of a vision test performed by an optometrist or ophthalmologist (opticians, technicians, and nurses can also perform a visual acuity measurement). It is usually expressed as a fraction that measures a patient's ability to see an object from 20 feet away compared to a person with normal vision who can see the object clearly from a longer distance. For example, 20/20 vision means that you can see an object clearly from 20 feet away. 20/40 vision means that you need to be 20 feet away to see clearly what a person with normal vision can see from 40 feet away (Michael Bayaba, 2021).

Visual acuity is dependent on a combination of optical and neural elements, including: the health and functionality of the retina, how sharply the retina forms images and how well a person's brain can interpret sensory inputs (Michael Bayaba, 2021).

Refractive errors or neural factors usually cause poor visual acuity. Refractive errors are visual impairments that affect the way light is bent, or refracted, in your eyeball, resulting in decreased visual acuity. Common refractive errors include: Hyperopia (farsightedness), Myopia (nearsightedness) and Astigmatism (irregular curvature of the cornea).

Neural factors that can decrease acuity occur in the retina, brain, or the pathway between the two. Examples include:

- Age-related macular degeneration (AMD)
- Detached retina
- Amblyopia (lazy eye)
- Brain injuries
- Stroke

Most of the time, lower visual acuity can be corrected by eyeglasses, contact lenses, or refractive surgeries.

Visual acuity is measured by charts, optical instruments, or computerized tests. Eye charts are the most common method of visual acuity testing. They show several rows of optotypes (letters, numbers, or symbols) that get progressively smaller towards the bottom. The most frequently used eye charts used are the Snellen chart (Michael Bayaba, 2021).

### **2.2.2. Visual Ability**

Visual acuity refers to a person's ability to discern the shapes and details of the things you see. It is just one factor in the person's overall vision. Others include color vision, peripheral vision, and depth perception. There are several different types of visual acuity

tests, most of which are very simple. Depending on the type of test and where it's conducted, the exam can be performed by: an optometrist, an ophthalmologist, an optician, a technician or a nurse. No risks are associated with visual acuity tests, and you don't need any special preparation (Michael Harkin, 2018).

The Visual Acuity Score (VAS) provides a convenient scale to estimate visual abilities. On this scale 20/20 is rated as 100; on charts with a logarithmic progression each line is worth 5 points and each letter read is 1 point. 50 VAS points stand for 20/200; it is reasonable to estimate that at this level the average person has lost 50% of visual ability. Zero is reached for 20/2000, a level at which it is difficult to speak about visual acuity, since 100x magnification is needed for detail recognition.

### 2.2.3. Logarithmic Progression

The above discussion already indicated why a logarithmic progression of letter sizes is desirable and leads to more consistent measurements. The following table compares the characteristics of Early Treatment Diabetic Retinopathy Study-type charts with previous charts with an irregular progression. Although the name "Snellen chart" should apply to any letter- or symbol-based chart, some authors use the term Snellen chart only for charts with a non-logarithmic progression.

Traditional charts	Early Treatment Diabetic Retinopathy Study type charts
The line-to-line steps are irregular, ranging from 14% (20/70 to 20/80) to 100% (20/100 to 20/200 to 20/400)	All line-to-line steps are equal $10\sqrt{10}$ , which is about a 4:5 ratio.
The number of letters per line varies. Thus the effect of missing one letter varies.	All lines have five letters. The effect of missing one letter is the same for all lines.
The spacing of letters and lines is dictated by the available space. Crowded letters are more difficult to recognize than widely spaced ones.	The letter-to-letter and line-to-line spacing is equal to the letter size. The relative crowding effect is the same for all lines.

Some letters are easier to recognize than others. This may result in easier and more difficult lines.	The difficulty of the letters used is taken into account. The average difficulty on each line is balanced.
Usually, only a single chart is used. This may lead to (voluntary or involuntary) memorization.	The ETDRS set consists of three charts to avoid memorization.
The shape of the chart is rectangular.	The shape is an inverted triangle.

The evolution of letter charts from Snellen's original chart to the Early Treatment Diabetic Retinopathy Study chart, is considered today's gold standard. Practitioners and researchers from all parts of the world turn to Precision Vision for "Early Treatment Diabetic Retinopathy Study" charts and other high-quality vision testing tools.

The following table compares different visual acuity notations.

