

**MASTER THESIS**  
**In**  
**Universal Design of ICT**

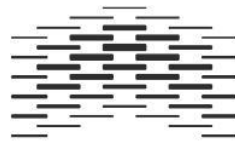
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Evaluation of Interactive Learning Materials for  
Universal Design: Case of GeoGebra in Norwegian  
High Schools

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## A. Preface

This master thesis is the study conducted on GeoGebra regarding how accessible and usable is GeoGebra in the website, and what are the experience of upper secondary student after using GeoGebra. The project was initiated by an assignment proposal and according to the scope of the research. The study has mostly focused on finding accessibility issues that can be achieved by utilizing available guideline and main features of Interactive learning material in the case of GeoGebra. This research has helped me to know invaluable in depth understanding about interactive learning materials, how to conduct research, methods to be used for the research and knowledge about other researchers that have conducted researches in interactive learning materials in the context of usability and accessibility.

I would like to express my most sincere thanks to my supervisor, Wondwossen for his constant support, never ending patience and kindness, guidance and expert tips throughout the research. I am very grateful for the time and energy spent by him for the guidance in research. I would also like extend my deepest thanks to my second supervisor, Anthony for the support, valuable suggestions and help for the research.

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## **B. Summary**

The popularity of interactive learning materials is increasing in the field of education. In the field of mathematics, the GeoGebra online web application has become the part of curriculum in the higher secondary education in many countries. In case of Norway, GeoGebra has been the important part of the teaching-learning process of mathematics and it has also been used in the examinations. However, in terms of accessibility, there has been little improvement in many ILMS. This same applies to GeoGebra too.

Within 2021, Norwegian Government has enforced the existing and new online system that are aimed towards the end-user, to fulfill the A and AA criteria of WCAG 2.0. As a result, the fundamental goals of this research are to study the user experience of few high school's students and to conduct conformance testing of the GeoGebra online application against the success criteria A and AA of WCAG 2.0.

For the study, two different qualitative methodologies were used. Semi-structured interview was done with the second and third year students from one of the high schools of Norway to study the user experience of using the GeoGebra. Similarly, heuristic evaluation was done by the two students from Master in Universal Design of ICT in Oslo and Akershus University College of Applied Science. The objective of the heuristic evaluation was to find out to what extent the GeoGebra has fulfilled the web accessibility criteria. The data from the semi-structured interview was analyzed based on Interpretative phenomenological analysis (IPA).

After the data collection from both qualitative methods and analyzing it, this research found some interesting results.

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## **F. Abbreviations**

ICT: Information and communication technologies

HCI: Human computer interface

ILM: Interactive learning material

CAS: computer algebra system

DGS: dynamic geometry software

GDC: graphing display calculators

UD: Universal design

AT: Assistive technology

W3C: World Wide Consortium

WAI: Web Accessibility Initiative

ATAG: Authoring Tools Accessibility Guidelines

WCAG: Web Content Accessibility Guidelines

WCAGem: Web Content Accessibility Guidelines evaluation tools

UAAG: User agent Accessibility Guidelines

NCTM: National Council of Teachers of Mathematics

IPA: Interpretative phenomenological analysis

# 1. Introduction

Information and Communication Technologies (ICTs) have affected people's daily lives in almost every way. From work places to educational institutions, at homes or even while travelling, we see the effects of ICT in every aspect of our lives (Haddon, 2004). In today's era, every corner of the world is connected to each other through internet. It has been used for immeasurable purposes by large number of population. Faster broadband access has allowed possibility to access information anywhere anytime and opening numerous possibilities in every field. Smart phones, tablets, phablets, netbooks, laptops and desktop computers are the popular devices used in everyday life. This is even more apparent with the younger generation where people have exposure to ICT even from a very small age (Buckingham, Banaji, Carr, Cranmer, & Willett, 2005).

According to Eurostat (2015), the greater proportion of young people from European union(EU) are using ICT. By the time they complete compulsory education, the young students in the EU would regularly use computers and other ICT equipment (Eurostat, 2015). ICT have been implemented in schools and other educational institutes not only for the students to develop their ICT skills but also for teachers to support their traditional teaching methods specially for subjects like science, mathematics and many other (Eurostat, 2015).

According to statistic found from (Internetlivestats, 2016), 5,167,573 people i.e. almost 98% of population of Norway use ICT. According to the (Statistik Sentralbyrå, 2016) of Norway, there is high usage of gadgets like mobile, laptop, tablet computer, smart TV, and desktop computers to connect internet and people. The data shows that people in age range from 16 to 24 years old are highly active in the ICT usage. The same survey which was done among 16 to 74-year old range showed that the use of personal computers has increased from 2000 to 2010 among both men and women. Especially those from 9 to 24 age range were found to be spending high amount of time on ICT every day.

Digital skills, as one of five skills with oral, reading, writing, and numeracy has been The basic five skills known as oral, reading, writing, numeracy and digital skills has been introduced in 2006 for both compulsory and secondary education in Norway

(schoolnet, 2015). The framework for digital skills is divided into four parts as searching and processing, producing, communicating and digital judgement. These are integrated in all the subjects and personal computers has become important part of school education today in Norway. According to the statistics given by sentralbyrå (2017), there are approximately 419 upper secondary schools with 200 731 students, 42683 apprentices and 26521 teachers in Norway. This statistics gives the justification for evaluating accessibility of interactive learning environments, including GeoGebra, which are being used in the curriculum of upper secondary schools.

There have been many changes in the field of education in short period of time. That include the use of computers, internet, multimedia, visual and audio information within the reach of everyone, changes in pedagogical syllabus virtual learning that is based on competence, and teachers being trained with ICT (Siemens & Tittenberger, 2009). The key aspect of all these changes is to have qualitative content to enhance learning with the help of technology (Baylor & Ritchie, 2002).

Web accessibility is the concern for all people, especially for disabled and older people, so that they can use and perceive web system in a range of environments, including both mainstream and assistive technology (Petrie, Savva, & Power, 2015)

Web accessibility encompasses every type of disability which is categorized into six categories as “visual, auditory, physical, speech, cognitive and neurological” (W3C, 2016). People with different types of disability tend to differ in their usage of the Web. Their needs and preferences may not be fully accommodated by web pages. Millions of people with disability around the world tend to be affected of accessibility barriers that pause difficulty while using the Web (World Health Organization, 2011). Nearly 18% of population in Norway is stated as living with disability, according to the (Statisk sentralbyrå, 2016). The solution to this is to make more websites and software accessible so that people with impairment can use them without any barrier.

The Anti-discrimination and Accessibility Act of Norway (Lovdata, 2013) section 14 states that “ICT means technology and technological systems employed to express, create, convert, exchange, store, duplicate and publish information or make usable information”. Moreover, the law demands for new ICT solutions to be universally designed from 1 January 2021. The agency for Public Management and government

(Difi) also states that website designs need to satisfy “Web Content Accessibility Guidelines (WCAG 2.0) with A and AA level standard with the exception of time based media: 1.2.3 Audio description or media alternative (prerecorded content), 1.2.4 Captions (live content) and 1.2.5 Audio description (prerecorded content)” (Difi, 2014).

The goal of this research is to evaluate an interactive learning material being used for teaching mathematics in high schools. It takes GeoGebra as a case and examines whether its accessibility and usability. The number of users of GeoGebra, including teachers and students, is increasing every year (M. Hohenwarter & Lavicza, 2010). This research has used heuristic evaluation method to evaluate accessibility of the GeoGebra website against WCAG 2.0 A and AA level standards. It also employed qualitative method to analyze the user experience of upper secondary students, which are using GeoGebra to support their learning of mathematics. The main aim of the research is to find accessibility and usability barriers so that GeoGebra can be improved to make it efficient and accessible to every student. As a mathematics learning material, GeoGebra has many challenges to accommodate the capabilities and requirements of all students.

There has been changes in teaching methods in Norway which have been integrated with ICT in primary, secondary and higher level of education (Krumsvik, 2006). GeoGebra has been used for learning mathematics in high schools of Norway. Recently, the Ministry of Education has implanted the requirement of using the digital tool GeoGebra for mathematics exam in primary and secondary school (UDIR, 2015a). The findings from this research conclude with suggestions for enhancing the interactive learning material and improve inclusive and adaptable mathematics learning.

## 1.1. GeoGebra

GeoGebra is known to be an open source dynamic mathematics software for innovative learning and teaching purposed for all levels (Kllogjeri & Kllogjeri, 2014). The software is compatible to desktop, laptops and tablets. It is freeware and can be used both online and offline. The offline version of GeoGebra can be downloaded from its main webpage [GeoGebra Downloads](http://www.geogebra.org/downloads)<sup>1</sup>. There are two parts of elementary mathematics which is algebra and geometry. Computer algebra systems (CAS) help to automate manipulation of mathematical expressions and Dynamic geometry packages help to define the relationship between points, lines circles and so on (Sangwin, 2004). So, firstly, as a dynamic geometric system, Geogebra enables students to work with points, vectors, segments, lines and conic sections. Secondly, as the researcher describes Sangwin (2007) the CAS tool of GeoGebra allows to “deal with variables for numbers, vectors and points, find derivatives and integral of functions and offers commands like root or extremum”. The relationship between the CAS and geometric views of Geogebra is that “expression in algebraic window corresponds to an object in geometry window and vice-versa”(Sangwin, 2007). Different mathematics tasks like geometry, algebra, probability and pre-calculus, calculus, discrete mathematics, probability and statics etc. can be practiced in the GeoGebra web application (Geogebra, 2011).

The main function of GeoGebra is to work as a supporting software in teaching, learning, and in evaluation. GeoGebra helps to create interactive learning materials to explore the concept of science, technology, engineering and mathematics education. Integration of GeoGebra with virtual learning environment (VLE) can help to create powerful teaching, learning and evaluating environment to both teachers and students (Heck, Houwing, & de Beurs, 2009).

GeoGebra also enables students to download, create, save, and share the files they have created using the application (Kllogjeri & Kllogjeri, 2014). GeoGebraTube and GeoGebraWiki are websites where free instructional materials can be used, uploaded

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<sup>1</sup> [www.geogebra.org/downloads](http://www.geogebra.org/downloads)

or shared with other users. Students can create their own applets and share them with fellow students (Saha, Ayub, & Tarmizi, 2010).

GeoGebra enables production of dynamic worksheet as interactive java applets embedded in html pages so that users can construct graphs, functions and other mathematical objects and interact with them (Velichova, 2011) . There has been lot of changes, improvements in features from older to newer versions. The latest available version at the time of this research is GeoGebra 5.0. GeoGebra 5.0 supports all the dynamic representation of mathematical objects by graphical view, algebraic calculation and spreadsheet view (Geogebra, 2017). By 2015, the GeoGebra software was available in 45 languages (Aydos, 2015). Availability of GeoGebra everywhere offers new possibilities for students to learn, communicate and grow their mathematical thinking. GeoGebra offers user friendly environment by easy to use interface, multilingual languages, commands and helpline (M. Hohenwarter & Preiner, 2007). Since, the application provides the opportunity for both students and teachers to experience math virtually, the application is popular in Europe and in North-America similarly, the Norwegian GeoGebra institute in Trondheim has more than 50 Geogebra trainers, mathematicians and mathematic teachers supporting teachers and collaborating on the project research on the free educational resources . (M. Hohenwarter, Jarvis, & Lavicza, 2009). From May 2008, local GeoGebra Institutes are established in Universities of many countries including Africa, Asia, Australia, Europe, North and South America (M. Hohenwarter & Lavicza, 2011). Currently, the software receives 300000 visitors every month from 188 countries estimating 100000 teachers using GeoGebra worldwide (Preiner, 2008a). The research M. Hohenwarter and Lavicza (2010) shows that there were nearly 5 million visitors to the website of GeoGebra in the year of 2010.

As discussed by (M. Hohenwarter et al., 2009), GeoGebra has in the recent few years become an open source project with the group of developers and more than 100 translators from all around the world The software was published in internet in the year of 2002 (M. Hohenwarter & Lavicza, 2007). According to M. Hohenwarter and Lavicza (2007), the responses of the software were immensely positive by many teachers. GeoGebra is supported by free additional resources that include tutorials, examples and various activities which can be used to support training the teachers



for integrating GeoGebra in their curriculum that meets with goals, objectives and standards. In real world mathematic problems, GeoGebra is credited for being able to support problem solving techniques, provide real visualization and interactive illustration of mathematic problems and help students by motivating and intellectual development (Preiner, 2008b).

## **1.2. Problem Background**

There has been broad increment in implementation of information and communication technologies in the field of education throughout the last decade at European countries and in many other countries (Srivastava, 2016). There has also been increasing popularization of interactive learning materials (ILMs). In case of GeoGebra, it has become one of the popular interactive learning platform for mathematics and already in 2015, it was available in 45 languages. The number of visitors are increasing rapidly each year and now the GeoGebra is said to have users from around 188 countries (Aydos, 2015).

However, one of the important issues is whether the GeoGebra is accessible or not to the people with disabilities as they are also among the end users of this application. Not so much has been done in the evaluation of accessibility of learning management system and to this date, we didn't find a research related to evaluation of GeoGebra against the WCAG 2.0 accessibility guidelines.

Since GeoGebra has possibility to be used by students and teacher with disabilities, accessibility is one of the attributes has to have. Mathematics requires the use of scientific graphing calculator which has been now replaced by GeoGebra. GeoGebra has been part of daily teaching of mathematics. The Norwegian government has made digital examination compulsory (UDIR, 2015a). However, there could be a possibility where students with disability and teachers can face problems using GeoGebra. In previous studies made to assess accessibility of ILMs, it has been found that people with disability still encounter accessibility barriers to when compared with students without disability (Begnum, 2008). Access to the internet and web contents has become the base of information society and global knowledge economy. If ILM design and development doesn't include user diversity, it will

disproportionately impact disabled people from contributing and becoming included (Adelsberger, Collis, & Pawlowski, 2013).

A successful interactive learning of mathematics requires considering “information design, visualization design, interaction design, perception, display technology and learning theories” (Souto, 2014). There are various principles and guidelines which can be helpful for designers and teachers to realize creative learning environments and take advantage of latest technologies. The researcher (Souto, 2014) has defined that powerful visualization is very important to learn mathematics, the main challenges now a days are focusing in the interactive design, make them useful, enhancing improvement and accessible to help students experience, motivate and retain real world knowledge . The main focus of this project is to evaluate the GeoGebra as it is used at Norwegian upper secondary schools.

### **1.3. Research Question**

ILMs facilitate successful implementation of curriculum not only limiting students to learn and practice but including in tutorials, recreations, games and applications (Conole & Alevizou, 2010). The goal of this project is to contribute ideas that would help making ILMs, more specifically GeoGebra, inclusive designed. This paper evaluates GeoGebra, which has been used in higher secondary schools in Norway. As it is already discussed, GeoGebra has been implemented in curriculum by education ministry for many years and recently been used in digital exams. Therefore, the main aim of the thesis is to evaluate if the website confirms WCAG 2.0 A and AA standards and find the user experience of student after using GeoGebra. Therefore, the following are the questions this research attempted to answer:

RQ 1). What is the experience of students regarding GeoGebra?

RQ 2). Does GeoGebra comply to WCAG 2.0 Guidelines?

### **1.4. Goals and Expectations**

This study aimed to determine whether GeoGebra, online interactive learning website is perceived by the students. The second purpose was to investigate the confirmation of the website with WCAG 2.0 success criteria.

This study expected to find firsthand account regarding accessibility and usability of the ILM from the perspectives of students at upper secondary schools. The success criteria evaluation is expected to find the criteria followed by GeoGebra for its accessibility. The overall purpose is to combine user input with heuristic/expert evaluation to contribute input that would improve accessibility and usability of GeoGebra.

## **1.5. Outline of the Thesis**

Section 2: Literature Review: This section includes the information about the education system in Norway and the implication of GeoGebra in the different level of schools. Furthermore, this section also includes literature on web accessibility, universal design, and the importance of universal design in ILMs. The section also provides the overview of related research on the field of LMS. Section 3

Methodology: This section includes explanations on the data collection methods used in this research. It also provides explanations on the method of data analysis. Section 4

Result: This section presents and analyzes data obtained during the course of the research. Section 5

Discussion: In this section, the information regarding the findings in the result section will be discussed. This section will also include the limitation of the research and the potential criticism of this research. Section 6

Conclusion: This section will provide the overall summary of this research. Section 7: References. Section 8: Appendix: This section will contain the resources used in this research like the interview questionnaire.

## 2. Literature Review

Information technology has enhanced traditional way for teaching and learning process (Khalifa & Lam, 2002). It has enabled new methods for education delivery and created innovative educational strategies. Large number of universities, colleges and schools are now offering virtual educational program. There are many sites that offer virtual courses and resources for educational purpose. Distance education, e-learning, virtual class, cyber course and interactive learning are just few terms describing technology enabled learning environment (Zhang & Nunamaker, 2003). Web based technology is definitely revolutionizing education.

The new generation learning method has become more individualized, learner-centered, situated, collaborated and ubiquitous. The technology used for learning purpose has become personalized, user centered, networked, universal and durable (Motiwalla, 2007). The characteristics of ILM fulfills the necessity of modern society and have produced greater demand for educational purpose (Sun, Tsai, Finger, Chen, & Yeh, 2008). The National Council of Teachers of Mathematics (NCTM) is the world's largest professional organization dedicated to improving mathematics education for all students. It has introduced visionary document named "Principles to action" (National Council of Teachers of Mathematics, 2014) has described to ensure mathematical success for everyone by using mathematical tools and technology to understand mathematics, its reasoning and visualization of learner's perception .

There are four main benefits of ILM according to Bouhnik and Marcus (2006). The benefits are freedom to decide what to learn, save time by reducing time restrictions of teachers, students will have freedom to express their idea and ask unlimited questions, students can choose the subject and related contents for further understanding if needed. Another researcher Capper (2001) has identified five advantages of ILM as users can access learning materials at their convenient time, users can learn anywhere without the need to be present physically in classroom, offers concise and focus to one point to stay on track so, that users can find what they actually need, use of group collaboration as user forums, chat, email etc. which offers new possibility to interact with group, share and learn together and ILM is used

as a new method for learning which is cost friendly that provides new options and new learning approaches.

UNESCO has stated that inclusive education has three things i.e. “physical presence of students within the main stream schooling system, their full and active participation within school life, their achievement of highest standard that they are capable of within the development of new skills”(iddcconsortium, 2013).

## **2.1. Web Accessibility, Usability and User Experience**

Web accessibility refers to the actual practice of design websites where people with disability can independently use and equally access information and their functionality. It means that “they are easily able to perceive, understand, navigate and interact in the web or contribute to the web, web accessibility is beneficial to everyone, even including the aging population”(W3C, 2005b). The accessibility ISO standard 9421-20 defines accessibility as usability for wide group of people with wide range of capabilities. This definition describes that accessible product cannot be equally usable for all people because, accessibility doesn't mean the presence of screen reader make it useful but focus on the user who feels equivalent or same experience as everyone. There is overlap among usability, accessibility and user experience. If the service is not accessible to a person, then it cannot be usable to that person.

Usability is known to be the extent of a system where the specified users are able to achieve specified task by the means of “effectiveness, efficiency and satisfaction” for specified context of use (Karat, 1997). In the context of e-learning, usability is effectiveness (completion of task by users), efficiency (time taken in task) and satisfaction of users (response according to user experience) achieved in specific learning task in specific environment (user, task, using precise tools and learning source). Usability is also called as ease of use. The usability ISO standard no. 9214-11:198 states that a product is usable if the users find that the product is effective, efficient according to their requirement, and satisfy them while achieving their goals.

User experience is considered to be more than ease of use but the satisfaction while using system so, according to ISO standard no 9241-210, it is concerned with “all the

aspect of user's experience when interacting with the product, service, environment or facility" (Quesenbery, 2009). It is also defined as "consequence of presentation, functionality, system performance, interactive behavior and assistive capabilities of interactive system. So, user experience is based on many aspects like users, design, ergonomics, HCI, marketing as well as usability and accessibility" (Wilson, 2012).

As impacts of innovative tools have always contributed in student's ability to learn and understand mathematics, use of appropriate instructional methods and tools used to support them is found to be very important and needs to be considered today (McDonald & Smith, 2013). Therefore, the increasing role of these tools in education invites evaluation of them to see how well they have been supportive to all groups of learners and what can be done for their betterment in the future (Atkin & Black, 2005).

Universal design (UD) is defined as the "design of products, environments, programs and services to be usable by all the people, to the greatest extent possible, without the need for adaptation or specialized design" (W3C, 2016). UD will include assistive devices for particular groups of persons with disabilities where it is necessary.

### **2.1.1. User diversity in web accessibility**

Disability has various definitions with diverse meanings around the world. According to Americans with disability act (ADA) defines "an individual with disability is a person who has a physical or mental impairment that substantially limits one or more major life activities, a person who has a history or record of such impairment or a person who is perceived by others as having such an impairment" (Justice, 2009).

Similarly, CRPD has described disability as "person with disability include people with long term physical, mental, intellectual or sensory impairments which in interaction may hinder various barriers may hinder their full and effective participation in society on an equal basis with others"(CRPD, 2008).

According to CRPD, it has stated many education laws for the right of person with disabilities. In order to give them the rights without discrimination and equal opportunity CRPD has ensured an inclusive education system for everyone in all educational level and life-long learning. The main aim behind this is to give "the full

development of human potential and sense dignity and self-worth and strengthening of human rights, fundamental freedom and human diversity“ (CRPD, 2008). The person with impairments are excluded from general education system due to disability whereas according to CRPD, they should be able to participate efficiently in a free society and achieve effective education.