US notation	6 meter notation	decimal notation	MAR	logMAR	VAS
20/10	6/3	2.0	0.5	-0.3	115
20/12.5	6/3.8	1.6	0.63	-0.2	110
20/16	6/4.8	1.25	0.8	-0.1	105
20/20	6/6	1.0	1.0	0.0	100
20/25	6/7.5	0.8	1.25	0.1	95
20/32	6/9.5	0.63	1.6	0.2	90
20/40	6/12	0.50	2.0	0.3	85
20/50	6/15	0.40	2.5	0.4	80
20/63	6/18	0.32	3.2	0.5	75
20/80	6/24	0.25	4.0	0.6	70
20/100	6/30	0.20	5.0	0.7	65
20/125	6/38	0.16	6.3	0.8	60

20/160	6/48	0.125	8.0	0.9	55
20/200	6/60	0.10	10.0	1.0	50
20/250	6/75	0.08	12.5	1.1	45
20/320	6/95	0.06	16	1.2	40
20/400	6/120	0.05	20	1.3	35
20/500	6/150	0.04	25	1.4	30

### 2.3. Color vision

The eye is very important to perceive colors using the photoreceptors (cones) found in the retina. Color vision requires the light absorbing molecules in photoreceptors (Neitz and Maureen, 2010). Cones are one of the two types of photoreceptors which help to see colors. There are three types of cones: S-cones (absorbing short-wave length), M-cones (absorbing medium-wave length) and L-cones (absorbing long-wave length) (Neitz and Maureen, 2010). The three versions of opsin in the cones absorb light at around 426nm (blue), 530nm (green) and 560nm (red), respectively (Nathans et al. 2011). The cone opsin, along with retinal, makes up the pigment. The cones have less stacked disks in their outer membrane, therefore, contain fewer photo pigments, and this characteristics makes them less sensitive to light, whereas in rods there are more photo pigments in the outer membrane. Stacked disks are the place where the photo pigments are found. The three types of cones respond to variation in color in different ways and make possible trichromatic vision (Maureen and Jay, 2000).

#### 2.3.1. What is color vision deficiency?

Color vision deficiency describes the inability or decreased ability to identify colors or perceive color differences, under normal lighting conditions. It may vary from not being able to tell certain colors apart to not being able to identify any color at all (Steven, 2012 in Tsega 2017). People born with color vision problems are unaware that what they see is different from what others see unless it is pointed out to them. Most people with color vision deficiency can see colors, but they have difficulty differentiating between particular shades of red and green or blue and yellow (Mulusew and Yilkal, 2013). The

term ‘color blind’ does not mean that objects are seen only in black and white. Total color blindness is very rare. There are many types and degrees of color blindness. The most appropriate term for color blindness is deficiency of color vision (Sembulingam, 2012).

### **2.3.2. Types of color vision deficiency**

There are three types of inherited color vision deficiency: monochromic, dichromic and anomalous trichromacy (Neitz and Maureen, 2010). These are further categorized into sub-types. The effect of color vision deficiency can be categorized by the effect they have on our visual sense.

Based on Young-Helmholtz trichromatic theory, color blindness is classified into three types. These are anomalous, trichromacy dichromat and monochromat (Hofmann and Palczewski, 2015).

#### ***Anomalous trichromacy***

This is a relatively mild form of defective color vision. The terms (protanomaly, deuteranomaly and tritanomaly) is given when there is defect in red, green and blue pigments, respectively (Mulusew and Yilikal, 2013 in Tsega 2017). Anomalous trichromatic forms were thought to be caused by genes for anomalous photo pigments replacing either the normal L or M pigment gene. Replacing one normal pigment with an anomalous one resulted in having peak sensitivities that were closer together than the peak sensitivities of the normal L and M cones (Neitz, 2011).

#### ***Dichromacy***

Dichromats base their color vision on only two pigments. The class of dichromats characterized by the entire absence of green cones is called deuteranopia, while those defects characterized by the absence of red cones are called protanopia and those characterized by the absence of blue cones are called tritanopia (Mulusew and Yilikal, 2013). It is the severest form of color vision deficiency (Neitz, 2011).

## ***Monochromacy***

Monochromacy an autosomal dominant trait with incomplete penetrance. The occurrence of tritanopia is much lower, affecting only 0.001% - 0.2% of the human population (Hofmann and Palczewski, 2015). Protanomaly and protanopia are collectively referred to as protan color vision defects, and deuteranomaly and deuteranopia are referred to as deutan defects. Protan and deutan color vision defects are often collectively described as red-green defects. Tritanopia and tritanomaly are often described as the tritan or blue-yellow color vision defects (Mulusew and Yilikal, 2013).