There are many researches describing diversity of users for disability have been described types of disability. The book of Lazar, Goldstein, and Taylor (2015) has described impairment is divided into three categories according to the computer interaction world’s functional needs of computer input and output: (a) Perceptual impairment: This impairment includes people with vision and hearing drawback, (b) Motor impairment: This impairment includes people with hands, arms and speech and (c) cognitive impairment.

According to user diversity group categorized by WAI (W3C, 2012), the author has related to disability to web accessibility so, even for millions of users worldwide have possibility to face barriers while using GeoGebra. Significant types of user diversity and their challenges can help in understanding heuristic evaluation criteria and its findings later in result stage. WAI has given a list of disabilities and their relation to accessibility issues in web. As WAI has introduced categorized six disability categories to explore wide range of users who are commonly affected by poor accessibility design and tools in a webpage. The description of disability below has been explained according to the function so, medical definitions are not included. The general barrier that is likely to be faced by these disability is also included with the introduction to disability.

Visual impairment has various type of impairment according from mild to moderate in one or both eyes to the user. The most common visual impairments are low/ partial vision, blindness, color blindness, excessive color brightness sensitivity. Blindness is substantial/ un-correctable loss of vision in both eyes. While using web, the user with blind mainly use screen reader which is a software that reads the text from monitor and gives output information from speech synthesizer and braille display. They read the web contents by using rapid navigation strategy using tab and going through main heading and links found in the web page sequentially. They avoid going through every word in the page. The user with multiple disability like deaf and blind when born

can face issues like video or audio content without transcript that cannot be changed into refreshable braille display. User with both deaf and low vision requires enlarged caption and high color contrast to audio and video contents. User with motor and vision impairment uses both voice command and screen reader so, they rely on precise navigation structure for location and navigating through webpages.

The main issues the vision impaired users face in web are the images, graphs, charts without alternative text, videos without text or audio, tables without description, frames without meaningful names, poorly labelled frames, websites without keyboard support, non-compatible to operating system they use, non-interpretative documents/contents with screen reader etc.

Low vision or partially sighted people has various type of vision disability. Some of them are: instance poor acuity with weak vision, tunnel vision who can see middle of vision field, central field loss who can see edges of vision field and clouded vision. This type of users use extra-large screens, increase size of font and images in system, use screen magnifiers or software for screen enhancement. Some users even select specific colors for text and background, choose different font according to the requirement. Low vision users face issues while using web, some of them are: websites without adjustable customization of fonts color, size, background color, inconsistency layout or loss contents while zooming contents, poor navigation options, poor contrast color, text in images deforms when enlarged etc.

User with color blindness lacks to the sensitivity for certain colors. The common color blindness found have difficulty in distinguishing red and green or yellow and blue. Some color-blind user lacks in sensitivity of all the colors. The issues color blind user face while using web are: specific color used for emphasizing text as a marker, warning, links etc., inadequate background and text color, browsers that is non-compatible to user's stylesheet.

There are many type of auditory impairment disabilities which are mild to moderate hearing disability in one or both ears. Some of the common hearing impairment are deafness includes un-correctable hearing loss in both ears. Most of the user with deafness has its first language as sign language. The user with deafness can or may not be able to read the text-content or understand speech or even sign language.



These users use hearing aids and other devices for improving listening. The barrier faced by deafness are lack of caption or transcript of multimedia like audio only, audio or video, lack of user setting to adjust volume, text size, color etc., lack of play, pause, rewind, stop buttons, lack of simple language content, lack of high quality foreground audio in contrast to background noise in web pages. The user with mild to moderate hearing impairment also rely on caption or amplification of audio content.

Physical impairment has many variety of its impairment. Some of them are person with weakness, limited muscular control like involuntary movements, lack of coordination, paralysis, limited sensation, joint problems like arthritis, missing of limbs. Few physical disability users also have pain that obstructs movement. The motor disability users that are affected by hand or arms use specialized mouse or mouse like device, adaptive keyboard according to hand movement, on-screen keyboard with trackball, joystick or switches, pointing devices like head pointer, mouth stick, voice recognition software, eye tracking system or hand free interaction approaches etc. The barrier faced by motor disabled users are limited time to complete task in webpages, non-supportive keyboard alternative for mouse commands, lack of sequential and logical order while using them through keyboard, small clickable area is provided, no error correction option, unable to skip block of contents like header, footer, navigation bars.

Cognitive and neurological impairment has many category for disability in any part of nervous system. This type of disability can be not affected to intelligence of user too. Some of them are visual and auditory perceptual disability like dyslexia/learning disability, dyscalculia i.e. having problem processing language and numbers. Some of users have problem in processing spoken language or spatial coordination. The visual and auditory perceptual users mainly rely on screen reader or synthesized speech to understand contents and use caption for audio contents. Some of them change font size and customize color of foreground and background for easy reading. Tools like grammar corrector, spelling checker can assist in writing. The main barriers faced by them are lack of alternative text which can be converted into audio or other supplemental visual option, lack of captions.

Attention deficit disorder users have difficulty in focusing into information provided in webpage. The problems faced by users are no options to turn off visual/audio contents, inconsistent organization of webpage contents.

Intellectual disability/ learning disability/ developmental disability are the term known for the disability who have impaired intelligence, they need more time to learn or have difficulty to understand complex conceptions. Down syndrome is known to be one of the causes of intellectual disability. This type of users face problems like unable to understand complex words or language used in web contents, lack of images or graphs, inconsistency of webpage contents.

Memory impairment users have short term memory, has loss of long term memory partly or fully and cannot recall language. This type of users relies on navigational structure for mapping the website. Lack of navigation support or consistency in webpage can create difficulty for these users in a webpage.

Mental health disability users have difficulty in vision, trembling of hand due to medication side effect. These users have problem with visual/ audio elements without turn off option, lack of user setting options for font size, inconsistency to enlarging contents.

Seizure disorder users are found to have difficulty with flickering, flashing visual/audio signal in certain frequency. This disorder includes epilepsy, photo-sensitive epilepsy. The problems faced by these users are no options to turn of animations, blinking contents, unable to change frequency of audio.

Aging is the changes in functional capability when people gets older. Aging can change in people's ability to hear, see, dexterity and memory. The challenges they face are similar to issues mentioned above.

The common approach used by various users are using assistive technology (AT) or using adaptive strategies while using websites (W3C, 2012). Assistive technology and adaptive strategy for visual, audio and visual contents are refreshable braille display, screen reader, voice browser. AT and adaptive strategy for presentation of contents are: block pop up and animations, read assistance, screen magnifier, setting for volume. AT and adaptive strategy for user interaction like type, write, clicks in

software are: accelerators e.g. creating shortcut commands, highlighting selection in contents, alternative keyboard or mouse, eye tracking system, customization of keyboard or mouse, on-screen keyboard, spelling and grammar tools, voice recognition software, word prediction software. AT and adaptive strategy for design of contents are: bookmark and history, search by keyword, navigation by keyword, page map, pictorial links. There are many new mathematic technologies for

Facilities like braille, alternative script, augmentative and alternative modes, means and formats of communication and orientation and mobility skills and facilitating peer support and mentoring is required by a web based interactive learning material. CRPD has also described that educating children who are blind, deaf and deafblind needs to be accommodated with most applicable language and every possible means of communication so that everyone can amplify latest academic and social developments (CRPD, 2008).

To ensure implementation of accessible education, teachers or teachers with impairments specially qualified with braille should be employed. The professional and employees working in every level of education needs to be trained. The steps like awareness about disability, knowledge about use of augmentative and accessibility tools, understanding the use of correct means of communication, educational methodology and materials can help the students with impairments. CRPD has described that everyone can achieve education by “being able to access tertiary schooling, vocational trainings, adult educations and lifelong learning without discrimination and on equal basis with others gives successful implementation of the stated acts” (CRPD, 2008).

### **2.1.2. Accessibility in interactive learning system**

There are several discussions made for making websites accessible. According to Thatcher (2011) almost all the web technology are compatible to make accessible without any impact to visual appearance and it has simple process. By an accessible website there is possibility to reach wide number of disabled people both nationally and internationally (Thatcher, 2011).

According to the researcher Thatcher (2011) the web designers are often found to be of young age in early 20's and they have perfect vision and tactile acuteness for example mouse professionals but in the advancement of medicine, science, technology and aging population. More people are forwarding towards disability in some form and tend to use technology in their life, if there is accessibility barrier in a webpage, those millions of users will choose another accessible webpage. Beside the positive experience of disabled users, accessibility of webpage has other effects too. Including features of accessibility like alternative text for pictures, proper heading, and sequential navigations also helps to have positive impact while ranking in search engine. This also helps in improving performance of the website including in the smaller websites (Thatcher, 2011).

According to CRPD (2008) has stated that empowering disabled person to live independently and contribute fully in all the aspects of life, state parties shall take appropriate measures to ensure to the person with disability access on an equal basis with others, to the physical environment, in transportation, in information and communication technology and systems and to all the facilities and services provided to the public and both in urban and country areas. These actions will also include the identification and elimination of obstacles and barriers to accessibility.

CRPD comprises ICT services, electronic services and emergency service. The states are also needed to follow measures as developing, disseminate and supervise the implementation of at least minimum standard and guidelines for the accessibility features to the facilities and services provided for public. Private entities are also required to ensure to offer the services for public give all the aspect of accessibility for the person with impairments. Impaired people have right to access information so the government should promote access to new ICT technologies and systems including internet. (Brezet, Bijma, Ehrenfeld, & Silvester, 2001).

Universal accessibility is an important feature while using the internet (W3C, 2005c). For the websites with several purposes like commercial, governmental, educational and non-profit should be equally accessible to all. The disabled people have their own requirement according to their physical limitations. They may have poor eyesight, hearing loss or motor impairment. The users may have problem in accessing information straightforwardly. Difficulty in reading and understanding text

content can be difficult for some people. The users who are not able to use mouse or keyboard can also be one of the users in GeoGebra. Certain conditions like use of text only screen, small screen size and slow internet connection speed are also possible issues in daily use of websites. The users with different culture and language may not be able to understand the content in the webpage. Old version of browsers, many types of browsers, voice browser or many type of operating system can also affect in the use of website.

Nevertheless, the Disability Discrimination Act of 1992 made obligatory for the organizations that offer services- websites should not discriminate person with disability. A visually impaired person named Bruce Maguire filed case against the Sydney Olympic Games Committee in the year of 2000. He was successfully litigated and was compensated with \$20,000 for the damaged caused because the web application forms were inaccessible while he used his screen reader (Mason & Casserley, 2005).

(Brownlie & Goodwin-Gill, 2010). Its objective was to provide people with disabilities have full, equal human right and acknowledge them. The convention stipulated the countries to implement necessary measure ensuring the people with disability have access to physical environment, transportation, information, communication and every other areas and services offered to general public. The countries were stipulated to promote universal design. In May 2009, 51 countries including seven European countries had ratified the convention.

According to CRPD, “communication includes language, display of text, braille, tactile communication, large print, accessible multimedia as well as written, audio, plain language, human reader and augmentative and alternative modes, means and formats of communication, including accessible information and communication technology “(CRPD, 2008).

According to the Cooper, Colwell, and Jelfs (2007) research, e-learning exploration and development projects needs to be implemented to real world teaching and learning context where both accessibility and usability should be addressed and integrated throughout the project. The issues related to both accessibility and

usability needs to be explicit throughout the documentation in a project with better allocation of time and resources.

Many researches like (Di Lucca & Fasolino, 2006; Matera, Rizzo, & Carughi, 2006; Murugesan, Deshpande, Hansen, & Ginige, 2001; Petrie & Kheir, 2007; Queirós, Silva, Alvarelhão, Rocha, & Teixeira, 2015) has found that accessibility and usability are interrelated. Accessibility and Usability are well established for the purpose of user interface and website. The determination of the flexibility in the e learning system or resource which meets every user's requirement according to the environment (e.g. Using it in noisy surrounding, low light), use of tools (e.g. alternative keyboard, screen reader, voice command etc.) or in predictable consciousness etc. can contribute to relate usability and accessibility (Petrie & Kheir, 2007).

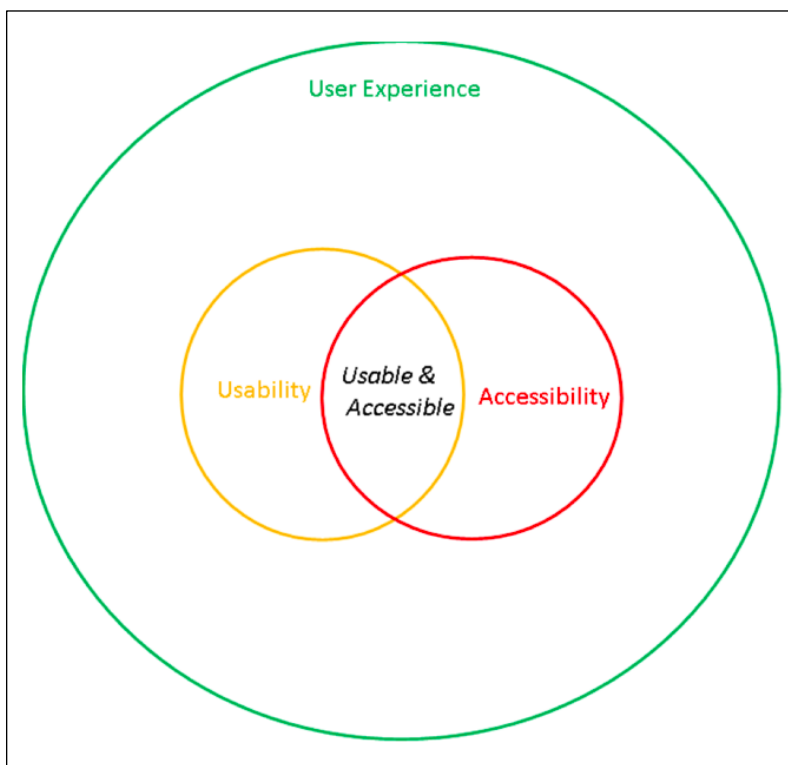


Figure 2-1: Relationship between user experience, usability and accessibility (University of Southampton, 2016)

As the Figure 2-1 describes experience of user incorporate accessibility and usability, so, the products and services should be both accessible and usable which brings good user experience among end users(University of Southampton, 2016). A

product or a service can be theoretically accessible but may take too long to achieve the task like eg, if blind user needs to find contact of a person in webpage but if it takes too long to find it then cannot be practically accessible. There is general legislation about the quality of product and service but no specific legislation is found.

Use of web has been increasing as an important resource in every aspect of our life for example in the fields like “education, employment, government, commerce health care, recreation and many more” (W3C, 2005b). So, it is important that web needs to be accessible equally to everyone and provide opportunity to participate actively.

The research (Cooper et al., 2007) has discussed that “accessibility and usability is intrinsically interlinked. The researcher based the case study on various projects done by open university (OU), i.e. the largest educational establishments in Europe that provides distant learning courses with 180000 active students and 9900 disabled students. The case studies were analyzed by identification of lesson learnt and suggestion for upcoming eLearning projects embedding both usability and accessibility into considerations.

The researcher Huffaker (2015) has defined eAccessibility to be a concept which ensures that people from all ability level has the same accessibility to the information in general. People with disability and elderly people with limited capabilities are also included in this concept. The web based good and services, its accessibility are needed to be ensured from the high authorities, government and international organization for equal and non-discriminated society. Under the branch of eAccessibility there are many subsection, one of them is known as web accessibility.

The inventor of web and director of W3C, Tim Berners-Lee defines “accessibility in terms of disability and universality as the power of web is in its universality. Access by everyone regardless of disability is an essential aspect ”(W3C, 2005c).

Another practitioner Jim Thatcher has also described “technology can be accessible of it can used as effectively by people with disability as by those without”(Thatcher, 2011)

The word usability refers to methods for improving ease while using in the designing process. According to the research Rimmer (2004), the interaction design field of HCI

needs to focus on usability of the software to enhance the experience of end users because the best system environment is not only easy to use but satisfying and supportive.

Accessible interaction design intends to bring better user experience by enhancing and extending the way people work, communicate and interact with the system. The leading advocate of web usability Jakob Nielsen has defined usability as “a quality attribute that assesses how easy user interface are to use”(Nielsen, 2012).

Another author (Quesenbery, 2001)has described usability as five “Es” as definition which includes “effectiveness, efficiency, engaging, error tolerant and easy to learn”

There are few difference between usability and accessibility. Firstly, usability focuses in design relating to a better user experience whereas accessible design focuses in removing the barriers in access due to disability, technical tool or limitation of environment. Secondly, the target audience of usability has wide range of users depending upon the purpose of website whereas accessibility is based on disabled users and other users are secondarily beneficial. Thirdly, the perspective of usability is to enhance user experience by identifying and understanding the targeted user and design for them in mind but the theme of web accessibility is related to universal design and primarily premise in using web accessibility standard and guidelines for improving accessibility.

There is also a saying as “one size does not fit all” (Olson & Wisher, 2002) because changes or improvement implanted for one group of users can create difficulty for another group of users. Access to information and interaction in web is a powerful tool to people but accessibility barriers like print, audio and visual media needs to be enhanced to overcome with the help of web technologies. There are many factors like social, economic, technical, legal, and policy that influence the development of accessible web in an organization.

Web developers are considered to have important responsibility for web accessibility. However, overall web software development process also important role in implementation of web accessibility. So, the software needs to be evaluated for the accessibility throughout the development and testing process.



### 2.1.3. Effective factors in web based interactive learning material

There are altogether seven fundamental components of web accessibility(W3C, 2005a). As they are dependent on each other, improvement on them can enhance web accessibility. The components are (1)Web Contents: The contents present in the website or an application such as text, pictures, videos, code and markups that defines the structure and present the contents, (2)Browsers for web, media players, (3)Assistive technologies like screen readers, alternate or adaptive mice, alternate keyboard, head operated pointing devices, eye gaze system, switches, voice recognition software, on screen keyboard, software for scanning contents etc., (4)User's education level, experiences and adaptive approach while using web, (5)Web Developers, designers, authors, code developers and even including developers, users with impairment for real contribution in accessible content, (6)Authoring tools for web for example the software which creates web sites, (7)Web evaluation tools like web accessibility tools, HTML and CSS validators etc.

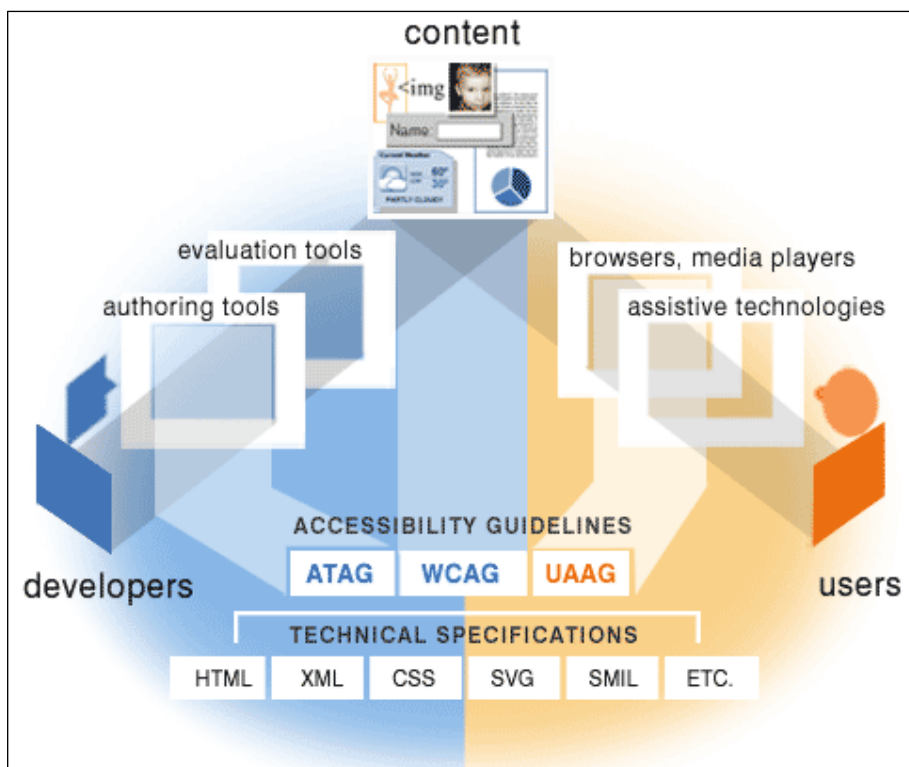


Figure 2-2: Relation between web components of website (Henry, 2005)

As the Figure 2-2 describes, the web components are the website, the developers use authoring tools and evaluation tool while creating a content in a web, whereas

end users use the browsers, media players, assistive technologies and many more while interacting with the website content.

The components are mutually dependent on each other. There is the necessity of components working together for an accessible web. For example, to have an alternative text in pictures, technical specifications state alternative text attribute as (alt) for picture element as (img) in platforms like HTML, guidelines of WAI like WCAG, ATAG and UAAG suggest how the alternative text can be implemented, developers provide meaningful alternative text, authoring tools helps to assist, simplify and stimulate to provide alternative text in the web site. User agent combines human and machine interface for alternative text, technologies for assistant supports interaction to website in different ways. Finally, users practice the alternative text provided by user agent by using assistive technology.