### **2.3.3. Tests for color vision deficiency**

Any person who is having difficulty in identifying colors should be checked for color vision impairment. Those who have family history of color vision deficiency are required to identify colors accurately or those who have problems in identifying colors should be tested.

There are different methods of testing individuals for color blindness. These include Ishihara plate tests, anomaloscope test, arrangement test and lanterns. For instance, Ishihara plate test, which is commonly used test, is the Ishihara 38 and 24 plate test. Ishihara 38 plates for color vision deficiency were introduced by Dr. Shinobu Ishihara from Japan. These plates are named after him and by far they are the best known test for red-green color blindness (Ananya, 2016). They are made up of many colored circles and contain written in them numbers or symbols, which can only be seen if one is not colorblind.

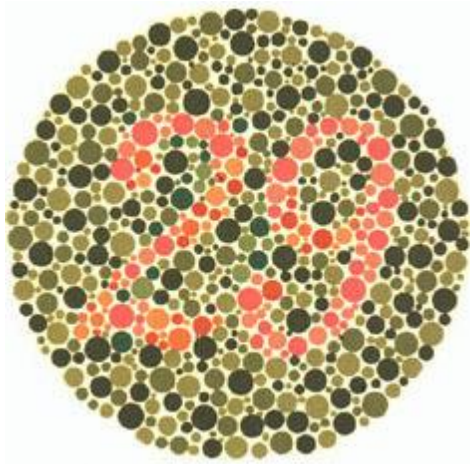


#### **Plate 1**

Normal view: 8

Red-green deficiency: 3

(Source: Kanehar Shuppan Co. Ltd., 2006)



**Plate 2**

Normal view: 29

Red-green deficiency: 70

(Source: Kanehar Shuppan Co. Ltd., 2006)



**Plate 3**

Normal view: 26

Protanopia or protanomaly: 6

Deuteranopia or deuteranomaly: 2

(Source: Kanehar Shuppan Co. Ltd., 2006)

## 2.4. Causes of color deficiency

The causes of color vision deficiency can be acquired or inherited.

### *Acquired deficiency*

Certain diseases, drugs and chemicals may cause color blindness. It can also be caused by accidents and trauma which produces swelling of the brain in the occipital lobe. Damage by exposure to ultraviolet light (10-300 nm) may also cause colorblindness; Color vision can also decline with age, most often because of cataract, a clouding and yellowing of the eye's lens (Maureen and Jay, 2000). Color blindness also occurs due to acquired conditions such as ocular diseases or injury or disease of retina by trauma, chronic

diseases, drugs, toxins, alcoholism, and aging. Acquired defects are the less common forms and do not involve inherited alterations to the opsin genes.

### ***Inherited deficiency***

Most of the inherited color vision deficiencies are due to the inheritance of mutated gene on the X-chromosome. This is the rearrangement or deletion of genes that encode the light absorbing photo pigment in the cones. Colorblindness typically is an X-linked recessive inheritance (Maureen and Jay, 2000).

Of the three types of inherited or congenital color vision deficiencies, which are (monochromacy, dichromacy and anomalous trichromacy) the most common colorblindness is the red-green deficiency or deuteranopia. This deficiency is present in about 8% of males and 0.5% of females of north european ancestry (Agarwal and Nishant, 2014).

Recent developments in molecular genetics have opened the possibility of gene therapy. The application of gene therapy to animal models of CVD has shown dramatic results; furthermore, it has provided interesting insights into the plasticity of the visual system with respect to extracting information about the spectral composition of the visual sensation. Certain rare forms of congenital CVD result in profound visual impairment. At this point in time, there is no effective treatment of CVD (Simunovic 2010 in Mengistu, 2017).

### 3. Materials and Methods

#### 3.1. Study place and participants

The study area which is Menelik II Preparatory School is found in Arada Sub-City of Addis Ababa at Arat Kilo. The school has enrolled approximately 2000 students for the regular education program during the study period of (2021).

Students who expressed consent to participate in this study with an upper limit of 1000 students were included. The purpose of the study was clearly explained to each participant with reassurance that their test outcomes would remain anonymous and confidential.

Based on written consent, 410 students were selected from Grade 11. Their age ranged from 17 up to 19. Out of 410 Grade 11th students, 206 of them were female and the rest 204 students were males. On the other hand, 414 Grade 12 students were taken. The ages of these students ranged from 18 up to 21. Of these, 213 were females while 201 were males. Hence, the total number of female participants in the study was 419 while the number of male participants was 405. Therefore, the total number of subjects participated in the study was 824.

##### 3.1.1. Visual acuity test

Snellen's chart was used to test visual acuity (Fig. 1)

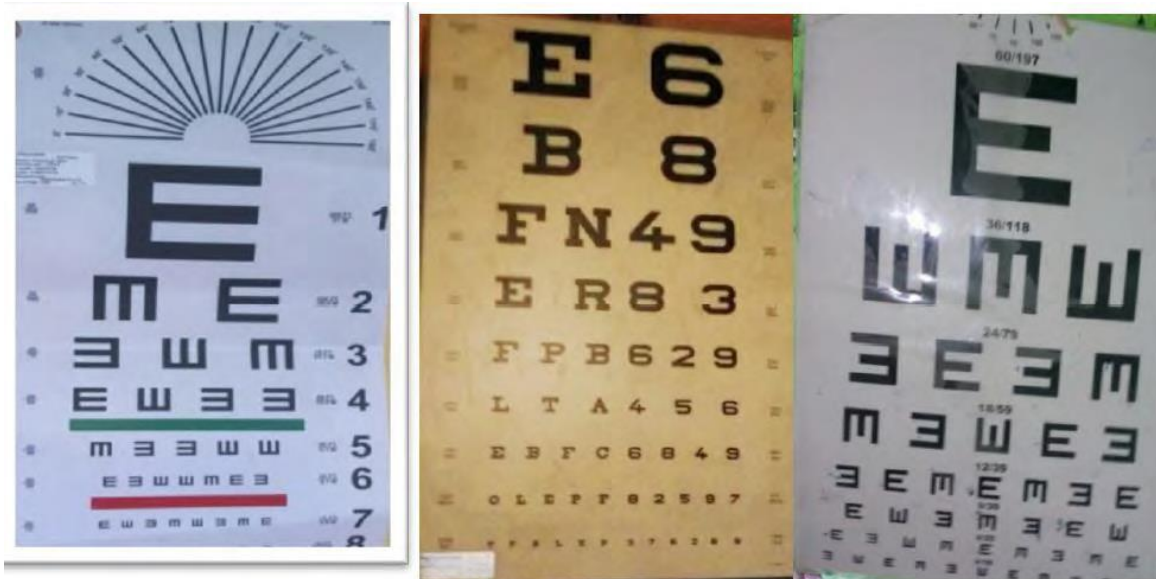
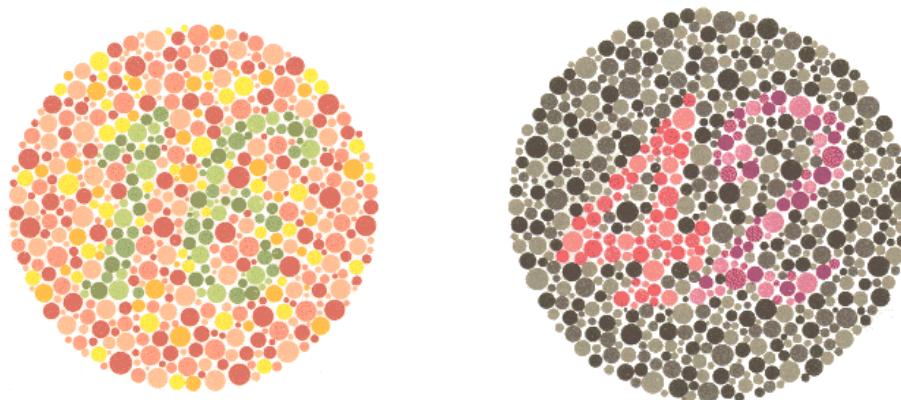


Figure 1. Snellen's chart used in standard visual acuity tests (Mengistu: 2017)

A health professional from Arada health center performed the test. Appropriate care was taken to avoid memorization of the chart by observing other students who had undergone the test. I had taken part in facilitating the testing process and recording the results. The test was performed under monocular viewing in day light (well illuminated room). Students covered one eye with a hand without pressing it. The distance between the person and the chart was 6m (20 feet). The students who properly could identify the letters of the size 6mm at 6m (20 at 20 feet) were taken as normal with 6/6 (20/20) vision. The participants in this study were considered to have visual impairment if their visual acuity was different from what is taken as normal in either eye. See plates at the back for demonstration of testing events.