If any one component is weak or does not implement accessibility features can lead to inaccessible user experience. When one component has deprived support for accessibility, other components are required to compensate by “work arounds” technique. For example, developers need to compensate by coding markup directly rather than the use of tools or users’ needs to use various browsers and assistive technologies to overcome issues. Though work around technique is used often yet that is not good practice and reasonably cannot overcome by other components resulting to inaccessible website.

#### **2.1.4. Guideline and Specification for accessible ILM**

According to W3C, WAI have developed web accessibility guidelines for the components which is worldwide standardized. There are three guidelines which are listed below:

ATAG is an authoring tools guidelines in order to help authors to make accessible content such as web developers, designers, writers etc. for creating accessible web content in webpages that are static, dynamic etc. ATAG primarily supports developers of many authoring tools like web page authoring tools (HTML editors etc.), software that develops websites (CMS, courseware tools etc.), software that converts web content as technology (word processor and other office documents

which can save as HTML), websites where user can add web contents as blogging, wikis, image sharing websites, online forum and many other social networking websites.

The user agent accessibility guidelines (UAAG) 1.0 includes accessibility of web user agent focusing to web content accessibility in the context of user agents like web browsers, media players and assistive technologies. It provides user agent implementation principles while interaction with accessibility content and its compatibility especially with assistive technologies.

WCAG is developed by WAI with the cooperation of people and organizations throughout the world to provide one standardized guideline to make web content accessible and meets the requirement of people, organizations and governments worldwide. WCAG helps to ensure web content are accessible to people with impairments. The web contents like images, text, audio, video, code and markup that gives structure and present information in a web. WCAG is intended primarily for developers of web content, authoring tools, accessibility evaluation tools and other who requires to standardize web accessibility even including mobile accessibility. The requirement of people like policy makers, managers, researchers are also intended to be fulfilled by the resource of WCAG.

WCAG 2.0 is a stable, reference able technical standard. It consists of 4 principles based on which 12 guidelines are organized. Each guideline contains success criteria from level A, AA and AAA. The four principles are:

- **Perceivable:** The information in a website and user interface components in it must be reasonable so that users can find them and can be perceived

By providing text alternatives for non-text contents so that people with these requirements can change into other form like larger print, braille, audio speech, symbols or in simple language.

Provide options for time based media

Contents needs to be created in such a way that they can be presented in many other way like in simpler layout without failing to present exact information or structure of it

Creating web contents easier to view for users by separating foreground and background.

- Operable: Operable user interface components and navigation of the website is required.
  - Keyboards needs to operative to all the available functions in the website.
  - Enough time should be provided to users for reading and using the content in a page.
  - Avoiding seizures caused by bad content designs.
  - Helping users with navigation, finding the contents and identify the structure
- Understandable:
  - The contents in the website should be clear and logical.
  - The appearance and operation of webpage functions needs to be predictable.
  - Support user to avoid and correct errors.
- Robust: Maximization of compatibility of the website with latest or various version of user agents incorporating with assistive technologies.

There are altogether three conformance level in WCAG. Level A is the minimum criteria level for the conformance. The content developers should be able to satisfy all the checkpoint in this level because, without successful implementation of this level criteria, many users will not be able to or impossible for the access of the web content in a website. Level AA is more focused in the content provider of the web page. This level also needs to be satisfied for accessible web content because users find difficulties in the process of accessing information. Level AAA is the uppermost level for the conformance. The content developers are recommended to satisfy this level because many user groups can find difficulty in access of the web content information in webpage.

IMS Global Learning Consortium (IMS Global/ IMS) (consortium, 2002) is non-profit organization that supports enabling adoption and impact of innovative learning technology. The main focus is to help interfaces and content become adaptable and can be personalized according to individual needs. IMS further describes that implementing accessibility will decrease disability exclusion and increase usability. IMS accessibility specification was introduced in July 2002 which consist of six specifications. Firstly, implement accessibility legislation to remove barriers in online learning proficiency. Most of the legislation is based on WCAG 2.0 and international standard experts. Secondly, ensuring and developing access with ILM web settings with assistive technology devices. Thirdly, implementing conformance with the standards and design principles like navigation, image text alternative etc. Fourthly, making the system interoperable by enabling to connect with other system and products. Every individual requires personal accessibility needs and preference for using the system. This can help disabled users to have control over the system. Fifthly, creating ILM with inclusive design supports accessibility and usability to disabled users without any special modification or design. Determination of specific learning requirement and end goal of instruction can help in achieving successful learning. Lastly, motivate authors to use accessibility enhanced authoring tools and learning strategies for creating accessible contents and enhance learning ability of students without any barriers.

#### **2.1.5. Web Accessible Legislation**

There are many guidelines and principles developed for usability, accessibility and user experience but only accessibility has the real legislation to make illegal if the product and services are inaccessible to disabled users. But the legislation differs from one country to another, state to state. Agreeing and implementing some legislation is difficult due to overlap of accessibility, usability and user experience.

It is important that web needs to be accessible equally to everyone and provide opportunity to participate actively. Use of web has been increasing as an important resource in every aspect of our life for example in the fields like “education, employment, government, commerce health care, recreation and many more” (W3C, 2005b).

*W3C has published a first working draft for “Accessibility Conformance testing rules format 1.0/ ACT rules format 1.0” in 6 April 2017(W3C, 2017). This draft is a complete draft which addresses the overall requirements the ACT task force suggest that are necessary to cover while scripting rules. The ACT rule format 1.0 is based on the rules developed by Auto WCAG community group and produced by group working in 5 February W3C Patent Policy. According to WAI, there are various type of products where users test web content as conformance for the standard of accessibility like WCAG 2.0. The format proposed is intended to provide consistency to interpret the testing can be carried out both manually or automated using accessibility test tools without conflict in results of accessibility test.*

Section 508 is the legislation published under the workforce rehabilitation Act in 1973 and signed into law on 7 August 1998. This rule is applied for the procurement of electronic and information technology by federal government which also includes “hardware, software, websites, phone systems and copiers”(Gov, 2000). This law implies access to both public and federal employees for technologies while developed, procured, maintained or while in use by federal agencies. This law is part of Federal Acquisition regulation and address access to physical, sensory, cognitive disabilities of people. They also contain specific technical criteria for technological and enactment based requirement centering on functional capability of the products. There specific criteria for “software applications, operating systems, web based information, computers, telecommunication products, video and multimedia and self-contained products”. Section 1194:22 is for web based intranet and internet information and application which has 16 specific criteria for web accessibility and also needs to follow specific checkpoints of WCAG 1.0.

ADA was implemented in the civil rights law in 1990 with the purpose of prohibiting discrimination to disable people. The law combines employers, state and local government and places for public accommodation to provide services and tools insuring that disable people are not discriminated due to disability. ADA was implemented before internet was substantial force in society so web was considered as “a place of public accommodation”. Later national federation of blind sued the company named AOL for the interpretation with subject to ADA. The suit was then settle down after AOL agreed to make accessible web browsing technology. The

New York State Attorney General filed action against inaccessible Priceline.com and Ramada Inn websites. This was settled down after company agreed to make accessible website. In the year of 2006 NFB sued Target Company for inaccessible websites and violating ADA. So, there has been many cases filed against inaccessible websites and makes sense to develop an accessible website.

There was recent settlement on discrimination class action against the social security administration in November 5 2014 by United States equal opportunity commission (EEOC) on the behalf of over 579 employees. Nearly 30 million dollars was provided for the settlement agreement to improve policies and process that impact on disabled employees, provide reasonable accommodated office, accessible technology, training and assistive support for the employees(Advocates, 2015).

A group of universities who tried to introduce Amazon's Kindle eBook reader replacing textbook were sued by disability rights organizations due to inaccessible speech to text feature. After the charge of violation under ADA and Section 504, the inaccessible device was refrained in the university. This shows that the educational institute also plays important role in procuring the accessible interactive learning materials that will be introduced among students.

#### **2.1.6. Previous researches in ILM accessibility**

Accessible web based learning materials is valuable for broader population. There are many issues like ignorance of webmaster and misconception that accessibility implementation is expensive and timewasting can be barrier in developing accessible websites (Sierkowski, 2002).

Web accessibility is important because of various reasons which are discussed in brief. Firstly, accessible web develops good ethical moral for everyone. It is amendable so that disabled user and aging users can access web easily. Secondly, accessibility cover large audience size, there is possibility to support large number of disabled user group worldwide. This kind of users always wants to use conventional web and are loyal customers. Thirdly, evolution of new technology trend is evolving. The new gadgets are adapted for using ICT in anywhere and anytime. ICT device dependency in daily use of people bring bigger scope to accessibility. Fourthly, this

can help organization to have sustainable cost saving process. Rather than implementing accessibility in the final stage of the website, it needs to be incorporated in the beginning stage, this will make the development cost cheaper than formatting in later stage, website functions will be highly manageable, flexible and there is possibility to implement powerful dynamic model. Lastly, developing accessible web system is respecting and following law regarding accessibility and ensuring human rights to the disabled people. There are many acts and legislation put forward to support accessibility so, it is legally correct to follow the rules and make web accessible (Sierkowski, 2002).

A research project conducted by University of UIO on the behalf of the Directorate of Education on 2015 (UDIR, 2015b). The research was a case study on mathematics in first year general study of high school in southeastern Norway. The research used structure observation notes, explanatory notes after class, video recording during the class and interview for three weeks as a data collection method. The study found that after using good mathematics teaching principles for three week during the research encouraged students to be more involved, increase in their conceptual understanding and reasoning skills. Using various teaching resources and aids played important in concept of theoretical and practical understanding of mathematics. The students were found to be more focused when they were taught through whiteboard, textbook and digital resource like Geogebra and Graph. The students were more committed with the digital teaching aids with more dynamic interaction forms.

The researcher Sanderson, Chen, Bong, and Kessel (2016) carried out study on accessibility evaluation of Massive open online course (MOOC). A systematic study of accessibility was done from instructor's perspective. For ensuring universal and accessible evaluation of MOOC, Canvas platform was chosen by instructors to creating course contents. Heuristic evaluation method is chosen using part A of Authoring tool accessibility guidelines 2.0 (ATAG). The evaluation result showed that Canvas didn't fully implement all the conformance level. The result showed 11 criteria were fully implied from 28 criteria that were selected for evaluation, 8 were partially fulfilled and one did not comply, other 8 were not applicable or available. The results were then compared with the previous research that evaluated Moodle. The comparison showed that Canvas complied better in selected criteria and can provide



better support to improve accessibility of MOOC. Considering the findings, the researcher has suggested in improving accessibility by improving efficient keyboard navigation, screen reader support and improving error correction option.

Another research by Iglesias, Moreno, Martínez, and Calvo (2014) that has evaluated three learning content management systems (LCMSs) The research used comparative study of web based systems “Moodle, Atutor and Sakai”. The systems were evaluated by two experts using WCAG 1.0 for user interface and ATAG 2.0 for compliance with each system. The result from the research was there was accessibility barriers in all three system.

The research Al-Mouh, Al-Khalifa, and Al-Khalifa (2014) conducted accessibility evaluation of Coursera.org which is a popular MOOCs environment. They used usability testing and heuristic evaluation approach. The usability evaluation method included two blind females and one blind male who were given predetermined task using screen reader and the issues were recorded. The heuristic evaluation method was done by analyzing ten courses of Coursera with WCAG 2.0 guideline. The heuristic evaluation result showed that conformity level A had 70 to 80% conformance of successful criteria and level AAA had lowest with 56 to 69%. The usability evaluation analyzed the accessibility problem faced by three participants. The result showed that they had general satisfaction and faced similar type of accessibility issues though the task were successfully fulfilled. The accessibility issues faced were no alternative text, lack of proper layout element like heading, lack description of labels in quizzes and tasks, no descriptive alternates for links, tables and pictures.

Interactive learning material has been popular over past two decades (Roberts, Crittenden, & Crittenden, 2011). However, there is requirement of evaluation and enforcement of accessibility standard in these online learning materials to maintain this momentum. This can be useful for teachers, students and legislators to acquire accessible learning platform. ILM has greater potential to benefit both current disabled students in their studies and facilitate with equitable representation of learning materials (Kent, 2015). It is often observed that the requirement of disabled students is poorly understood by ILM. So, in order to make ILM accessible, ILM needs to be developed focusing wide range of disabled user ensuring that users are

capable of using learning materials without barrier and experience offered through interaction on the ground of their disability (Seale, 2013).

Learning materials available online has many accessibility options replacing analogue content, the electronic text can be read through screen reader, translate it into braille, audio files can be interpreted by the text transcript and captions (Kent, 2015).

In the last ten years, there has been many researches about GeoGebra. Researches like M. Hohenwarter and Jones (2007), M. Hohenwarter and Preiner (2007), M. Hohenwarter and Lavicza (2007) focused in developing GeoGebra as a powerful teaching resource. Whereas, Chrysanthou (2008) and Mehdiyev (2009) focused in discovering GeoGebra potential to support mathematics linking algebraic and geometric analysis. Similarly, other researches Diković (2009), Preiner (2008a), J. Hohenwarter, Hohenwarter, and Lavicza (2010), Kovács (2015)<sup>2</sup> were found to be focused regarding GeoGebra in teaching and learning mathematics.

Various researches like (Andrade-Aréchiga, López, & López-Morteo, 2012; Buteau, Jarvis, & Lavicza, 2014; Gono, 2016; Helsel, Hitchcock, Miller, Malinow, & Murray, 2006; M. Hohenwarter & Lavicza, 2009; Saha et al., 2010; YAĞMUR, 2014) have proved that effective use of technology integrated in mathematics education has developed noteworthy benefit in conceptual understanding of various mathematics topics like geometry, algebra, calculus etc.

The research of Knipping and Manya-Ndjeka (2009) has identified that learning and teaching mathematics can be challenging. Thus, with the help of interactive visualization can help it to learn by a different approach. The factors that affect quality in visualization are “expressiveness, effectiveness, adequateness, objectives (information extracted by graphical concept representation of mathematics), foreknowledge (preconditioned foreknowledge of mathematical concept and objects of students), perceptibility (perception capability of students), representation medium like the resolution, representable colors” (Knipping & Manya-Ndjeka, 2009). These all factors are combination of visualization, observation, interactive design and education. Informative design and experience of users are useful to achieve qualitative visualization of mathematics and good user experience (Spence, 2001).

J. Hohenwarter et al. (2010) evaluated the difficulties while using the tools of GeoGebra. 44 mathematics teachers took part in the evaluation process. During the process, the participants were provided The Likert Scale to evaluate the tools available in GeoGebra. The Likert scale included numbers from 0 to 5 ranging from very easy to difficult. After the findings, the tools were classified into three types according to the findings. The easy to use tools was found that it could be used with specific instruction in home or school, the middle tool group needed the help of presenter for demonstration and difficult group tools should be used after the preparation using different actions. Studying the literature found for DGS (Dynamic geometric system), the study found that DGS are adopted by students and teachers within the classroom but lacking in usability and accessibility evaluation in this type of environment.

In a research Wikan and Molster (2011) explores about the use of ICT in the classroom by the teachers in their teaching and what were the teaching level factors implementation the use of ICT. The used both qualitative and quantitative methodology. The researchers analyzed 10 focus group interviews with 10 teachers and quantitative study with 59 teachers of three lower secondary schools situated in Hamar, Norway. The result showed that the teachers were committed using ICT but did not find educational value but accepted increase in access of learning materials and stimulates user's motivation. Teachers were found to be lacking ICT confidence though they had been taking ICT courses. The main finding was that teachers found the integration of ICT in teaching was difficult and gradually takes time and they need to be given time to manage merging ICT with their teaching method.

The quasi experimental research by Saha et al. (2010) examined the effect of implementing GeoGebra to learn coordinate geometry among 53 students. The participants were categorized into two groups of 27 students with high and 26 students with low visual spatial ability based in spatial visualization ability test instruments (SVATI). The result found that GeoGebra helped in enhancing performance of students in learning coordinate Geometry.

### **2.1.7. Universal design in Norway**

The government of Norway had released an action plan in 2009 for universal design and accessibility 2009 to 2013 (Regjeringen, 2009). The vision of the plan is to make Norway universally designed by 2025. This action plan describes the foundation for achieving its ambition through its goals and measures subjecting to its deadline. Ministry of education and equality has been promoting equality and prevent discrimination by “gender, age, sexual orientation, skin color, ethnicity, religion or disability” (Regjeringen, 2009).

The main idea behind the action plan is to bring equality and sustainable policy step further. Accessibility has always been an important factor for people with disability to take part in society. Lack of accessibility brings discriminatory effect on them. The government works according to universal design standards. According to the article of Easton (2013), the existing accessibility acts are intended to support the implementation gap but there is need to define accessibility in a broad way and provide the standard of basic accessibility requirement during public procurement and contracting process.

The Soria Moria Declaration (Solhaug, 2011) have stated that the parties in power prepares an action plan concerning the accessibility of transport, buildings, information and other important areas of society. The declaration states that the binding timetable of accessibility has to be ensured and make principle of universal design as the base of government works. The government has been making systematic efforts for promoting knowledge and stipulating the necessity of universal design in human created environment. It brings positive social qualities among the entire population of Norway as a society. UD contributes in bringing both social and economic sustainability so, it has been made as a part of national sustainability strategy. The plan will affect every part of society and all the ministries are involved in implementing the plan. There is wide range of tool that needs to be used to reach all level of public and private sectors.

Norway has ratified the UN CRPD on 3 June 2013 but did not sign the CRPD optional protocol on individual complaints mechanism (Strand, 2014). According to the Norwegian Anti-discrimination and Accessibility act implemented in 21 June 2013

forbids discrimination based on disability in every sector of society exceptionally family and personal relationship. This act also implements accessibility, universal design and reasonable accommodation. The governmental action plan of Universal design and improved accessibility was implemented between 2009 to 2013 (Strand, 2014). Norway has been promoting social living and deinstitutionalization for disabled people over decades and moreover municipalities providing personal assistance has become individual right from January 2015 (Lovdata, 2013).

The main purpose of the convention is to stimulate, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by every person with disability and to stimulate respect for their inherent dignity. Person having long term physical, mental, intellectual or sensory impairments faces various barriers while interacting which may hinder their full and effective participation in society on an equal basis comparing with others (Bringa, 2001).

In this research, we are focusing on acts related to higher education so we have described these acts in detail according to the requirement of the research.

## **2.2. Accessibility in inclusive education**

According to the article (Wendelborg & Tøssebro, 2008) has described the main idea and improvements relating to inclusive education. The article has that had identified three model approaches for education related to children with SEN; two track approach was distinguished by division between regular and special education system, one track approach had policies and practice in favor of inclusion of all children and multi-track approach ranging from variety option of inclusion to special school.

Norway changed from two track to one track model In 1970 . After 1975, legal and administrative integration was implemented. The special school act was included in the general education act and municipalities became accountable for education for all children.

According to the ministry of education and research of Norway (Wikan & Molster, 2011), its aim is to make high quality schools that equip every individuals and society

with the tools they require in order to develop prosperous and sustainable future. The article (Krumsvik, 2006) have described that the digital inclusion policy is successful when it is based on three main pillars i.e. “access to internet, equipment and content, universally designed solution and digital skills”. The Norwegian school system follows the principles of equality and adapted learning services for everyone in inclusive environment so the government has ensured for “access to broadband internet all over Norway, target universally designed technology, strengthen the commitment for digital skills in the population, intensify ICT commitment in education” (Wikan & Molster, 2011).

The main focus of ICT implementation in Norwegian education is that all the students should be able develop key skills according to the courses of the education; they need to face challenges and experience a sense of achievements. Interactive learning materials (ILM) allows the distribution of various courses to wide range of age. ILMs became popular after the development of multimedia and internet development around 1990s (Skellas & Ioannidis, 2011).

There are plenty of evidences which show that Norwegian school students underperform in maths and science. This may lead to shortages in skilled manpower in labor market so, the government is working in new national strategy.

“Science subjects for future 2010-2014” to strengthen the position of maths and science in education system. Its goals are firstly to increase interest in maths, science and technology, improvement in recruitment and courses completion rates in all level and secondly to improve Norwegian student’s math and science skills, reinforcing teachers’ skill and increasing recruitment to higher education courses in math, science and technology. In the national budget of 2015, the government has allocated NOK 20 million to establishing special science municipalities where 20 to 30 municipalities will be selected to participate for the period of 2015 to 2019 which will be based on Danish model of science municipalities (Jensen, 2011; “rengjeringen,” 2015).

### **2.2.1. ICT in Upper Secondary Curriculum**

The ministry of education of Norway has implemented the GeoGebra software from level 8 of lower secondary school to upper secondary education and training (UDIR, 2014). Upper secondary education and training is available all over the country ensuring education for all with a unified upper secondary structure coordinating general and vocational studies.

The program consists of three-year general education or four years of vocational training leading either to admission to higher education, to vocational qualifications or to basic skills. The education is divided into three levels Vg1, Vg2 and Vg3 with few cases for four years with Vg 4. All the courses are accredited by Norwegian Agency of quality assurance in education (NOKUT) (Utdanningen, N/A).

The upper secondary education embraces all courses leading to qualifications above the lower secondary level and below the level of higher education after 10 years of compulsory education in Norway. The students with special needs have right to an extra two years of upper secondary education if necessary to achieve his/her educational objectives. This right even applies for students who need education in sign language and in braille.