### **3.1.2. Color vision test**

Color vision was tested using Ishihara chart (24- Plate edition) (Fig. 2). The test was performed by the health professional making the research subjects view the plates in day light at reading distance (75 cm from the subject) and by making tilted so that the plane of the paper would be at right angles to the line of vision. All participants were asked to read the impressions in the color chart. The types of color blindness were differentiated with the help of key provided with the chart. Direct sunlight and use of electric light was also avoided. As recommended by Ishihara guideline, for color vision screening test, out of 24 Plates, 1-17 were used. All the research participants were made to respond within an average duration of 3 seconds per test plate (Ishihara 1972).



**Figure 2: Ishihara color vision test plates (A person with normal color vision identifies the plates as 16, left, and 42, right)**

### **3.2. Ethical Clearance**

Ethical clearance for this research was obtained from the Institute Board of the College of Natural and Computational Sciences. The results obtained remained anonymous to third parties, but revealed to the individual participant.

### **3.3. Interviews**

In order to gather additional data, interviews were conducted with the study participants with visual or color vision problems. The interview focused on the subjects' family history and their challenges related to school performance.

### **3.4. Study Period**

The period of the study was from March to May 2021.

### **3.5. Statistical Analysis**

Both qualitative and quantitative methods were employed to analyze the data. Accordingly, quantitative method of data analysis was used to analyze differences in visual problems and color vision prevalence between sex and age groups. For this purpose, the nonparametric test was conducted using chi square. On the other hand, qualitative method was employed to analyze data obtained from the interviews that were conducted with the participants who had visual problems. This is presented as descriptive data to show the level of predicament students are having in their school performance and possible underlying reasons for their visual problems.

Variabilities on prevalence of visual acuity and color blindness, among sexes, and between the different types of color blindness were statistically compared using the chi square test on the SPSS (V 17) software. The level of significance was considered at  $P \leq 0.05$ .

## 4. Results and Discussion

### 4.1. Respondents Demographic Data

Table 1 shows the respondents' demographic characteristics in terms of sex, age and grade level. The number of male and female respondents was nearly equal. Regarding their ages, most participants were between the age of 17 and 18. With respect to the study subjects grade levels, 410 (49.75%) of them were Grade 11<sup>th</sup> students whereas 414 (50.24%) were Grade 12<sup>th</sup>. Similarly, the representative of participants from the two grade levels was almost equal.

**Table-1: A table showing demographic characteristics of respondents**

Characteristics of respondents		No. of students	Percent
Sex	Male	405	49.15%
	Female	419	50.84%
	Total	824	100%
Age	16-18	447	54.24%
	19-20	377	45.75%
	Total	824	100%
Grade level	11th	410	49.75%
	12th	414	50.24%
	Total	824	100%

### 4.2. Visual acuity test results

Table 2 presents the study participants' visual acuity test results. It shows that 366 (44.41%) male subjects and 391 (47.45%) of female subjects had normal visual acuity. On the other hand, this table shows that 39 (4.73%) and 28 (3.39%) of males and females respectively were found to have mild visual acuity. This visual acuity test result indicates that 757 (91.86%) of the total subjects of the study had normal visual acuity while 67 (8.13%) of them had mild level of visual acuity.

Almost 92% of the students had a normal visual acuity. On the other hand, a small percentage i.e. nearly eight percent had mild visual deficiency where they were unable to discriminate all the letters in Snellens chart. More males showed the mild visual deficiency compared to females (39 vs 28), however this difference was not statistically significant ( $p=0.179$ ).

**Table-2: Respondents' visual acuity test results**

Diagnosis	Male (%)	Age	No	Female(%)	Age	No	Total	%
Normal	366(44.41)	16-18	179	391(47.45)	16-18	194	757	91.86%
		19-20	187		19-20	197		
Mild deficiency	39(4.73)	16-18	16	28(3.39%)	16-18	12	67	8.13%
		19-20	23		19-20	16		
Sever deficiency	-	-		-	-		-	-
Total	405(49.15%)			419(50.84)			824	100%

### 4.3. Color Vision Test Results

#### 4.3.1. Prevalence of color vision deficiency

Table 3 presents the subjects' color vision test results. Accordingly, 373 (45.26%) of male subjects and 390 (47.33%) of female subjects were found to have normal color vision. On the contrary, 32 (3.88%) male and 29 (3.51%) female testees were found to be color deficient. Hence, we can understand that 763 (92.59%) of the total subjects had normal color vision: whereas, 61 (7.40%) of them were color deficient. The difference between male and female students with color deficiency was not statistically significant ( $p=0.701$ ).