According to education system in Norway (UDIR, 2015b), when students begin their high school in Norway, each of them are provided laptop from school for educational purpose. The school uses full class teaching methodology which consists of class discussion between teacher and students. The teaching is primarily based on whiteboard, textbooks and web based digital learning tool GeoGebra for mathematics. The students are able to select mathematics according to their choices. In the first year of upper secondary school, students learn 10 hours of mathematics every week. According to their choices in next two years they will be able to choose different sub-subjects in mathematics. According to the record found has described in the Figure 2-3 below about the subjects that can be chosen in upper secondary school.

VG1	VG2	VG3
1P (5t./uke):	2P (3t./uke)	
1T (5t./uke):	S1 (5t/uke) (gir 0,5 ekstra poeng)	S2 (5t/uke): (gir 0,5 ekstra poeng)
	R1 (5t/uke): (gir 0,5 ekstra poeng)	R2 (5t/uke): (gir 1 ekstra poeng)

Figure 2-3: Mathematic course that can be selected in upper secondary school of Norway (Utdanningen, N/A)

According to the curriculum (Regjeringen, N/A), when a student chooses general study course in first year, they will study the following types of mathematics which is learned by collaborating with GeoGebra as following: “Mathematics Vg1P: Numbers and algebra, economy, geometry, geometry in 3D, probability and functions, Mathematics Vg1Py: Numbers and algebra I, Numbers and algebra II, economy I, economy II, geometry, geometry in 3D, Mathematic Vg1T: Arithmetic and algebra, trigonometry, functions and graphs, probability, algebra, derivation, Mathematic Vg2P: Arithmetic and algebra (I, II), linear model, non-linear model, statistics (I,II)”

When a student chooses vocational study, they will learn following type of mathematics: Mathematics S1: Arithmetic and algebra, equations and inequalities, probability, functions and graphs, derivation, linear optimization, Mathematics R1: Vectors, algebra, probability, functions, classic geometry, Mathematics S2: Sequence and series, algebra, derivation (I, II), economic model, probability, Mathematics R2: Vector and geometry, Numerical sequence and series, Trigonometry, Functions and graphs, Integration, Differential equations, Mathematics 2T: Arithmetic and Algebra I, Mathematics 2Ty.

Students use spreadsheet software like Microsoft excel office, open office calc are used for description. Similarly, graphing and CAS software like GeoGebra, Texas



instruments TI-Nspire CAS, Casio ClassPad 400, Scientific Notebook is suggested to be used to calculation. Some of the software are free and others are license based. The analog calculator is no longer sufficient to be used in written exam of mathematics of high school. The students are introduced and trained to use various tools during mathematical classes. The *Figure 2-4* describes the subject and time given for the ICT examination in mathematics exam of upper secondary school in Norway.

<b>Videregående opplæring (praktisk matematikk). Elever og privatister.</b>			
<b>Eksamenskode</b>	<b>Krav til digitale verktøy på datamaskin i Del 2</b>	<b>Del 1 Uten hjelpemidler</b>	<b>Del 2 Alle hjelpemidler</b>
MAT1011 Matematikk 1P MAT1015 Matematikk 2P MAT1005 Matematikk 2P-Y	1) Regneark 2) Graftegner	2 timer	3 timer
<b>Videregående opplæring (teoretisk matematikk og matematikk programfag). Elever og privatister.</b>			
<b>Eksamenskode</b>	<b>Krav til digitale verktøy på datamaskin i Del 2</b>	<b>Del 1 Uten hjelpemidler</b>	<b>Del 2 Alle hjelpemidler</b>
MAT1013 Matematikk 1T MAT1017 Matematikk 2T MAT1010 Matematikk 2T-Y  REA3022 Matematikk R1 REA3024 Matematikk R2 REA3026 Matematikk S1 REA3028 Matematikk S2	1) CAS* 2) Graftegner	3 timer	2 timer
*CAS: Computer Algebra Systems			

*Figure 2-4: Math subjects used for ICT examination in high school of Norway (UDIR, 2015a)*

All the software is required to be pre-installed before beginning of the exam. There is no access to internet during the exam. If the exam candidates are unable to use digital tool for the requested task, alternative assignment will provide low or just one count. In ICT based exam, candidates use Microsoft word program to write the solution and use print screen in the spreadsheet, graph drawing or CAS and these images is then pasted in relation to the question paper. The Part one of examination is written in answer sheet but part two is partly ICT based examination. The file with answers is then uploaded in education ministry test execution system.

### **3. Methodology**

This section is presenting the methodologies used for the primary data collection and analysis of the data in this research. Section 3.1 describes the method of data collection process used in this research. This section also includes sub section 3.1.1 detailed procedure taken throughout the interview, environment chosen for the interview, types of participants included, development of questionnaire and main objectives of interview taken for achieving research goal.

Section 3.1.2. discusses heuristic evaluation as a method of data collection. Heuristic evaluation was one of the methods used to evaluate GeoGebra in this research. It consists of five process which is described in following subsection. It defines the heuristic evaluation and scope of evaluation on GeoGebra; offering detailed exploration of the webpage and pages in GeoGebra selected for this research. Moreover, it includes explanation on detail evaluation of the pages selected in GeoGebra, and the overall method is documented for reporting of the findings from the heuristic evaluation.

#### **3.1. Method of Data Collection**

The researcher has described that accessibility and usability issues are found to be overlapping and defined them into three categories (Petrie & Kheir, 2007). The first category defines the problems identified or faced by disabled people as pure accessibility problems. The second category describes that the problem identified or affect non-disabled people as pure usability problems. The third category describes the problems that affect both disabled and non-disabled users and termed them as “Universal usability problems” (Petrie & Kheir, 2007). In this research we have used interviews from non-disabled students to identify usability related problems. The heuristic evaluation of GeoGebra according to WCAG 2.0 aimed at identifying accessibility problems.

There are many types of evaluation methods and practices for a research. “According to Baecker, there are four various HCI research and evaluation strategies. They are field strategy, respondent strategy, experimental strategy and theoretical strategy” (Te'eni, Carey, & Zhang, 2005).

For the educational research, there many types of interpretation and definition for qualitative research. Also, called as naturalistic inquiry, field study, case study, participant observation and ethnography. It is also known as “a form of social enquiry focusing on people interpretation and making sense to their experiences” (Holloway & Galvin, 2016), “a systematic approach used to describe life experience and situations to give them meaning” (Burns & Grove, 2003). In a qualitative research, researchers are focused in the meaning about the issues identified by participant. For example, in a mathematics classroom, data can be collected by observing student’s interaction in the classrooms, discussing with students in small groups or in the whole classroom.

In this research, the interactive learning material GeoGebra is studied in detail using respondent strategy(interviews) (Te'eni et al., 2005). For this research, it was believed that the qualitative, semi structured interview technique would help to gain perspectives from students point of view.

Sampling techniques includes the selection of numbers of study units through defined study population. A sample can be a small group from a population from which information is acquired (Cochran, 2007). Qualitative researcher is usually done with small numbers. Sampling process is conducted to select a group of people with whom to conduct a study. The common sampling methods for qualitative research are “purposive sampling, quota sampling and snowballing” (Gono, 2016). Qualitative research usually includes purposive sampling in order to get insights into participant’s user experience in a precise situation, context and period (Gray, 2013; Larkin & Thompson, 2012). Sampling also depends on the researchers to select participants based on their study and perception of their knowledge so, many researchers advice the best strategy to select participants is to target users who are most likely to give richest data and in-depth explanations (Gono, 2016). Smith (2015) also recommends that participant selection should be done on the basis of participant’s perception representation not overall population.

The study was done in a high school located in Oslo, Norway. The high school has 841 students in all three level of classes. The research sample was taken from second and third year students from the school who were interested in volunteering for the research. As the main aim of this research was to select the participants that

had been using GeoGebra. All the seven participants had one or more years of experience and were interested in sharing their view about GeoGebra. The interview sessions were taken according to the time selected by the participants, during the free hours of high school. The session was intended for knowing the real experience while using GeoGebra.

To plan the interview, there is need for key informants who are “privileged witnesses or the people due to their position, activities and responsibilities and have good understanding of problems that need to be explored” (Smith, 2007). So, the researcher has chosen the key informant among students who are using GeoGebra. The sampling for the research was purposive. Therefore, the interviewees were selected in consultation with the head of science and mathematics department in the school. The interviewees were selected according to their knowledge of GeoGebra- for using GeoGebra for at least two years.

After taking the permission from high school principle, curriculum leader and mathematics teacher, the purpose of the research was explained to all the students in the class and request was made to the selected students to volunteer for the research. Three students agreed to participate from second level and four students from third level. The participants were requested for available time and email address for arranging the time schedule for meetings.

According to Holloway and Galvin (2016), “sample size does not influence the importance or quality of the [qualitative] study” and there are no particular guidelines for sampling recruitment in qualitative type of research. Onwuegbuzie and Leech (2007) and Flick (2008) also stated that in qualitative research, the sample size should not be huge because it will be difficult to obtain rich data and it would also take lot of time.

The selection of students for this research was made in 2016. The second level students were already introduced GeoGebra in their first year whereas third year student had two year of experience in GeoGebra. The students had been taught several mathematics subjects discussed above about the upper secondary education in Norway (see Figure 2-3).

### **3.1.1. Semi-structured Interview**

This research has used qualitative research methodology for the data collection process of the research. Interviews are known as the verbal exchanges among the interviewer and a person to elicit the information from the person with the purpose of collecting data relevant to the research and research aims (Cohen, 1994; Gray, 2013). There are four types of interview method used in qualitative method known as one to one, focus group, through telephone and through electronic email or conference (Creswell, 2002).

Therefore, with the help of semi structured interview, the information was collected in order to find out the issues related to GeoGebra while using it to learn mathematics. Semi structured interview is flexible technique for small scale research like this one. It offers the opportunity to approach different respondents but still covers same arena of data collection. The interviews taken were audio recorded for securing the accuracy of conversation and avoiding loss of data. The interviews helped to identify issues clearly. Semi structured questions allowed the students to share their perspective as much as possible. It was possible to learn their perception about GeoGebra, what the main issues were and how GeoGebra helped them to learn mathematics.

The interview is the primary methods chosen for data collection in this research. Therefore, the semi structured interview questions were designed carefully, in order to fully cover the main purpose of the research.

#### **Procedures for semi structure interview**

For preparing the semi structured interview, the research objectives were defined, an interview plan was created and designed consent form. The main steps taken were first, make study plan; second, design questions that were appropriate to ask the interviewees; third, design consent form that explains the interview intent and commitment to confidentiality; and four, contact the respondents where they were explained the main aim of the interview, secure his/her permission and plan the place and time for the interview. The consent form was signed by 4 students that were 18

years old whereas consent forms for 3 students that were 17 years old were signed by their parents, to allow their children to take part in the research.

### **Environment for conducting semi structure interview**

The place selected for the research was the meeting room in the school itself which was comfortable and easily accessible to the respondents. An audio recorder was used for recording the interview. Each session of interview was taken for minimum half an hour. The interview was conducted successfully ensuring full concentration and towards the aim of the research.

The semi structured interview was used for the in-depth insight of the challenges faced by the students who are using GeoGebra. In the present case scenario of the interactive learning material “GeoGebra” has been used in the curriculum of high schools all over Norway. This methodology can help to identify the real problems from the perspective of end users who has been using the webpage in their daily life.

There are certain limitations in every type of methodology used for a research (Flick, 2008). The ability to find in-depth view of the participants is the strong argument to favor the interview method. The questions asked during the interview process helps to recognize the wide range of problems of users (Gray, 2013). Interviewees can get the responses in detail which can be difficult to get using other methodologies. The conversation between the interviewee and interviewer can encourage in reflecting and considering the goals of the research too. An interview gives freedom to interviewees to express their thought in detail which can be useful for research. This type of freedom in expression could be lost if other methodologies were chosen.

Similar to ethnography and many other observational practices, interviews are open ended and about facts-finding (Holloway & Galvin, 2016). Although interviewers are required to have specific question for the interviewee, there can be some consideration to flexibility. According to Holloway and Galvin (2016), the responses of the participants, interviewers can go with the situation and ask questions accordingly, reorder the questions or even ask them more if needed. Interviews can be an opportunity to explore new ideas from the participants. This can also be helpful to understand the issues more clearly. But the flexibility on the other hand can also be

one of the challenges to manage the unbounded thoughts (Service, 2009). Interviews are more difficult than to conduct a survey. Interview can be time consuming. Interviewers are also required to be skillful and practiced. Furthermore, the book (Patton, 1990) adds that observing participants, writing notes, deciding how to take the interview further according to response and analyzing non-verbal gestures of participants can be tricky.

The number of participants used in an interview comparing to a survey is very less. Survey can reach hundreds of potential participants and analyze the data later whereas the resources and hours spend for an interview can be limited so there would be no surprise if the research is not be able to conduct all the interviews as planned at first (Merriam, 1998). Analysis of the interview is the challenging part after conducting the interview. The raw data and recorded audio of the responses can be time consuming for analysis. Decision to separate good data and the bad ones can be difficult. Both survey and interview depends on the idea of the participants so, this can change overtime. "As few researcher have suggested to look at the behavior and listen to perceptions" (Crabtree & Miller, 1999). The data provided can be different as the perception of participants can differ depending on what they actually do in real life.

### **Participants**

The name of the participants is kept anonymous and the students were identified by numbers. The numbers of interviewee were difficult to be determined for a research at first and the aim of the interviews which needs to cover all the topics related to the purpose of research, we have chosen seven students who were using GeoGebra in mathematics.

The students were studying in second and third year of high school. They were introduced GeoGebra before first year of the school. The four of the participants are male and three of them are female. The age range of the student is from 17 years to 18 years. None of the students have reported any form of disability.

### **Objectives of interview in the research**

The interviews were carried out to get the information about GeoGebra from student who have been using GeoGebra for more than one year. The main objective of the interview is to collect as many information about GeoGebra in their daily use, learn about their problems while using GeoGebra and find out reasons behind them. The usability of the interactive material is mainly focused in the interviews. The questions asked during the interview are presented in the appendix section 8.2.

#### **3.1.2. Heuristic evaluation**

The aim of accessibility testing is to emphasize the need for making the web accessible for users with impairments. This can helpful in many other ways for all user of the web or the search engines. Evaluating website accessibility is important and it should be done while releasing, acquiring or re-designing websites (Eric Velleman, 2014).

One of the important purpose conformance testing is to check whether the web pages follow the existing guideline and standards. There are two different methods of heuristic confirmation evaluations for accessibility (Brajnik, 2008). They are automated heuristic evaluation and manual heuristic evaluation. For this research, I have chosen manual heuristic accessibility evaluation method using WCAG 2.0 guidelines as a tool. the advantages and disadvantages of the two accessibility tools is discussed below. That can help to explain the manual heuristic evaluation and the reason it is chosen for this research. These two method can be selected according to the type of research and its goal.

The first accessibility testing method is the use of automated testing tools that assist evaluators during the process of evaluation and contribute in efficient evaluation of the website programmatically. For the automation conformance testing, there are many software applications and free online services which can show accessibility issues in a webpage, employing several accessibility guidelines. There are many web accessibility tools which automatically validates the webpage. Some of them are WAVE, AChecker, Total Validator, TAW, eXaminator, A-Tester, Accessibility checklist, 508 checker etc (Eric, 2016).



Though automated accessibility evaluation tools are fast and programmatically reliable but that does not necessarily mean every issue can be automatically detected because these tools could provide false positives which needs to be evaluated and checked by experts again (Vigo, Brown, & Conway, 2013). This type of tools is used best by expertise. Without expertise, developers will be relying on result of automated test only. Automated tools are useful to identify the accessibility problems but are not able to solve them. To solve the problems, developers are required to make changes according to the issues identified in the result.

The research by Pivetta, Saito, da Silva Flor, Ulbricht, and Vanzin (2014), evaluated automated accessibility evaluation software (ASES) by using heuristic usability inspection method with three experts. Heuristic evaluation is based on expert's experience and knowledge. The participants were doctoral candidates and participated with research group of web accessibility. They tested two software called "Access monitor, AChecker ASES 2.0, WAAT, WAVE". The final result of the research identified issues with "high workload, consistency, compatibility and status of the system" as critical issues that needed urgent solution. The research also found that the suggestion of error and warning given by ASES tools required users to have computing and coding knowledge. The research concludes that the ASES tools requires to be re-designed and have high adaptation flexibility for achieving greater usability.

The research Mankoff, Fait, and Tran (2005) has done a comparative study of methods used to access web page accessibility for blind. The research stated that most common methods used for accessibility evaluation of website were automated tools, design guidelines, user studies, and blending of these. Their research involved 5 blind adult computer users in the range of 19 to 52-year-old. The researcher selected four web pages, gave task to participants and asked them to review the sites. The result from the research showed that expert reviews are dependent of the accessibility experience of the expert have about the accessibility issues. the experimental setting where screen readers and monitors are used was effective in identifying WCAG 1.0 related accessibility issues. The result analyzed that there was no single evaluator or tool to find all accessibility problems. However, developers found less than 70% of problems that are actually present in the task. Therefore, the

researcher does not recommend to use of automated testing tools for full-fledged user study involving disabled users as they can introduce false positives and fail to find every problem. But they suggested to use that method in early stage of web development for detecting accessibility problems.

Manual conformance testing is a method of evaluation conducted by using a set of accessibility guidelines that focus on accessibility barriers (Brajnik, 2008). The experts involved will find whether a page is compatible or conforms the guidelines. The purpose of this research is the identification of the problems or its consequences while students use GeoGebra. With this test, we aimed to generate qualitative output in accordance with the aim of the research. Manual conformance testing was useful in this research. Though there was some usability evaluation done on GeoGebra, heuristic accessibility evaluation was not found to be carried out by another research.

In this research, we used the Website accessibility conformance evaluation methodology (WCAG-EM) to test the conformance of GeoGebra to WCAG 2.0 guidelines. WCAG-EM is an approach to determine the conformance of a website to web content accessibility guidelines.(WAI, 2016.) WCAG-EM methodology can be used for testing GeoGebra to know if the system whether it follows the accessibility guidelines.

The heuristic evaluation is conducted by certain process involving various steps (Eric, 2016). The overall process influenced by the aspects like the variety of a website for example static, dynamic, responsive, mobile etc., size and complexity and technologies used to create the website. The expertise level of the evaluators who knows about the process used during the development, designing of the website and the main purpose behind the evaluation like identifying the issue of accessibility, to plan redesign process, to perform research” (Eric Velleman, 2014).

WCAG 2.0 helps to highlight the criteria the evaluators have to apply in the context of the website chosen. According to Velleman and Abou-Zahra (2014), this type of conformance testing can be done by anyone who wants to monitor the common approach for evaluation for example “web consultants for analysis and documenting accessibility conformance, web accessibility evaluation providers”. Moreover, website developers, website owners, procurers and suppliers, web compliance and quality

assurance managers, analytical or observational process, the expertise who is carrying out the research, web accessibility trainers and educators, web master, content authors, designers and other who intend to learn more about accessibility and evaluation can use WCAG-EM” (Eric Velleman, 2014).

Following WCAG 2.0 guidelines helps to understand the potential accessibility barriers in the first hand. According to Velleman and Abou-Zahra (2014) WCAG-EM is applicable to any websites, web application and mobile websites. Further, this conformance process covers different situation, self-assessment and third party evaluation which is a common procedure to evaluate websites and can be used directly by internal, external evaluators, bench markers and researchers. Successful application of WCAG-EM requires knowledge about WCAG, accessible web design, assistive technology and how people with different disability use the web system (Eric Velleman, 2014).

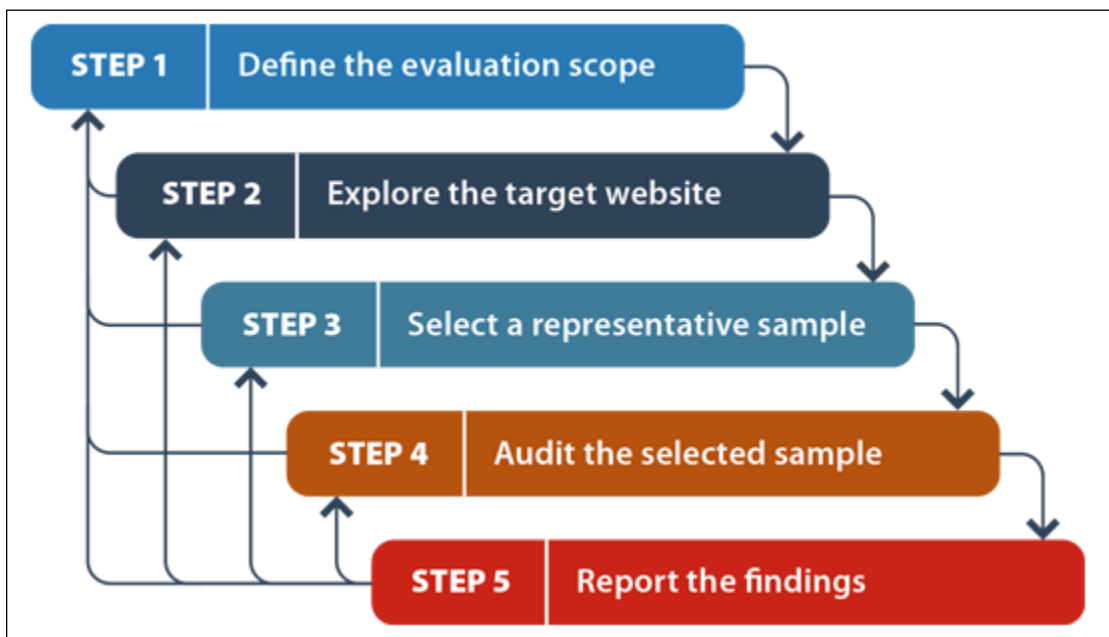


Figure 3-1: Five steps of Heuristic Evaluation WCAG-EM 2.0 (Velleman & Abou-Zahra, 2014)

As described by Velleman and Abou-Zahra (2014) the evaluation procedure contains five steps which needs to be followed to perform the task in Figure 3-1. To begin the conformance testing with the involvement of evaluator and steps in the conformance

testing procedure was discussed. Planning of the process should be carried out carefully in order to implement the overall evaluation.

In this research, the heuristic evaluation was conducted by two experts at the Oslo and Akershus University College. The evaluators were not allowed to communicate throughout the evaluation process in order to have their own genuine evaluation. Every observation of the website was conducted more than one time for the reliability purpose. Each observation and finding were thoroughly noted down, filling out a template similar to WCAG evaluation template developed for evaluation.

### **Defining the evaluation scope of GeoGebra**

GeoGebra is evaluated in the conformance testing process. Furthermore, GeoGebra is available in three platforms. For desktop, it is available in chrome application, windows, iOS and Linux. For mobile and tablets it is available in both android, iOS as an application.

For this research, we have chosen the conformance level A and AA which is both manually evaluated and tested for GeoGebra because as described in introduction section above, every new or existing ICT system are required to be designed and developed implementing the criteria of conformance level A and AA of WCAG 2.0. From first January of 2021 onward every ICT system needs to be universally designed and developed accordingly so, this can be the initial steps towards the WCAG 2.0 evaluation of the website.

The GeoGebra.org website is tested in two different operating system in two different platforms. The first operating system environment was device with model Pavilion g6- Intel core i3 and Windows 10 OS as the operating system. The browser was Mozilla Firefox. As assistive technology tools, JAW was used as a screen reader software. Furthermore, the plugins “Web Developer” and “Juicy Studio Accessibility Tool” was used in the Mozilla Firefox.

Similarly, for the other operating system environment included was mac OS. The device used during the evaluation was MacBook Air- Intel core i5. The operating system was mac OS sierra version of 10.12.1. The web browser used was safari

10.0.1. The assistive technology tool for the evaluation was Voiceover which was inbuilt screen reading software in it.

Furthermore, to check the validity of the HTML of the GeoGebra webpages, “W3C Markup Validation Service”<sup>2</sup> was also used.

### **Exploring the GeoGebra website**

For the further exploration of the ILM, we first identified the major function of the ILM and the main purpose of the GeoGebra system. After the exploration, the common web pages were selected. The pages were selected according to the availability of the pages that were linked through the menu of the main page. The main function of GeoGebra is described above in section 1.1.

### **Selecting the representative pages of GeoGebra**

The representative page was selected considering the various constraints. The common web pages were chosen according to their importance to the services provided. As structured sample, few pages were selected.

The common pages of GeoGebra.org are

- i. [GeoGebra Home Page](#): This is the front page of the GeoGebra.
- ii. [GeoGebra Sign-In Page](#): Through this page, the user can log in to their profile. The user can also login through different other accounts like Google, Office 365, Microsoft, etc.
- iii. [GeoGebra Sign-Up Page](#): This is the webpage user can access to create account on GeoGebra.
- iv. [GeoGebra Profile Page](#): This webpage is where user can see their profile details and edit their profile. They can also see their works in this page.
- v. [GeoGebra Mathematics Application \(CAS\)](#): This is the main application page where user can practice with mathematics equation, produce graphs, and other task related to algebra.

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<sup>2</sup> <https://validator.w3.org/>

After selection of common page, few pages were randomly selected to evaluate the other functions provided by the website. The random pages are listed below:

- i. [GeoGebra Forgot Password Page](#): If user forgets his/her password, then they can recovery their password through this page.
- ii. [GeoGebra Help Page](#): In this page, end-user can look for help or post a post if they want to know something about any topics related to GeoGebra.

Lastly other few pages were selected according to the overall functionality of the process that needs to be taken to complete the task in the webpage.

- i. [GeoGebra Materials Page](#): Through this webpage, user can access to various materials from conferences or paper related to different mathematics topics.
- ii. [GeoGebra Download Page](#): In this webpage, the user can download the offline version of software for different platforms.
- iii. [GeoGebra Tutorial Webpage](#): Through this page, user can get access to tutorials for quick start and introduction book which can help them to get use to different functions in the math application.

### **Evaluation of the selected pages of GeoGebra**

The ten selected pages of GeoGebra (listed above) is evaluated by two experts. They were the researcher itself and another student who was studying in the last semester of Masters in ICT of Universal Design. Both evaluators did the manual evaluation of every pages which done in two platforms as described above.

### **Report of the evaluation finding of GeoGebra**

Finally, in this stage, the evaluation the pages are documented and structured manually. Later, the reports from two different experts was compared and the common issues identified in both of the report were outlined.

## **3.2. Methods of Data Analysis**

This research was conducted to explore GeoGebra in upper secondary school and find the user experience of students, who has more than one year of experience.

Interpretative phenomenological analysis (IPA) approach was suitable for this research as this study was concerned about user experience. The interview was the direct source for data collection for capturing the real experience faced by the real students in upper secondary school.

The researcher Smith (2007) has described IPA method to insight into user experiences of the participants while they used technology. This analysis method is new and quickly growing methodology for qualitative enquiry. To follow this methodology the researcher needs to collect thorough, reflexive first person accounts from the participant of research. API methodology provides an “established, phenomenological focused approach to the interpretation of these accounts”. This approach has philosophical influence to existential approach but with different analytic process and outcomes.

As the book Silverman (2013) describes a successful IPA study includes the elements from “using audio recorded data as capturing and reflecting upon the principle claims and concerns of the participants” and “making sense by offering the interpretation of this material which is grounded in the accounts, it can be even used in psychological concepts to extend beyond them”. This method described by (Smith, 2015) is an accessible qualitative approach used in many researches and best suited when time and effort components are balanced. IPA method is chosen for this research as the participant have understanding of the topic with semi-structured and one to one interview research.

The researcher’s aim in IPA method is to remain unbiased and facilitative to give participant opportunity to tell their story. However, it is recognized that they cannot be truly neutral when interview data comes with certain expectation but researchers needs to capture rich, detailed and reflective data. “IPA interviews is not about collecting facts but it is about exploring meanings”(Smith, 2007).

This IPA study requires small sample as it is based on quality for developing insightful analysis depending upon the aim, level and context of the research. So, for this research, we have focused on the experience of seven student participants about GeoGebra.

Working with small number of participants in the context of GeoGebra to understand the user experience was done. The IPA approach guided me to get the insight understanding of the experiences and perception of students as they had been using GeoGebra since their first year in upper secondary school. As the main purpose of this study is to find the student's experience after using GeoGebra especially for mathematics.

In the initial step the interview was that the data was transcribed and structured according to the question asked and answers of the students from audio recording of interview. After careful observation of the interview data achieved was then analyzed for the study. The IPA frame work was used for the analysis. The data acquired was summarized and decoded according to the research questions. Quotations of the students are included for reflecting the perception they had expressed during the interview. The analysis reflected in what ways GeoGebra was used and what type of tools were used.

The data transcription from the recorded data during the interview was evaluated, equated and differentiated with heuristic accessibility evaluation. Finally, comments and suggestion are given on the basis of successful criteria required by WCAG 2.0 guidelines and conclusion of the research is drawn.

### 3.3. Data Transcription

The audio recording was transcribed throughout the investigation of study. According to Powell, Francisco, and Maher (2003) transcribing is "the process of transferring to a page the activities and positioning the discussions that occur during the record session."



## **4. Result**

This section contains the result from the two-different data collection method i.e. semi structured interview and manual heuristic evaluation. The first sub-section presents the result from semi-structured interview while the second sub-section presents the result from the heuristic evaluation.

### **4.1.1. User Experience of GeoGebra and Interactive Learning**

#### **Materials**

From the interview, it was found that the most of the participants have experienced GeoGebra before they start attending the high school. Although five students mentioned that they got familiarized with GeoGebra from grade 10 in lower secondary school. However, they have described that in grade 10 they didn't used the GeoGebra application as often as they are using now in the upper secondary school. In the school, they use the GeoGebra on weekly basis according to the curriculum.

GeoGebra is designed to be used for supporting teaching and learning mathematics. The students were asked whether they use GeoGebra or any other interactive learning materials in other subjects. Five of the students said that they use GeoGebra for math and physics, while the other two mentioned that they use it for math, physics, and chemistry subjects. Furthermore, the majority of the students admitted that they use other interactive learning materials too. The participants also mentioned the use of other learning support materials they use in addition to GeoGebra. One of them mentioned kunskap.no which contains videos for every subject taught on different subjects and level. He also added that they often get chemistry homework where they watch videos to get the answers. He also added that there is a system similar to kunskap.no, ndla and there is one privately operated by their teacher, campus.inkrement.no, where the teacher uploads some premade courses. Two of them said they use CAS from geogebra to draw some figures and graphs. Other tools mentioned include Excel.

### **4.1.2. Purpose and Benefits of Using GeoGebra**

The students were asked about why and how often they use GeoGebra. All the students explained that they generally use GeoGebra in mathematics for doing exercises related to Vectors, Graphs, Statistics, for visualization of functions and derivatives, and for visualization of objects in 3D, and calculating different equations. The students use it to do homework too. Furthermore, the GeoGebra is found to be used in the examination as compulsory task as digital tool to solve mathematics.

The students use GeoGebra at least once a week but they mentioned that according to the curriculum, it depends on the choice of mathematics subjects they have taken during their class as in three years. Mathematics subjects changes according to the curriculum and which year they are in.

The participants were also able to mention some benefits of GeoGebra. All the students generally said that GeoGebra is useful learning materials in their study. Six students said that drawing graphs and graphical visualization is easier with GeoGebra. One student has mentioned the difficulty of learning mathematics in the beginning saying, "Something that is difficult as we learn lot of new mathematics functions and stuff at the same time learning GeoGebra, so I really didn't know functions before GeoGebra but I think I got better sensation of how small adjustment change behavior of functions". However, three of the participants said that it is difficult to access the commands and remember them while using GeoGebra.

### **4.1.3. Barriers of GeoGebra and Learners' Coping Mechanism**

The participants were encouraged to mention if they had faced any problem while they used GeoGebra or during the beginning of learning to use it. The issues described below is briefly described in discussion section 5. Four of the students have found using CAS in GeoGebra is difficult due to many function buttons. Four students have found GeoGebra difficult because there is no indication of error (feedback) and don't know what went wrong. Six of them found that GeoGebra didn't respond as expected sometimes and it's up to them to sort it out. some coping mechanism were raised. Six of the students tend to ask help of friends and teachers if they come across error. Two of them answered that typing the functions very

accurate and specific to avoid error. Three students restart the process if they get error. One student even mentioned that in exam they are given simple problems to avoid error of complexity. The problems identified are divided under five categories according to its similarities.

### **Lack of error indication and feedback on state of a task**

In GeoGebra while proceeding for the task, where data input for example typing equations can take time. A problem identified by the respondents was the absence of error detection and feedback from Geogebra as they conduct their tasks. For instance, student1 said that the website can be more sorted and organized so that the task done in GeoGebra can be easily accomplished. Student1 also said that GeoGebra is messy. Therefore, there is the need to remember the functions and commands being executed as they progress through the tasks. Student2 said that he often gets confused at what stage of the process he is as there is no feedback from the system. Student3 mentioned that the buttons used in GeoGebra are confusing because when the similarity of colors for buttons assigned for different tasks raises the possibility of making errors. The overall discussion showed the need for the addition of notification or feedback functionalities which could guide students as they perform their tasks on the ILM.

Another student feels that teachers play important roll to help the students while using GeoGebra, but GeoGebra should be designed to make the process easier for students. The signs or icons used for buttons and actions label used in GeoGebra should be understandable and self-explanatory so that there is less requirement of support from teachers and friends. The following is an example of the response from students that helped to identify the problems mentioned above:

Student 1” it is very incredible but it can be bit more sorted and organized”

Student 2” sometimes when we plot in two things it doesn’t work, maybe it works in different computer and not in mine.”

Student 2 “to some extend it is a huge problem that we cannot see what problem I have”

Student 3 “Differential equation is really hard in CAS it is very confusing, that is the biggest complain I really have.”

### **Complexity and Confusion in using Icons, Buttons, and Symbols**

According to the students, typing a given task given GeoGebra is difficult. Another participant also mentioned that, at the beginning, learning to use GeoGebra was scary and the buttons on it present an increase the level of difficulty. Another participant described the exams tend to be simpler. However, there is the expectation to use GeoGebra to work in all kind of task whether it is simple or complex. Therefore, there is the need for consistency and predictability. Understandability and meaningful representation of labels, symbols etc. is necessary to reduce the difficulty involved in using an e-learning system. The following are examples from what the students said regarding the difficulties and barriers they faced while using GeoGebra.

Student3” Lot of students say that defining functions, defining equations, writing down the syntax is bit confusing”

Student4 “It is kind of scary if you are using GeoGebra for the first time, as there are so many button and don’t know what they are”

Student5” During the exam we are not give complicated ones and normally given simple ones to solve.”

The other problem the participants discussed was lack of consistency in GeoGebra when being used at different screen sizes. One participant also said that small screen size makes it difficult to find the buttons. He said,” I like GeoGebra as it works better at my home pc as it has the big screen and I can do everything but on small screens, GeoGebra may skip [hide] the symbols for like desktop computers.”

Two participants said that they sometime find that the CAS in GeoGebra doesn’t work as expected while they work on a task. The differential equation tends to be difficult for most of the users and this was identified as a problem by four of the participants.

According to the finding from interview, the students have difficulties in using the CAS. The following are examples selected from the interviews to present some difficulties as described by the participants. Student 2 thinks that including many buttons at one place can be problem in the interface design. Student7 has specifically identified that in mathematics, they use symbols while solving problems so; even small error will make the mathematical solution go wrong. He suggested that if there were a help button in the website, it would helpful for him and new users to find the exact buttons they are searching for in the page.

student2 said, "it's important to have not too many icons because it is too difficult because it will be then used by too less students, so it has to be open to everybody, and also the students who doesn't understand mathematics so, I think till now it is good but I am sure there should be some improvements that needs to be done."

student7" if we had some kind of help button kind of thing which can guide you when you press because we need to use many type of symbols that you need in math which is not same like big "e" in derivation stuff and that is not normal "e" so it can be confusing for new one to find those buttons."

### **Lack of predictability in task**

The participants described that they have to recall the information from previous task so, it clearly shows that there is requirement of remembering and prediction of the process to complete a task. The following is what some of the respondents said:

Student1 "Because I think it is very well designed but it is kind of messy as well because, you know, you need to know the functions and the commands you are going to use beforehand."

Student1 "all the functions of GeoGebra are a bit confusing."

Student3 "in many times, I find problems with the CAS that don't behave as expected"

Student5 “the CAS tool, there are some problems while using it for differential equation. It does some kind of unexpected thing if you don’t know what you are looking for. It can be difficult. Lots of students face this problem”

Student5 “sometimes it’s too general and tries to adapt too much and sometime we need to give a very specific command to do very specific thing and then you misinterpret so the command work out differently”

### **Lack of flexibility for beginners**

Two participants described that, for the experienced users, GeoGebra seems to be easy while using it than in the beginning. The flexibility was analyzed to be less in GeoGebra as users cannot modify the settings, the students could understand the process, some of the students were found to be restart from the beginning if there was any error in the result.

Student1 “it kind of lies on yourself to practice them but if there would be more logical interface or some sorts it would actually kind of help you a lot and make it easier to begin with”

Student4 “the only problem is lack of experience”

Student4 “CAS is extremely handy, when I had exam last spring there was one task you were supposed to do in CAS but it was little difficult as I wasn’t used to.”

Student3 “If the students are introduced properly there would little problems.”

Student5 “I think some part also belong to teachers as they don’t know how to use it but yeah sort of assignment and things.”

Student6” I don’t face this kind of problem very often but I have one I try to solve it one more time then I take help from friends and teachers.”

### **Lack of instructions to solve errors**

One participant said that he is dependent on his teacher to identify the problem while using GeoGebra. Four of the participants said that they have usually restarted the

task whenever there is any error because they are not often able to identify the error. One other participant said that students need to be very careful to not to create any error. Possibility of error is usual for everyone while working a mathematical operation so suggestion, or identification is very important for an ILM like this. Another participant said that GeoGebra is also used during exam so, there is possibility of making mistakes. He added that, if there is simple error and you have to restart, the whole procedure can be time consuming during exams. The following are some of the issues as mentioned by the participants:

Student1 “I consult my teacher or restart to do it again.”

Student2 “CAS that a big problem actually because in a test if you actually do it right but it doesn’t work so I think they should improve that”

Student3 “You just have to be very accurate about what you type and then it works as expected”

Student4” if we find a bug or a problem we just restart GeoGebra”

Student5” Everyone in the class only managed to make differential equation by working in a very specific way if you stumble along the way you had to start all over again”

Student6”it tends to sometime it is a bit difficult to do something as we get error at a point but that is up to us to sort it out”

One Participants said that due to difficulty in understand source of errors, he found that GeoGebra is difficult to use during his exams. Three of the participants have suggested GeoGebra to have help or search button so that it can make the task completion accessible. If the instruction or steps to accomplish a process were documented, then there would be a possibility for less error. For a beginner, the help function could be extremely helpful for completing task.

#### **4.1.4. Suggestions by the Participants**

Finally, the students were asked if they have any suggestion to improve GeoGebra as they had already faced the problems while using it. All the students have defined

GeoGebra as confusing in the beginning. Three of them said that too many icons and buttons have made GeoGebra difficult to operate so the toolbox should be simpler and all the buttons should be identified clearly. Three students suggested adding a search box. Two of them even suggested for comment box or help button to get helps for fixing errors. One of them suggested for a page where there is explanation or identification of common errors. One of them even suggested two GeoGebra pages for beginners and for “experts”.

One participant suggested GeoGebra to provide a toolbar to save in his profile so that he can find the tools he usually uses for the task. GeoGebra need to give the students freedom to create their own toolbars and save them in their profile so that they can use them when necessary. This can be one of the clever ways to easily find the buttons if the user frequently needs them. One participant said, “I want to have some login system where I press button command where it brings flow chart or something so that it could guide me to whatever function I am about to use or whatever command I want to use”.

Three of the students have said that there is a need for general error prevention technique. If there is possibility for user to face error, we can assume that there is a lack of good design. Meaningful instructions or error message tend to be helpful to the student. When there are, any changes occurring in the system during the task, then the user should give permission for the system to proceed.

Another participant even has suggested GeoGebra to have two different interfaces for users according to their requirement. He said that” if it’s possible to develop two types of GeoGebra, one for younger students and one for older and more experienced ones who understand and learn math because I know few students who just love computer math and for them it would be very helpful with more functions. For younger one like 10th grade make it simpler and not difficult to understand.” This suggestion can be a helpful way to motivate new users to use GeoGebra rather than leaving the impression that it is complex. The following are among the suggestions to make GeoGebra informative:

student2“may be have a page where everything is explained and that is accessible to everybody”



student4 “I kind of want a search function so when we have to create a line between two points, I have to like look for every button but I f I had search button probable use it.”

student6 “It would be very helpful if we had comment box about helping the issue. Lot of major people doesn’t understand what error needs to be solved. Even search button would be ideal to help students.”

The suggestions from the participants show that the real time interactive response to the real users in order to get feedbacks can be very important to improve the ILM. As presented above, the participants mentioned the importance of individual setting toolbars where they can keep tools relevant to their tasks, error-tracing and detection mechanisms, help and search boxes, and versions for beginners and “expert” users, which could make GeoGebra better for user. As the researcher (Martin et al., 2007), has described that usability and accessibility needs to be the top most priority support to ILMs. Combining both design and runtime adaptation can help in delivery of learning services to people with disability. The next chapter presents the result of heuristic evaluation to finally related the usability issues explored so far. The accessibility issues explored through the heuristic evaluation is similar to the usability issues which are elaborated in detail in section 5.1 and 5.2.

## **4.2. Result of Heuristic Accessibility Evaluation**

This section will consist the result from the heuristic evaluation. The first part will cover the overview of the issues that has been identified through the conformance testing. The second section of the result from the conformance testing will describe the individually error with description and in details.

### **4.2.1. Overview of the Identified Issues**

In the conformance testing, two success criteria of WCAG 2.0 (A and AA) where tested against the selected pages of GeoGebra. Only two success criteria A and AA among three was chosen, as in Norway, inside 2021, all the system that has focused to the end-user should have fulfilled the two success criteria in minimum i.e. (A and AA). In total, there are 38 A and AA criteria of WCAG 2.0.

From the result of evaluation process, it was found that out of 38 criteria, only 6 criteria were met by the ten evaluated pages of GeoGebra, 22 criteria were not met, and 10 criteria were not applicable. The following table below presents the overview of the criteria and the issues identified in the conformance testing. Only the overall success criteria that did not meet by the ten evaluated pages are listed below.