**Table-3: Color vision test results**

Diagnosis	Male (%)	Age	No	Female (%)	Age	No	Total	%
Normal	373(45.26)	16-18	164	390(47.33%)	16-18	172	763	92.71%
		19-20	209		19-20	218		
Color vision deficiency	32(3.88)	16-18	13	29(3.51)	16-18	11	61	7.40%
		19-20	19		19-20	18		
Total	405(49.15)			419(50.84)			824	100%

### 4.3.2. Frequency of color vision deficiency type

Of the total subjects found to have color deficiency, 24 (2.91%) males and 18 (2.18%) females were deutans; whereas, 8 (0.97%) and 11 (1.33%) males and females respectively were protans. These data imply that 42 (5.09%) of the subjects were deutans and 19 (2.30%) were protans.

Out of the 61 students who showed color vision deficiency 69% had the Deutran type while 31% had the Protan type. None of the students were Protanopan. Deutranopia was more common among males while the reverse was true for protan. The overall difference between deutans and protans was statistically significant ( $p=0.003$ ).

**Table 4: Prevalence of color deficiency types**

Type	Male (%)	Age	No	Female(%)	Age	No	Total	%
Deutan	24(39.34)	16-18	10	18(29.50)	16-18	12	42	68.85%
		19-20	14		19-20	6		
Protan	8(13.11%)	16-18	3	11(18.03)	16-18	7	19	31.14%%
		19-20	5		19-20	4		
Protopian	-	-		-	-		-	-
Total	32(52.45)			29(47.54)			61	100%

In addition to the results obtained through conducting visual acuity and color vision tests, certain results were obtained by making use of a questionnaire and conducting interviews. Only results that have relevance to the problem studied are presented below.

Regarding the subjects out of school daily practices, the result of the study reveals that 697 (84.58%) of them had strong habit of watching television and/or playing games regularly. A large number of them spent long time doing these. In this regard, the result

of the study shows that 386 (55.38%) of them spent 2-5 hours per day. This is perhaps a harmful exposure of the eye to colorful scenes. On top of this, many of them did not keep proper distancing while watching films. The result reveals that 474 (68%) of the subjects did this from a distance ranging from 1 meter to 2 meters. The same fact was mentioned during interviews conducted with some of the study participants.

For questions presented to the study subjects with regard to their vision ability, 92 (11.16%) of them indicated they had problem with night vision. Besides, the result of the study shows that 70 (8.49%) of them responded they didn't read their learning materials without difficulty where 65 (7.88%) indicated that they couldn't read what their teachers write on the board sitting anywhere in the classroom.

**Table-5: A table showing data regarding the respondents' practices and vision ability**

No	Item	Alternatives	Fr.	Percent
1	Do you watch TV or play video games?	Yes	697	84.58%
		No	127	15.41%
		Total	824	100%
2	If "Yes", how often do you watch or play it in a day?	More than 8 hrs	11	1.57%
		6-8 hrs	144	20.65%
		About 2-5 hrs	386	55.38%
		Less than 2 hrs	156	22.38%
		Total	697	100%
3	How far the distance is that you watch TV or play the video games?	Less than 1 m	86	12.33%
		1-2 m	474	68%
		3-4 m	132	18.93%
		More than 10 m	5	0.71%
		Total	697	100%
4	Do you have problem with night vision?	Yes	92	11.16%
		No	732	88.83%
		Total	824	100%
5	Do you read your learning materials without vision difficulty?	Yes	751	91.14%
		No	70	8.49%
		Total	821	99.63%
6	Can you read what teachers write on the board without difficulty sitting anywhere in the classroom?	Yes	754	91.50%
		No	65	7.88%
		Total	819	99.39%

Attempts were also made to get background vision history of the students' parents and relatives. In this respect, few of the study subjects, i.e. 23(2.79%) responded that either of their parents had vision problems; whereas, 17(2.06%) responded at least one of their parents had problem of identifying colors. On the other hand, 86(10.43%) of the subjects responded that there were people among their close relatives such as grandparents, uncles and aunts, etc. who had clinically diagnosed vision problems.