Table 4-1: The overview of the criteria and the issues identified in the conformance testing

Principle and Guidelines	Success Criteria (levels)	Result
1. Perceivable 1.1. Text Alternative 1.2. Time Based Media 1.3. Adaptable 1.4. Distinguishable	1.1.1 Non-Text Content (A)	<ul style="list-style-type: none"> <li>❖ The images used for the decoration purpose contains alternative text.</li> <li>❖ The non-text content which accepts inputs or are controls in the page do not have name that describes its purpose.</li> <li>❖ The biggest issue found was that the available buttons as a control in the CAS math application do not have any text alternatives.</li> </ul>
	1.3.1 Info and relationships (A)	<ul style="list-style-type: none"> <li>❖ Many control elements and elements that accepts user inputs do not have labels or names describing its purpose.</li> <li>❖ The required fields in the form are not defined.</li> </ul>
	1.3.3 Sensory characteristics (A)	<ul style="list-style-type: none"> <li>❖ Due to use of shapes for different math functions and the shapes not having name, the shapes are not easily</li> </ul>

		understandable to many users.
	1.4.3 Contrast(minimized) (AA)	❖ Some of the text in few of the evaluated webpages do not meet the contrast ratio of 4.5:1.
2. Operable 2.1. Keyboard Accessible 2.2. Enough Time 2.3. Seizures 2.4. Navigable	2.1.1 Keyboard (A)	❖ In some of the webpages, some of the interface elements are not operable only with keyboard.
	2.4.1 Bypass blocks (A)	❖ No bypass facilities available to skip the repetitive contents.
	2.4.2 Page titled (A)	❖ In some of the pages, title that help to define the purpose of the webpage was not found or unclear.
	2.4.4 Link purpose (A)	❖ The purpose of the link is not clear and in few cases no any labels or name of the link is provided.
	2.4.5 Multiple ways (AA)	❖ Multiple ways to locate the webpage within a group of webpages was not found.
	2.4.6 Heading and labels (AA)	❖ Form elements do not have labels describing the purpose of the elements.
	2.4.7 Focus Visible (AA)	❖ In some of the pages, the focus is not visible at all

		<p>although the webpages are accessible with only keyboard.</p> <ul style="list-style-type: none"> <li>❖ In other pages, the visibility of the focus is very poor.</li> </ul>
<p>3. Understandable</p> <p>3.1. Readable</p> <p>3.2. Predictable</p> <p>3.3. Input Assistance</p>	3.1.1 Language of Page (A)	<ul style="list-style-type: none"> <li>❖ There is a webpage where the language of the page is not defined.</li> </ul>
	3.2.2 On Input (A)	<ul style="list-style-type: none"> <li>❖ On providing in one of the element, the content of the page gets modified without any prior information to the user.</li> </ul>
	3.2.3 Consistent Navigation (AA)	<ul style="list-style-type: none"> <li>❖ In few pages, the way of navigation in the webpages changes resulting in inconsistency.</li> </ul>
	3.3.1 Error Identification (A)	<ul style="list-style-type: none"> <li>❖ Error identification of the input is not detected automatically.</li> </ul>
	3.3.2 Labels or instructions (A)	<ul style="list-style-type: none"> <li>❖ In many input elements, labels for the input elements and the instructions to fill the input elements are not provided.</li> </ul>
	3.3.3 Error suggestion (AA)	<ul style="list-style-type: none"> <li>❖ General error descriptions are provided instead of descriptive and specific errors.</li> </ul>
4. Robust	4.1.1 Parsing (A)	<ul style="list-style-type: none"> <li>❖ Duplicate Id's found.</li> </ul>

4.1. Compatible	4.1.2 Name, Role, Value (A)	❖ No any roles are identified. No major sections are landmarked.
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The following section provides the discussion of each criterion of WCAG 2.0 level A and AA evaluated in this research.

#### **4.2.2. Perceivable**

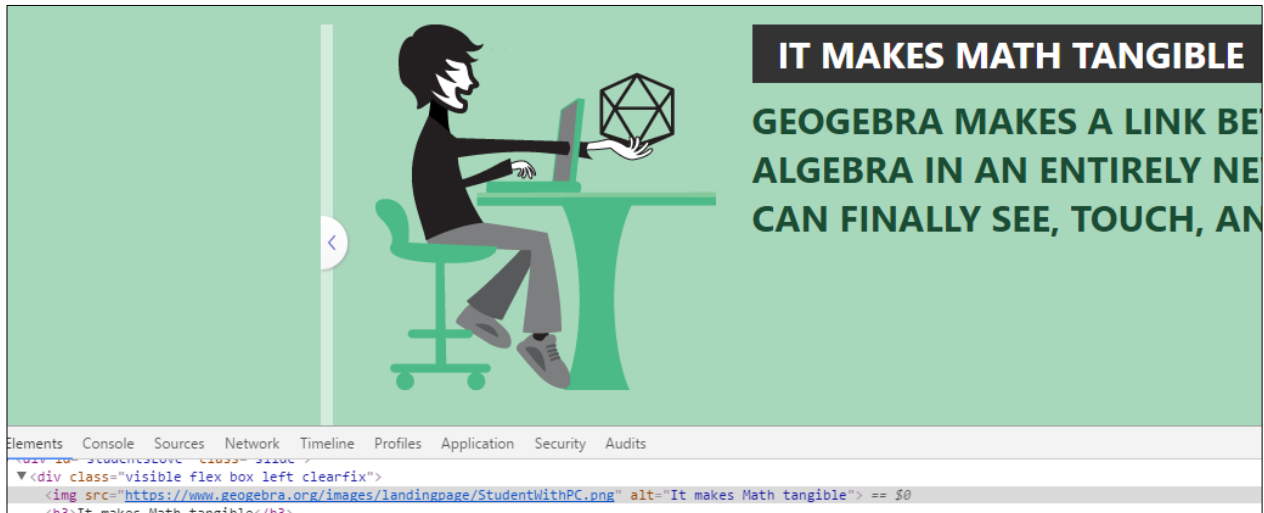
One of the foundation of web accessibility is to make the information and user interface component perceivable which means that the contents and interface component should be available such that the user can perceive it. Under this principle, there are four guidelines namely non-text content, time-based media, adaptable, and distinguishable. Within these four guidelines, there are 14 A and AA success criteria (SC).

Among 14 SC, four of the SC were not met in the set of pages. Since in the evaluated pages, there were no any presence of audio and video, so the guideline “Time-based Media” was not applicable. Similarly, other three SC i.e. “Use of Color”, “Audio Control”, and “Images of Text”, were not applicable too. The rest of the two SC i.e. “Meaningful Sequence” and “Resize Text” were met.

#### **Guideline 1.1. Text Alternatives**

The non-text contents like images, graphs, diagram, multimedia, controls, and inputs in the webpage requires alternative text or short description of the content to make it conveying. This gives the equivalent purpose and make the content accessible to different types of disabled users. Providing alternative text can benefits several people. For example, the blind people can perceive the information of the image through alternative text, and similarly, the deaf people can perceive the information of the audio through text description. People with both disability (deaf and blind) can perceive the information through text in Braille.

In the context of GeoGebra, some of the non-text contents had meaningful alternative text, however, it was not the same for every non-text contents. Some of the non-text content do not have alternative text; some controls and input element do not have name that described their purpose; and in few cases the decorative images contained alternative text.



*Figure 4-1: Image kept as a decorative image in the page has alternative text*

For example, in the above *Figure 4-1*, the image used for the decoration purpose contains alternative text. The alternative text for the decoration images should be kept empty as (`alt = ""`). When such images are accessed through screen readers, the alternative texts are read by the screen leaders, resulting confusion to the end-users. In addition, they do not provide any important information.

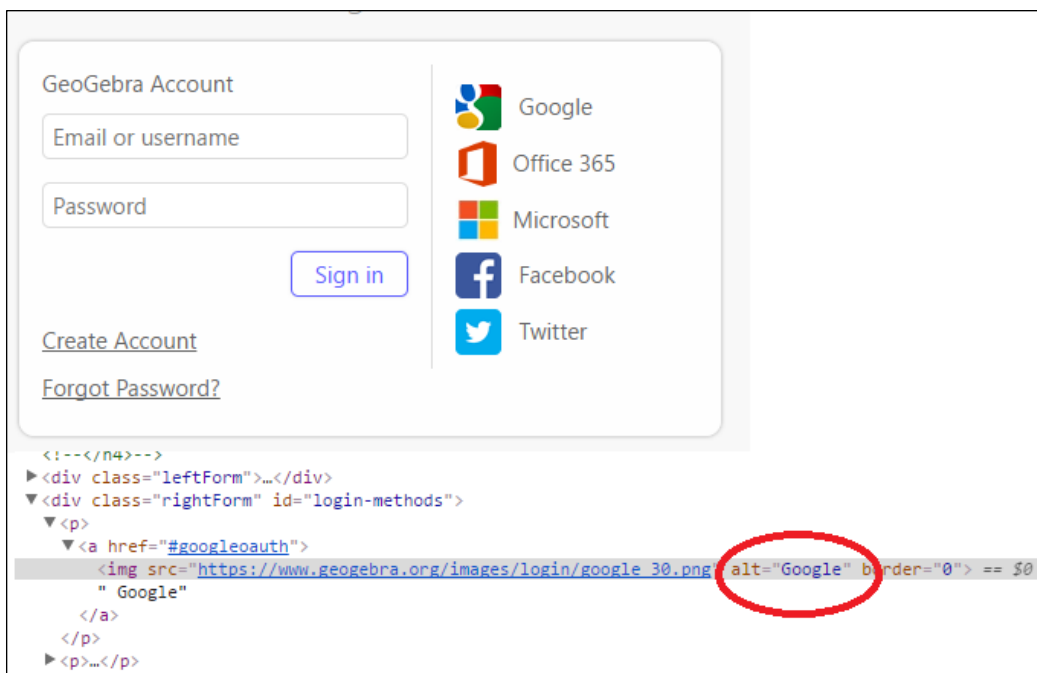


Figure 4-2: The Google Logo used as decorative images contain alternative text.

The above Figure 4-2 is also another example of using alternative text for the decorative images. Here, when the screen readers access the logo, it speaks the word “Google” and furthermore another “Google” as the link text. This could confuse the users.

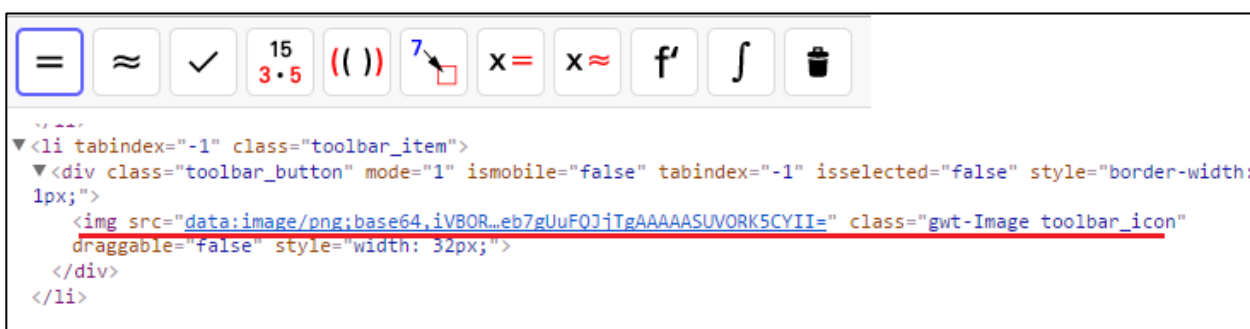


Figure 4-3: The control button does not have alternative text defining the purpose of the button.

The above Figure 4-3 is taken from the main math application, CAS, in the GeoGebra. The figures contain several mathematic related buttons and do not have any labels describing the purpose of the buttons. Accessing with the screen reader, since the button do not have any alternative texts either, the screen reader reads the

file names instead making the users really hard to understand the name and the purpose of the controls/button. In the CAS, there are many examples of the controls not having the alternative texts.

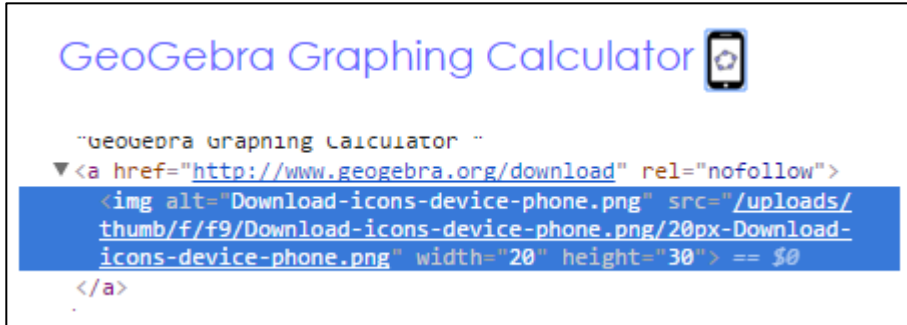


Figure 4-4: The alternative text does not contain meaningful text.

In the above *Figure 4-4*, the image contains the alternative text. However, the text “Download-icons-device-phone.png” seems to be the file name of the image used in the webpage. The alternative text does not give any meaning and does not make sense to the link either.

### **Guideline 1.2. Time-Based Media**

Since there was no any presence of video and audio content in the ten selected pages for evaluation, the five SC criteria under the above-mentioned guideline was not applicable.

### **Guideline 1.3. Adaptable**

The objective of this guideline is to present the content in different ways so that the content is perceivable to every user. There are namely three success criteria under this guideline. All the three criteria were not met by the evaluated pages.

### **Info and Relationships**

When the user changes the presentation format of the page, the information, relation, and structure should be accessible through programmatically that are available through the presentation. Fulfillment of this SC will help user to perceive and adapt the information according to their requirements through the user agents. Specially,



people with blind and blind-deaf disability can have vast advantages with the successful implementation of this SC.

After evaluation, in multiple pages, the label/name describing the purpose of the input elements was not found. For instance, in the help page, the users were provided the options to search for the familiar issues or any help through the search field. For the sighted users, they can easily identify that this field is for search, however, for the blind users, it is quite difficult to identify the purpose of the input element since the input element does not have the name describing its purpose.



Figure 4-5: Search Field and Search Button do not have name and value respectively describing its purpose

Moreover, as seen in the above Figure 4-5, the search input element is immediately followed by the search button. Only the symbol of search is provided. Checking it programmatically, the search element does not have any value. As seen in the figure above Figure 4-5, the value filed is empty for the button element. Accessing it through the screen reader, the screen reader only spells the word “button” resulting the user to confusion.

Similarly, in the CAS page, there are several tools without the name. As shown in the *Figure 4-3* above, the tools do not have names/labels. For a sighted user with knowledge of the math tools, there won't be any issues accessing the tools.

However, for blind users, new users, or people with short memory can find difficult knowing what the buttons do.



Figure 4-6: The language select options is without its labels

In the home page, there is a Select element as in Figure 4-6 above, where user can change the language of the page. However, the select element does not have any name describing its purpose. Screen reader reads it as “English, Pop up Button” making user difficult to understand what the pop up button is for.

Sign up

Sign up using a login from ...

Google Office 365 Microsoft Facebook Twitter

Sign up using GeoGebra login

Email A valid email address (required, but never shown)

Username Your public display name

Password A strong password with at least 6 characters

Password confirmation

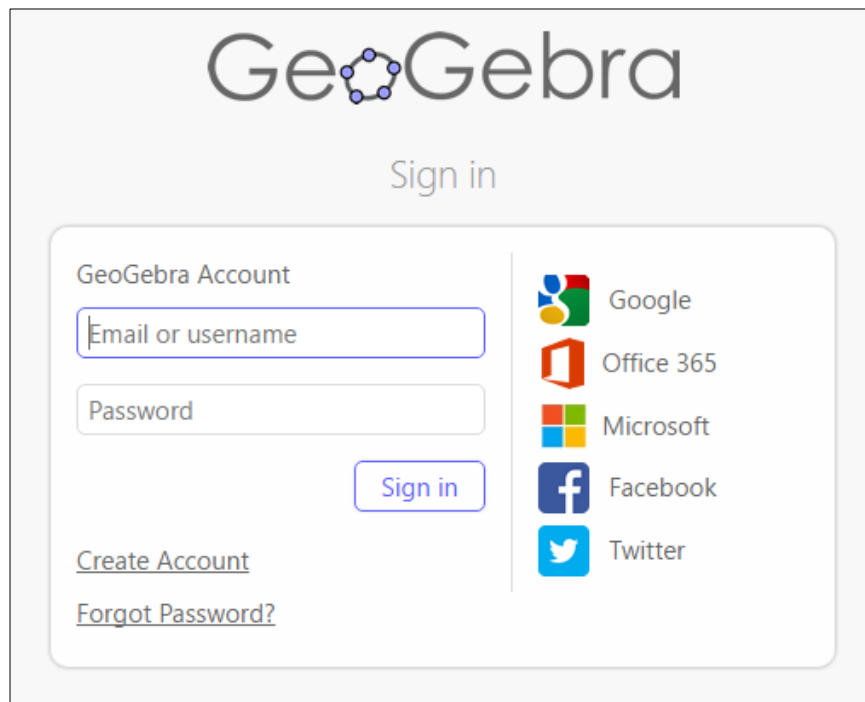
I'm not a robot reCAPTCHA Privacy - Terms

By creating an account you agree to our [Terms & Privacy Policy](#).

Create Account

*Figure 4-7: A sign up form for GeoGebra is without marking of any required fields*

A form in a webpage needs to follow certain criteria. They may contain numerous required area so, the label text with required field needs to be displayed in red color, '\*' sign beside every label and also instruction beside or top of the form explaining that they are required to be filled in and how user can do it. Here, as seen in the below Figure 4-7, sign up page below, the form with required fields are not marked with any signs like (\*, required) or colored text (**Email**). Furthermore, a clear instruction in the beginning of the form saying what are required by the users are not provided. Instead, the instructions are provided as a placeholder inside the input element. The placeholder gets lost when user starts typing in the input element.

The image shows the GeoGebra sign-in interface. At the top is the GeoGebra logo. Below it is the text "Sign in". The main form area is titled "GeoGebra Account" and contains two input fields: "Email or username" and "Password". A "Sign in" button is positioned to the right of the password field. Below the input fields are two links: "Create Account" and "Forgot Password?". To the right of the form, there are five social media login options, each with its respective icon: Google, Office 365, Microsoft, Facebook, and Twitter.

*Figure 4-8: No labels, required fields, and labels of instructions is provided for form*

In a form, every input field needs to have informative heading beside them or right next to them so that users are confident to fill in the information needed. In the Figure 4-8, sign up page, the label of the input field is inside the rectangle area which disappears while typing inside them so users can forget or get mistaken. So, it is important to have correct label in a form. People using assistive technology will follow the form programmatically so it is important to understand the requirement of the input field.

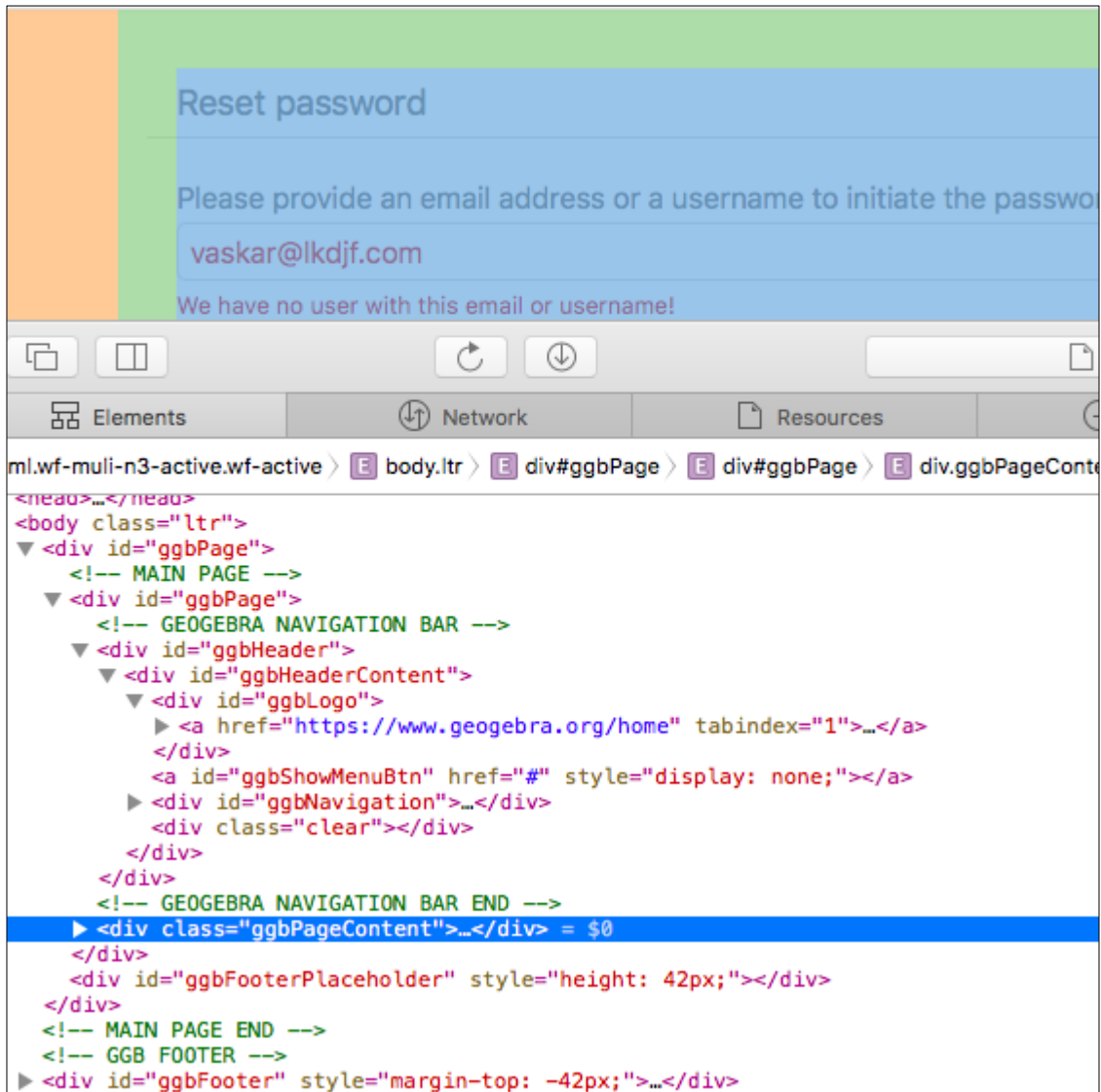


Figure 4-9: An example of page from the GeoGebra which lacks the identification of major region of the page with WAI-ARIA.