**Table-6: A table showing data regarding the respondents' parents and kins vision ability**

No	Items	Alternatives	Fr.	Percent
1	Do any of your parents have visual acuity problem?	Yes	23	2.79%
		No	673	81.67%
		I don't know	128	15.53%
		Total	824	100%
2	Do any of your parents have color identifying problem?	Yes	17	2.06%
		No	603	73.17%
		I don't know	204	24.75%
		Total	824	100%
3	Are there people who have vision problem among your relatives such as grandparents, uncles, aunts, etc?	Yes	86	10.43%
		No	581	70.50%
		I don't know	146	17.71%
		Total	813	98.66%

In this study, out of the total subjects, 757 which account 91.86% had normal visual acuity. On the other hand, 67 (8.13%) of them were found to have mild visual deficiency. In this regard, the study identified that 366 (44.41%) were females. In similar view, 39 (4.73%) among subjects who were found to have mild visual deficiency were males and 28 (3.39%) of them were females.

Among 1134 preschool and schoolchildren studied in Ethiopia, 93 (8.2%) children had a visual impairment in either eye or both (Kassa and Alene, 2003). This prevalence was nearly similar with the present study, 70 (8.1%). Another study conducted in Ethiopia, Merhabete found the prevalence of blindness, 1% (Teshome, 2002). This prevalence was by far different from this our study 67 (8.13%).

Another study conducted in Ethiopia, Addis Ababa among schoolchildren, the prevalence of visual impairment in either eye, VA 6/12 or worse was 5.8 % (Haile, 2014). This finding was nearly equivalent with the present study 67 (8.13%). This may be due to the variations in study areas and the higher sample size compared to ours.

With respect to color vision, 373 (45.26%) males and 390 (47.33%) female subjects were found to have normal color vision. Whereas, 32(3.88%) males and 29 (3.51%) females among those diagnosed for color vision had deficiency of color vision. The overall color vision test result reveals that 763 (92.71%) of the study subjects had normal color vision while 61 (7.40%) of them were color vision deficient.

The prevalence of color blindness in males in this study was 7.40% which is different from studies that were carried out in Libya, 2.2%, India 2.3%, Colombia 2.4%, Saudi Arabia 2.9% (Fareed et al., 2015). In addition, the prevalence of color blindness among male students in this study is higher than that was reported from Pakistan 1.1%, India 1.2%.

In connection, two types of color deficiencies were found to be prevalent among those who had color vision deficiency. Accordingly, 24 (39.34%) males and 18 (29.50%) females were found to be deutans where 8 (13.11%) males and 11 (18.03%) females were protans. This gives rise to a total of 42 (68.85%) were deutans and 19 (31.14%) of them were protans regardless of sex differences. To this end, the outcome of the study reveals deuthropathy was more prevalent among the study participants than protanopathy. The frequency of prevalence of deutropathy exceeded that of protanopathy by more than two fold.

## 5. Conclusion

Based on the outcomes of the study the following conclusions are drawn:

- Regarding visual deficiency, the study concludes that 8.13% out of the total subjects of the study had mild visual deficiency. The study identified that the prevalence of visual deficiency was 4.73% in male and 3.39% in female students. The difference observed in the prevalence of visual deficiency between males and females was not statistically significant.
- The study also concludes that the prevalence of color blindness with inclusion of both sexes was 7.40%. This result is different from other studies conducted in Ethiopia regarding color blindness among school children. The study shows that color blindness was prevalent among 3.88% male and 3.51% female students of the referred school.
- Two types of color vision deficiencies were prevalent among these students (i.e. deutan and protan). In this regard, 39.34% males and 29.50% females among those found to be color deficient were deutan while 13.11% males and 18.03% females were protan.
- Moreover, the study indicates that the prevalence of deutan is higher than protan. It also indicates that the prevalence of color blindness is higher in males than females.

## **6. Recommendations**

- It is evident that few studies had been conducted in Ethiopia regarding the prevalence of visual deficiency and color blindness among students. However, the studies conducted on this area are not enough. Therefore, it is recommendable to conduct further studies relatively at larger scales by incorporating various demographic variables such as sex, age, ethnicity, religion among others.
- Schools' special need clubs should extend their activities so as to create better learning situations for students. One major area the clubs need to work on should be identifying students with vision problems through conducting school-based visual deficiency and color blindness screening. Doing this would be helpful to improve the students' classroom learning situation by designing effective mechanisms.
- At the beginning of each school year, classroom teachers have to make sure that each learner takes the right seat and position as well as feels comfortable with his/her vision in the classroom. This would be helpful to make proper classroom sitting arrangement for the students based on their vision conditions.

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## Appendix I

### Testing events

Visual acuity test plate-1



Visual acuity test plate-2





Visual acuity test plate-3

**APPENDIX II a**  
**Addis Ababa University**  
**College of Computational and Natural Sciences**  
**Department of Zoological Science**

To....., parents/guardians

This letter is written to you to request you to give your consent so that your son/daughter who is attending regular education in Menelik II Preparatory School to be chosen as a participant for a study that will be conducted to identify students with visual problem and color deficiency. I would like to inform you that the visual acuity and color blindness test will be conducted by a health care professional.

The result of the study will be useful to suggest and create conducive situations in the way students living with this vision problems be able to attend their education in a better classroom learning environment.

With regards  
The researcher

Put a tick mark in one of the given alternatives below.

- A. I agree.....
- B. I disagree.....

**APPENDIX II b**  
**አዲስ አበባ ዩኒቨርሲቲ**  
**የሰሌት እና የተፈጥሮ ሳይንስ ኮሌጅ**  
**የሰነ-እንስሳት ሳይንስ ክፍል**

ለ..... ወላጆች / አሳዳጊዎች

በዳግማዊ ምኒልክ መሰናዶ ት / ቤት መደበኛ ትምህርት የሚከታተል ልጅዎ / ሴት ልጅዎ የእይታ ችግር እና ቀለም ያላቸውን ተማሪዎች ለመለየት በሚደረገው ጥናት ተሳታፊ ሆኖ እንዲመረጥ ይህ ደብዳቤ ለእርስዎ የተፃፈ ነው ፡ እጥረት. የማየት ችሎታ እና የቀለም ዓይነ ስውርነት ምርመራ በጤና አጠባበቅ ባለሙያ እንደሚከናወን ላሳውቅዎ እወዳለሁ ፡

የዚህ ራዕይ ችግር ያለባቸው ተማሪዎች በተሻለ የክፍል ትምህርት አካባቢ ትምህርታቸውን መከታተል በሚችሉበት ሁኔታ የጥናቱ ውጤት ለመጠቀም እና ተስማሚ ሁኔታዎችን ለመፍጠር ይጠቅማል ፡፡

ከሰላምታ ጋር  
ተመራማሪው

ከዚህ በታች ከተሰጡት አማራጮች ውስጥ በአንዱ ውስጥ የቲክ ምልክት ያድርጉ ፡፡

- A. እስማማለሁ .....
- ቢ. አልስማም .....

## **APPENDIX III**

### **Addis Ababa University**

#### **College of Computational and Natural Sciences**

##### **Department of Zoological Science**

### **A questionnaire to be filled by regular students of Menelik II Preparatory School**

#### **Introduction**

This questionnaire is prepared for a study to be conducted among students of Menelik II Preparatory School with the view of assessing the frequency of visual problem and color deficiency among grade 11 and 12 students. The result of the study will be useful to suggest and create conducive situations in the way students living with this vision problems be able to attend their education in a better classroom learning environment.

Therefore, by taking the importance of the study in to consideration, you are kindly requested to respond to all the questions genuinely.

The researcher would like to thank you for your cooperation in advance!

#### **Part I: Personal information of the participants**

1. Code No-----
2. Sex: Male  Female
4. Age-----
5. Grade-----
6. Nationality: -----

#### **Part II: Questions related to your practice and vision situations**

1. Do you wash your face every day?
2. If your answer is yes, how often do you wash?  
A. Once a day B. Twice a day C. More than twice a day
3. Do you watch TV or play video games regularly? A. Yes B. No
4. If your answer is yes, how often do you watch or play them?  
A. More than 8 hrs/ day B. 6-8 hrs/day C. About 2-5 hrs/day

- D. Less than 2 hrs/day
5. If your answer is yes for the above question, at what distance do you watch or play it?  
A. Less than 1 m, B. 1 -2m, C. 3-4 m D. More than 4 m
6. Do you have visual acuity problem or color blindness before?  
A. Yes B. No. C. I don't know
7. Did your eyes were injured due to accidents or strokes? A. Yes B. No
8. Did you have chronic diseases such as sickle cell anemia, diabetes or liver diseases?  
A. Yes B. No C. Yes other than this
9. Have you taken/did you consume/ drugs such as, Antibiotics and or TB Drugs frequently or for longer time?  
A. Yes B. No
10. Do you have problems with night vision/Night Blindness/?  
A. Yes B. No
11. Do read your learning materials without difficulty?  
A. Yes B. No
12. Do you read what teachers write on the board sitting anywhere in the classroom?  
A. Yes B. No