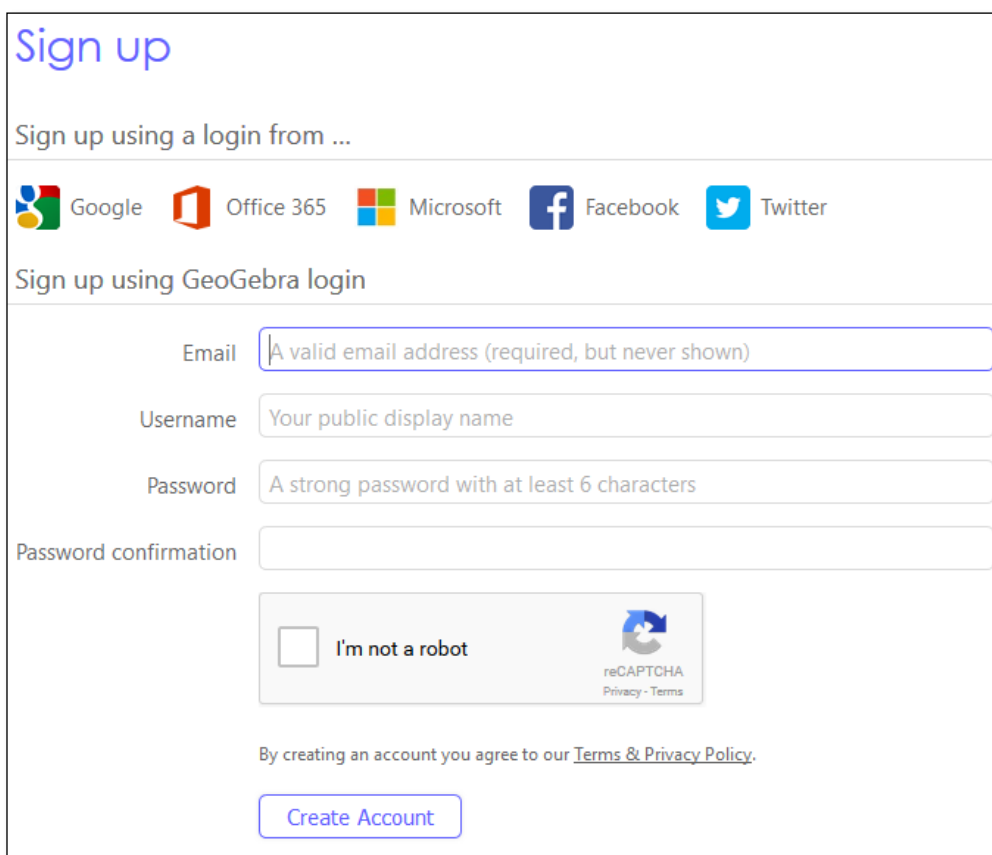
In of reset password page in above Figure 4-9, there was requirement of ARIA landmark for the identification of the region in the page. The reason to this practice this technique to show sections that is programmatically accessible and identifiable. Assistive technology users tend to navigate blocks of the information which are repeated in many pages so landmark helps them to skip and easily use them. For example, through common navigation menu users can skip big chunks of contents and bypass unnecessary menu links and use main landmarks for navigation. The landmarks are necessary for the attributes like banner, complementary section

contents, content information about the webpage, elements related to forms, main contents in the page, search.

Landmarks are written in hyper semantic markups like heading, menu, list of links, footer and many other structural markups. Every content in the page should include landmark because the users who totally rely on the navigation by landmark can lose the navigation track of the page content.

There are few more examples of input elements not having proper name. In the help page, the search elements do not have name/labels. It only contains the placeholder mentioning what the user can do through the search field.

### No meaningful sequence



The image shows a sign-up form titled "Sign up". It features several sections: "Sign up using a login from ..." with icons for Google, Office 365, Microsoft, Facebook, and Twitter; "Sign up using GeoGebra login"; and a main registration section with fields for "Email" (placeholder: "A valid email address (required, but never shown)"), "Username" (placeholder: "Your public display name"), "Password" (placeholder: "A strong password with at least 6 characters"), and "Password confirmation". Below these fields is a reCAPTCHA "I'm not a robot" checkbox and a "Create Account" button. At the bottom, there is a link to "Terms & Privacy Policy".

Figure 4-10: the focus element directly goes to the sign-up form instead of coming sequentially

Here, as seen in the above Figure 4-10, the sign-up page has different options of logging in. However, upon coming to this page, the focus element directly goes to the sign-up form instead of coming sequentially from the beginning of the page. So, for the users who have accounts in Google, Facebook, and who have visual impairment, they lack thorough guidance to the sign in options available in the first line.

### Presence of Sensory Characters

The objective of this criterion is to ensure that there is no any information or operating content that completely depends on understanding the shape, size for understanding the information or operating. In the evaluated pages of GeoGebra, there are many shapes without its name present in the pages. To understand these shapes, people need to have sensory abilities. One of the instances is discussed below.



Figure 4-11: Shape in the page needs sensory abilities to identify its purpose

For instance, in the Figure 4-11, there is three vertical dots in the right end corner of each listed materials. Since it does not have any alternative name, it is difficult to predict what it does. Furthermore, it is not accessible through only keyboard. Upon clicking the three dots, a small window is popped down with some more links. Many users can also think it as a decorative substance.

### **Guideline 1.4. Distinguishable**

The content in the webpage must be easier for the user to see and hear. The main objective of this guideline is to make content foreground information distinguishable from background. Here, out of five available A and AA success criteria, two were not applicable since they were not present in the evaluated pages, two SC were met, and one criteria were not met.

#### **Use of Color**

There were not any contents dependent only on color to convey the information.

#### **Audio Control**

Since no any audio control was available in the evaluated pages, it was not applicable.

#### **Contrast (Minimum)**

To distinguish the foreground text or images of text from the background, the contrast ratio of the color of the text or images of text with the background should be 4.5:1. Providing enough contrast of the text with relation to the background can help the people with color deficiency and low vision. From the evaluation, there were few examples which didn't meet this requirement.

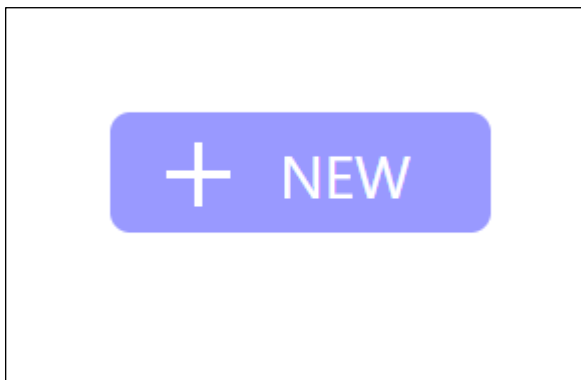


Figure 4-12:A button where the foreground text color and background color does not meet the Contrast ration of 4.5:1.



The above Figure 4-12 is the image of button from the “Materials” page of GeoGebra. The background color of the button (#9999FF) and foreground text color (#FFFFFF) does not meet the minimum contrast ration of 4.5:1 making it inaccessible for the people with low vision.

### Resize Text

The evaluated pages were zoomed to 200%, every evaluated page met this criteria without losing any functionalities and content.

### Images of Text

There was not any text provided in the form of images in the evaluated pages of GeoGebra.

### **4.2.3. Operable**

Another fundamental goal of the WCAG guidelines is to make all the contents available in the page operable. Under this principle there are four guidelines namely “Keyboard Accessible”, “Enough Time”, “Seizures”, and “Navigable”. Among these four guidelines, there are in total 12 A and AA success criteria. Among 12 SC, three were not applicable, while rest of the success criteria were not met.

#### ***Guideline 2.1. Keyboard Accessible***

The objective of this guideline is to make contents and interface elements operable through only keyboard.

### Keyboard

All the functionality available in the page were not accessible only with keyboard. There was necessary for the user to be dependent in the mouse device to explore some of the interface components. Among 10 evaluated pages, there were keyboard issue in four of the pages. Among the four pages, in some pages, content navigation through only keyboard was impossible.

In the help page, the major part of the page was accessible through only the keyboard. However, it was difficult for the users to locate where they are currently focusing since the focus visible was completely unavailable. Furthermore, there were some elements which were not accessible through only keyboard.

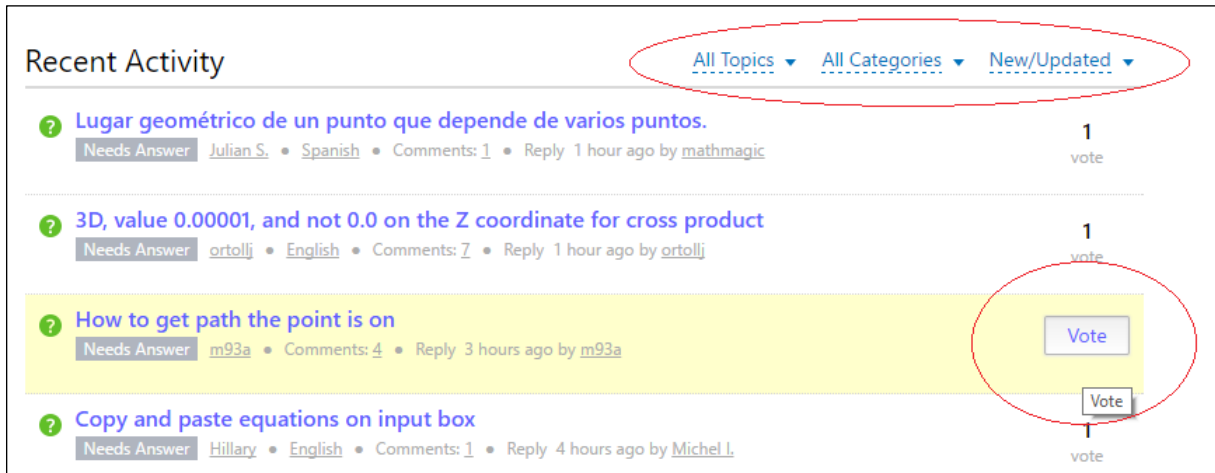


Figure 4-13: The elements (shown inside the red oval) that are inaccessible only with keyboard.

As shown in the above Figure 4-13, the elements (inside the red oval) were not accessible through keyboard. And in case of one element “vote”, it was repetitive in every recent activity posted by the GeoGebra users.

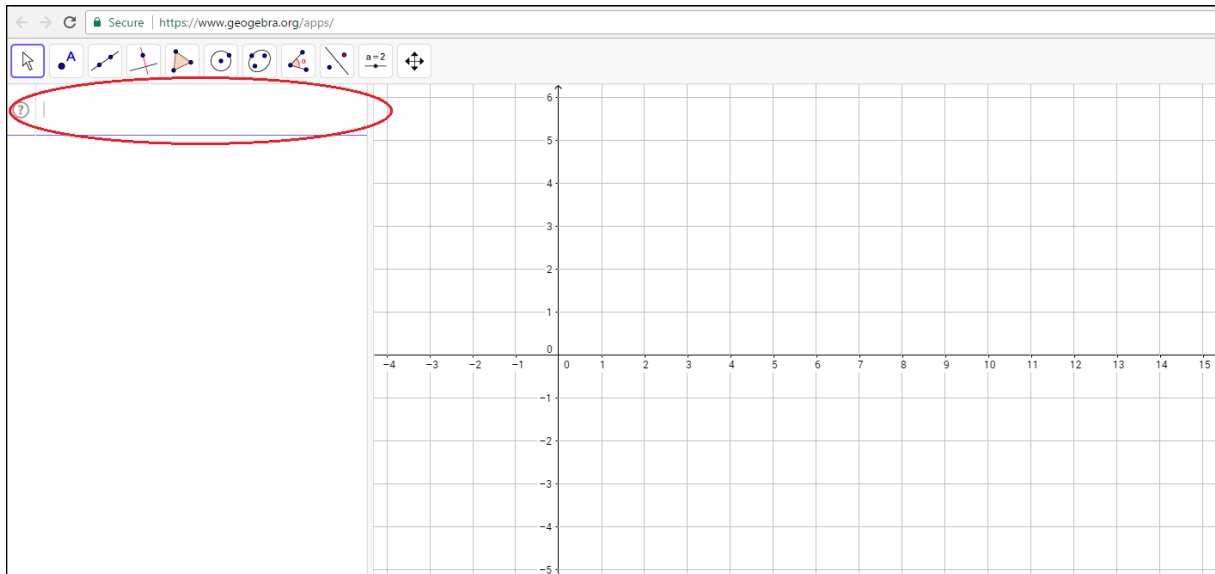


Figure 4-14: The focus on the input element in the CAS page of GeoGebra is not sequential

The poorest scenario was that the main application for the mathematics learning in the GeoGebra website – CAS – was completely inaccessible only with keyboard. When the page loads, the focus is centered on the input element as shown Figure 4-14 inside the red oval.

### ***Guideline 2.2. Enough Time***

The aim of this guideline is to provide the disabled users enough time to read content and do the task. There are in total two A and AA success criteria namely “Timing Adjustable” and “Pause, Stop, Hide”. Since in the evaluation pages, there was no any time limit nor any blinking objects, thus the two success criteria are not applicable.

### ***Guideline 2.3. Seizures***

The objective of this guideline is to not design the page that includes flashes and caused seizures to the users prone to seizure. The only Success Criteria A - “Three Flashes or Below Threshold” - is not applicable since the evaluated page do not have any kind of flashes available.

## ***Guideline 2.1. Navigable***

The objective of this guideline is to help users to keep track while navigating the webpage and to find their current location within the webpage, to help the users to find the content, and to help users to find other pages within the set of webpages.

There are in total seven success criteria A and AA in this guideline. Among the evaluated pages, in overall, not one of the success criteria was met.

### Bypass blocks

The content like header, navigation bar, and footer, usually, are repeated in multiple pages. For some users who access the page sequentially for example through keyboard, mechanism should be available to skip those repetitive blocks of contents and to move directly into the primary section or content within the webpage. The repetitive blocks of content are for example block of advertisement, header, navigation links, however it is not limited. Fulfillment of this criteria will help the users to skip the repetitive blocks of contents and to reach the desired content quickly and easily.

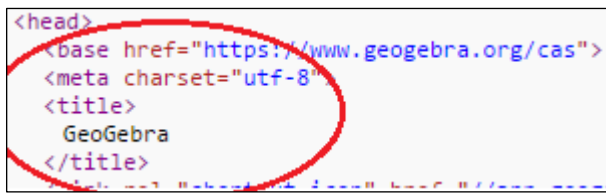
In the evaluated pages, although some of the webpages in GeoGebra have relatively fewer contents than other, no any mechanism was available to skip the repetitive blocks of contents. For the user dependent with screen reader and only keyboard, the user needs to go every element from the top to the desired destination.

For instance, in the material and help webpage of GeoGebra, there are many elements listed out. If the users have to reach the bottom of the element list, the user has to go all the way through the logo of the GeoGebra to the desired list. In addition, each list contains around 6-7 interactive elements. This could annoy the users.

### Page Titled

The intent of this success criteria is to have a clear and descriptive title that unambiguously describes the purpose of the page. A proper title will help the users to identify the purpose of the page without going inside of the page and interpreting the contents of the webpage. Specially, if the page is an application or contains the

document, the name of the application or document will help the users to sufficiently understand the purpose of the page.



```
<head>
<base href="https://www.geogebra.org/cas">
<meta charset="utf-8">
<title>
  GeoGebra
</title>
```

Figure 4-15: A part of program of CAS application shows the unclear title of the page

Among the evaluated pages, majority of the pages has a descriptive and clear title. However, in the main application i.e. CAS application in Figure 4-15, the title of the page is ambiguous and not clear enough for the user to identify the purpose of the page.

### Focus Order

The objective of this success criteria is to make sure that the focus order of the contents in the webpage is logical, gives meaning, and intuitive in terms of operability, if the contents can be navigated sequentially through keyboard. People with visual disabilities, people relying on keyboard to interact with the contents, and people with reading difficulties can have benefits of logical focus order.

Although, the majority of the pages evaluated has logical focus order. However, in the create account webpage, first the focus order, after the page loads, is in the form element that contains different input elements related in creating account. After going through each elements of the form, the focus order goes to the interactive elements in the footer section. Than after the focus order moves back to the top of the webpage.

To create account in GeoGebra, a user can use other login form from Google, Microsoft, Facebook, Twitter, and Office 365. However, the issue is that the focus order of the page is not logical. As discussed above, when the page loads, the focus is in one of the element in the form section. The options of choosing the login form provided by above-mentioned service provider comes after the focus order moves

from form elements to footer, to the main header, and to the other options provided for the login. This causes problem mainly to the visual disabled users.

### Link Purpose (In Context)

Simply, the link text should be clear and unambiguous so that the user can clearly identify the purpose of the link and can decide whether to follow the link or not. The objective of this criterion is to make the link text clear either by link text alone or by the combination of the links attribute determined programmatically. Clear and meaningful links can help users to understand the purpose of the link without even activating the link.

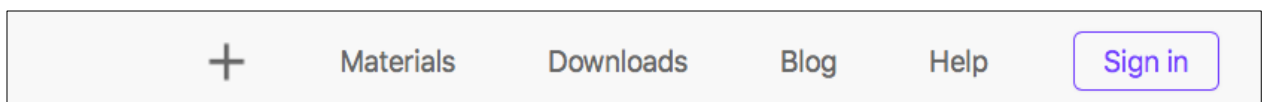


Figure 4-16: example of link without link text present in the website

The symbols used in the Figure 4-16 is lacking the proper identification of the link purpose. This may lead the user to unnecessary confusion and requires to open it every time to know the purpose. There is no description of the sign in the webpage so this can be difficult for people with motion impairment, who have cognitive limitations and visual impaired.



Figure 4-17: The links lack descriptive text

In the Figure 4-17, there is no proper heading for the links so if the image is not selected while viewing the webpage, these links lack descriptive text.

### Multiple Ways

To help users find the webpage within a set of webpages, different ways of identifying the webpage should be provided. This can help the users to find the

required information quickly and faster according to their preferences and requirement. Some users find it easier to use search field rather than navigating the multiple webpages sequentially to find the desired content in the webpage. Similarly, some user will be benefited by the site map provided in the webpage which helps them to understand the content and layout of the webpage rather than going through every webpage.

In case of GeoGebra, there was no any method found to navigate the webpage. Neither search mechanism, table of contents, nor site map was found to locate the webpage the user wants to access. There are few consistent links of the webpage available from the footer and header section of the webpage. However, the footer and header section is not available to some of the webpages. The only method to access the other webpage is hierarchical navigation feature which can be problematic for different kind of users.

The intention behind the criterion is to help users finding the content according to their preference and requirement. A webpage requires to have more than one technique to locate the contents present in it. The site map should be linked from and to the home page so that it is much simpler to identify the location of the content. Finding the opportunity to navigate page in different ways can help in faster scanning of information with proper search mechanism. This will help visually impaired to navigate pages within correctly. Cognitive impaired users also find table of contents or site map navigation useful instead of visiting every page in hierarchical manner. The site navigation also helps users to visit the page sequentially and easily find the features. The GeoGebra webpage has only one hierarchical navigation feature which can be problematic for all users.

### Headings and Labels

The main purpose of this criteria is to facilitate users to give clear and precise information contain in the webpage. The distinct and descriptive heading and labels can help to easily find correct information and understand the relationship between other contents. A short and meaningful labels and heading are always well received by the users. People having difficulties with reading, visual stress or people with dyslexia can benefit with proper use of heading and label of each section so that they

can predict the contents inside them. People with cognitive impairment and motor impairment will also be able to save time through visiting the right contents by reducing the number of keystrokes that is required to search through every unclear content. People using screen reader will also have benefits from meaningful contents header to find their requirements. People with low vision impairments will be beneficial as short meaning header will help them if they can see only few words once in a time.



Figure 4-18: User input area is without label

After the evaluation of the GeoGebra pages, there are few instances where the heading and labels are either not provided or not clear resulting in the unsuccessful implementation of this criterion. For instance, in the Figure 4-18, the input section to change the language of the website does not contain the label describing the purpose of the input element. For many users, it might be difficult to perceive what the input element is for, especially to the person with visual disabilities.

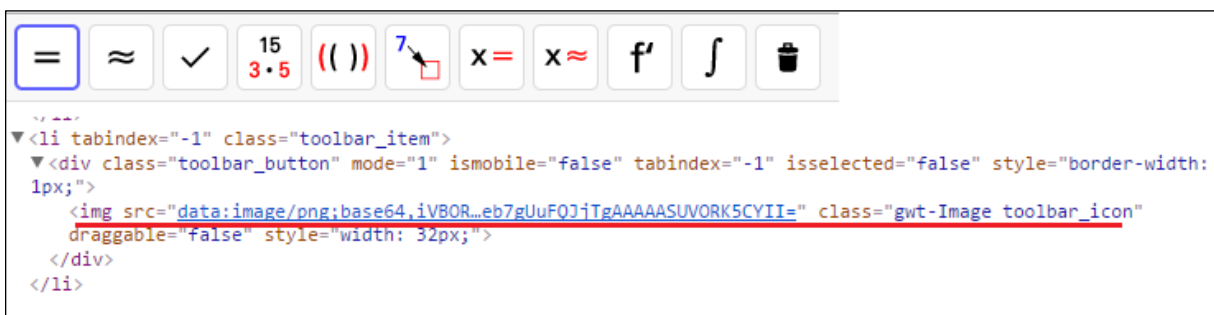


Figure 4-19: The mathematic tools available in the CAS math application that does not have heading or label

Similarly, another example in Figure 4-19 the contents not having the proper headings and labels is the tools available in the CAS application in the GeoGebra. As shown in the figure above Figure 4-19, the tools in the application page do not have labels or headings describing the purpose of the tools. For the normal sighted people



and people who have proper understanding of these tools, they can easily identify the purpose, however, to the people who are not familiar with the tools and people with visual disabilities can find the tools ambiguity.

Furthermore, there are few form elements in different evaluated webpages where the heading and labels to describe the purpose of the input elements are not defined at all. The information on how to provide input are rather provided as a placeholder. Particularly, in the “Sign In” page, the username and password field do not have labels. In the help and materials page, the search field input element does not have headings and labels.

### Focus Visible

The intent of this success criterion is to help the users to locate where they are currently while navigating the webpage by highlighting the elements with keyboard focus. The visibility of the focus can be highlighted either by marking the focus elements or by changing the visual properties of the focus element.

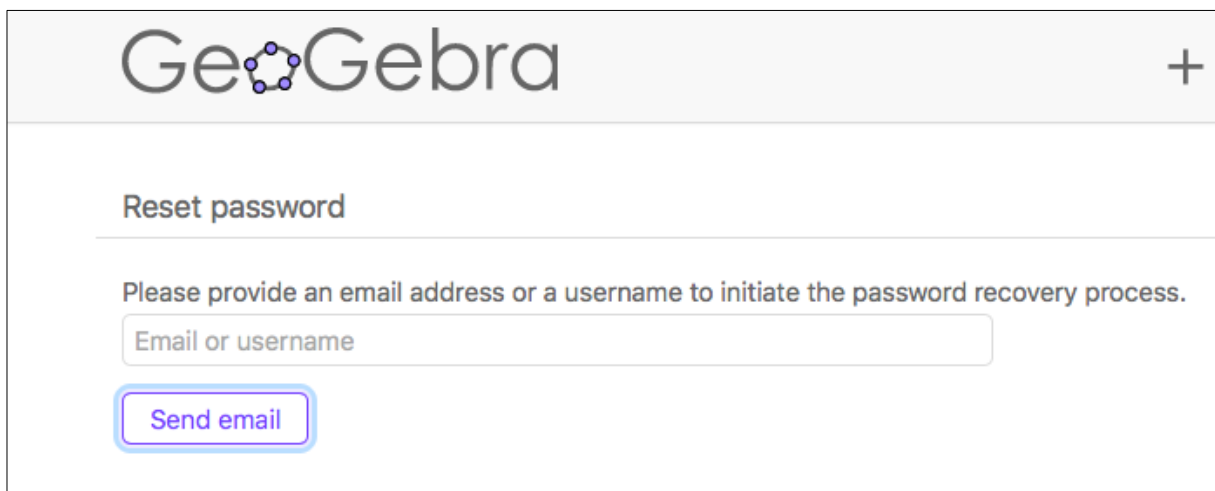


Figure 4-20: Low visibility of focus in "Send Email" user interface component

In case of GeoGebra, this criterion was not met. In few of the major pages like Home Page, Downloads, and Sign In/Up page, the focus visibility is available. However, the contrast of the focus indicator was very poor. For instance, in Figure 4-20, reset password page, the user interface components “Send Email” have focus and is

highlighted with a blue colored rectangle around the button. However, the focus indicator is not so distinguishable and do not have high contrast.



Figure 4-21: Tool element with unclear focus indication of Tutorial Page.

Similarly, in the Figure 4-21 of Tutorial Page, there are small icons which represents a link. However, when the icons receive the focus, it is not so clearly distinguishable, as shown in the figure above Figure 4-21.

The other worst case scenario was that in the help page of GeoGebra. Sighted users can know where the focus of the keyboard is with the help of link shown in the bottom of the page when the users navigate through the page. However, no any focus indication is available making it completely inaccessible to the people dependent with the focus indication to identify the current location.

#### **4.2.4. Understandable**

The objective of this principle is to make the contents and the user interface components in the webpage easy to understand.

##### ***Guideline 3.1. Readable***

The intent of this guidelines is to make sure that the text content in the webpage is readable by users and assistive technology, and the necessary techniques is available to make the contents understandable.

Under this guideline, there are two A and AA success criteria. One was not applicable, and another was not met by one of the evaluated webpage of GeoGebra.

##### Language of Page

To understand the language that is present in the webpage, the language of the page must be programmatically determined by the user agent. For example, when the

screen reader identifies the language of the page, it can adjust the pronunciation according to the language identified in the page.

```
<html style="overflow: auto;">
  <head>
    <base href="https://www.geogebra.org/apps/">
    <meta charset="utf-8">
    <title>
      GeoGebra
    </title>
```

Figure 4-22: The programmatically view of the CAS application in GeoGebra where the language of the page is not determined.

In the case of GeoGebra, although the majority of the webpages have language determined programmatically. However, one of the webpage do not have language assigned. The CAS page do not have language of page assigned to it, as shown in the above Figure 4-22.

### Language of Parts

If multiple languages in a webpage are present, the intent of this criterion is to ensure that the user agent can identify the language and present correctly it to the users. This criterion was not met by the GeoGebra.

In the help page of GeoGebra, users can ask help or post any math solutions in their language if it is listed in the list of languages GeoGebra is available on. However, the use of the different language in the page was not defined.

? [Grafik um Ursprung rotieren lassen](#) 2 votes  
 Needs Answer Laura • German • Comments: 2 • Reply 5 hours ago by rami

---

? [Wie wird diese Nullstelle berechnet?](#) 1 vote  
 Needs Answer Martin • German • Comments: 3 • Reply 1 day ago by Michel L.

? [Wie mache ich einen Winkel an einer Strecke bei einem Punkt?](#) Vote  
 Answered Marco W. • German • Comments: 1 • Reply 2 days ago by Zbynek

```

<div class="object-icons">...</div>
<div class="content-object floatLeft">
  <h3 class="content-object-title">
    <a href="https://help.geogebra.org/topic/grafik-um-ursprung-rotieren-lassen">Grafik um Ursprung rotieren lassen</a>
  </h3>
  <div class="content-object-info">...</div>
</div>
<div class="all-votes">...</div>
<div class="clear"></div>
</div>
<div id="topic-78054" object-type="question" class="object question">
  <div class="object-icons">...</div>
  <div class="content-object floatLeft">
    <h3 class="content-object-title"> == $0
      <a href="https://help.geogebra.org/topic/wie-wird-diese-nullstelle-berechnet">Wie wird diese Nullstelle berechnet?</a>
    </h3>
  </div>

```

Figure 4-23: the use of the different language in the page was not defined in the Help webpage of GeoGebra.

In the above Figure 4-23, the user has posted requesting for the help writing the title in the German Language. However, checking the title programmatically, the language of the title is not defined not meeting the success criteria successfully.

### **Guideline 3.2. Predictable**

The objective of this guideline is to present the content and the interactive components in a predictable order. Under this guideline, there are four A and AA success criteria. In the case of GeoGebra, two were not met by the evaluated pages, while one was not applicable and other was successfully met.

### On Focus

The intent of this success criterion is to make sure that no any contents changes when any of the component in the webpage receives focus.

In the evaluation of the GeoGebra page, no any changes in context was identified when any of the components in the page received the focus.

## On Input

The intent of this success criterion is to make sure that there is no any change in the contents when any of the component receives inputs unless otherwise advised to the users previously.

In the GeoGebra, it was found that providing input in one of the component leads to change in the contents of the webpage. Since GeoGebra is available in multiple language, the user can change the language of the page according to their preferences. This feature is provided by the select options.

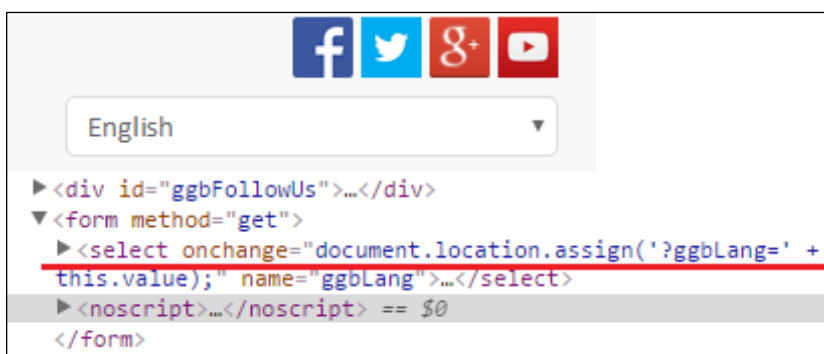


Figure 4-24: The event handler "on-change" changes the content in the page without advising the users beforehand

When user selects any one of the language from the list as in above Figure 4-24, it suddenly changes the language of the page and contents in the page according to the selected input. However, no any information about the changes was provided to the user before the change of the context in the page. The event handler "on change" was found when checked it programmatically. Furthermore, the language selection option is available in the footer section of the pages and is repetitive in many webpages of GeoGebra.

## Consistent Navigation

The objective of this criterion is to make sure that the repetitive blocks of contents is placed consistently in the other webpages so that the users can locate it easily and quickly.

In the case of GeoGebra, this criterion was successfully met. The repetitive blocks of element in different page was found to have placed in same order letting user to predict the contents easily.

### Consistent Identification

The objective of this criterion is to make sure that the repetitive functional components in the different pages can be identified consistently.

In the evaluated pages of GeoGebra, this criterion was successfully met. All the repeated functional components in different webpages had the same functions.

### ***Guideline 2.1. Input Assistance***

The objective of this guideline is to ensure that the users are provided the required help when they input incorrectly generating mistakes. This guideline consists of four A and AA success criteria. Among four, the evaluated webpages of GeoGebra did not met three, while the other one was not applicable.

### Error Identification

The objective of this criterion is to help user to know that error has occurred and to provide clear and specific description of the error. Providing such information can help especially the visual impairment people to perceive that there has been an error.


Sign up using GeoGebra login

Email

Username

Password   
Your password is too short, please enter at least 6 characters.

Password confirmation

I'm not a robot  reCAPTCHA  
[Privacy - Terms](#)

By creating an account you agree to our [Terms & Privacy Policy](#).

Figure 4-25: The sign-up page shows error display with wrong example when the incorrect email address was typed.

In the case of GeoGebra, in the Sign-Up Page Figure 4-25, users are required to provide the email address. After intentionally providing the email address in a wrong format, the form was submitted. The error was shown in a small pop-up window (as shown in the figure above Figure 4-25). The window disappears after around 5 sec. To the people with visual disabilities, this could cause a problem since the pop-up window is not accessible to the screen reader and furthermore, the error message in the pop-up window appears for quite short period of time.

The screenshot shows a web form titled "Reset password". Below the title is a heading: "Please provide an email address or a username to initiate the password recovery process." There is a text input field containing the text "afasdfas". Below the input field is a red error message: "We have no user with this email or username!". At the bottom of the form is a blue button labeled "Send email".

Figure 4-26: Forgot Password form with error message that is not helpful

Similarly, in the Forget Password Page as in Figure 4-26, the “Send Email” button was pressed leaving the input element for “Email or Username” blank. Even though the field was empty, the form was accepted and directly forwarded to sign in page and an instruction appears in the top of the page as “Check your inbox for further instructions to reset your password”. This shows that the validation of the form was not done when submitting the form with empty fields. However, when wrong username or email is provided, a clear and descriptive error message was provided.

### Labels or Instructions

To fulfill the objective of this success criterion, the elements that control the form should contain the labels and description of what kind of data is expected from the users in the input elements. The instructions could include the format of the data the users need to follow. The instruction should contain short and clear information without any confusion rather than long and unnecessary information. Providing labels or instructions could help various kinds of disabled people like people using magnifiers, screen readers, and people with cognitive disabilities. This can also help users to fill the form correctly.



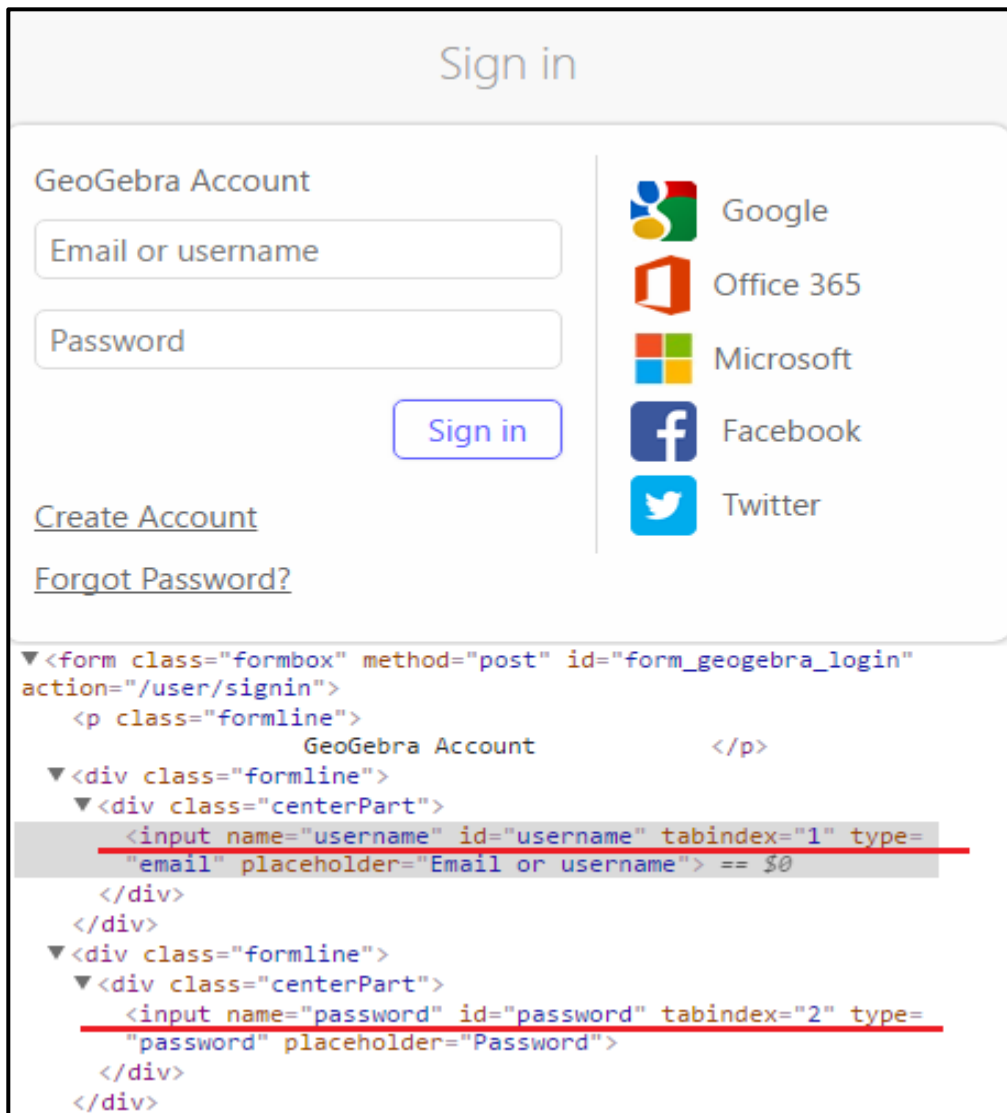


Figure 4-27: Form elements do not have labels describing the purpose of the elements in the Sign In page

In case of GeoGebra, there are many forms available without labels or instruction resulting in the unsuccessful implementation of this criteria. One of the example of form elements not having a labels or instructions is in the Sign In page of GeoGebra in Figure 4-27. As shown in the figure above Figure 4-27, the “username” and “password” field do not have labels describing the purpose of the form elements. The instructions are provided inside the form elements as placeholder. The disadvantage of placeholder is that it disappears when user starts typing in the input field.

Similarly, in the 'Material Page', 'Help Page', and 'Sign Up page', there are few input elements which does not contain neither instructions nor labels to describe the purpose of the input element. Another example of missing labels or instruction is the select option to change the language of the page in the footer section in the Home Page of GeoGebra. These issues have resulted in the failure of this success criterion.

### Error Suggestion

Unless the suggestion for the error does not jeopardize the security, the suggestion for the automatically detected error should be provided to the users. Providing clear suggestion for the correction of the input error will help many kind of users. For example, people with cognitive and visual disabilities will have greater benefits when they are able to figure out how to fix the error.

As discussed in the earlier section "Identification of Error", the form elements named as "Email" in the Sign-Up page provides the error suggestion in the pop-up box and it is appeared for short period of time resulting it to be inaccessible for many users. Although the pop-up window contains the suggestion of the error, many users would not be able to identify the suggestion.

### Error Prevention (Legal, Financial, Data)

The objective of this success criterion is to ensure that the form submissions are reversible, checked for any kind of input errors, or the input provided by the users are confirmed before finalizing, if the form in the web page relates to legal commitments of conduct any kind of financial transaction.

Since in GeoGebra, there is no any form related to legal commitments or financial transactions, this success criterion is not applicable.

The data entered or selection of any form control should have predictable effect. Any changes in the user interface of the webpage needs to be verified so that the user can identify the changes after response to the action. People with impairment who are using assistive technology requires the interactive content to be more predictable so unexpected changes without verification can disoriented them. Without proper warning or window pop up, users are likely to create error.

#### 4.2.5. Robust

For the webpage to adopt with the future user agents, the objective of this guidelines is to increase the compatibility of the webpage. There are in total two ‘A’ success criteria under this guideline namely “Parsing” and “Name, Role, Value”.

##### Parsing

The objective of this success criterion is to make sure that the content developed can be interpreted and parsed by the assistive technologies. To achieve this criterion successfully, the semantic markup must be well implemented. For example, the ID’s must be unique, the coding must have proper opening and closing ends and nested properly.

```
<html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en" lang="en" dir="ltr" class="wf-multi-n3-active wf-active">
  <head>...</head>
  <body class="ltr">
    <div id="page">
      <div id="main">
        <div id="logo">
          <a id="logo" href="https://www.geogebra.org"> == $0
            
          </a>
        </div>
```

Figure 4-28: Presence of duplicate ID's in the Sign In page

In the evaluated pages of GeoGebra in Figure 4-28, there was presence of duplicated IDs in multiple pages resulting in the failure of this success criterion. As shown in the above Figure 4-28, the ID “logo” was found to be used in two places at a same page.

```
▼<body class="ltr">
  ▼<div id="ggbPage">
    <!-- MAIN PAGE -->
    ▼<div id="ggbPage">
      <!-- GEOGEBRA NAVIGATION BAR -->
      ▼<div id="ggbHeader">
        ▼<div id="ggbHeaderContent">
          ▼<div id="ggbLogo">
```

Figure 4-29: Presence of duplicate ID's in Sign-Up Page

Similarly, in the Sign-Up page Figure 4-29, the ID “ggbPage” was found used in two “DIVs” resulting in the violation of this success criterion.

### Name, Role, Value

The objective of this success criterion is to provide name and role of every user interface components programmatically but not limited to some types of components generated by the script language.

After the evaluation of the selected pages, many input elements (described earlier in various success criterion like “Info and Relationships”) was found not having label attributes describing the purpose of the input elements.

## 5. Discussion

Given the fact that the use of interactive learning materials in the schools is increasing, there is the need to evaluate ILMs to find out whether the tools are accessible for everyone. The fundamental goal of this research was to evaluate the interactive learning material GeoGebra with semi-structured interview and heuristic evaluation against WCAG 2.0 success criteria A and AA. This section interprets the results of this research in order to answer the main research questions.

### 5.1. What is the experience of students regarding GeoGebra?

The research has found that according to the students, GeoGebra is useful to perform mathematical operations to support the teaching and learning process. It was found that working with GeoGebra has helped them to visualize mathematical concepts. The students were found to be using GeoGebra as a supporting tool learn mathematics curriculum. Many researchers like (Capper, 2001; M. Hohenwarter & Lavicza, 2009; Khalifa & Lam, 2002; McDonald & Smith, 2013) reported that there are several factors that affect the learning process. Using appropriate ILMs was found to be one important factor in enhancing the ability to learn.

#### 5.1.1. Main accessibility and usability challenges faced by the students.

The research found out some user interface related issues experienced by the students while using GeoGebra. As the students were non-disabled users, the issues they described were related to both accessibility and usability barriers. The issues described were presented into five categories i.e. lack of error indication and feedback on the state of a task, complexity and Confusion in using icons of buttons, and symbols, lack of predictability in task, lack of flexibility for beginners, lack of instruction to solve errors. These categories are separated according to the similarity of the issues. These issues identified are related to user interface related issues. According to the well-known user interface design principle of Jacob Nielsen (Nielsen, 2012), the user interface principles needs to be implemented for enhancing user interface design during the development and testing stage. There were some usability evaluation studies carried out for GeoGebra previously as described in

section 2.1.6. These usability evaluations of GeoGebra and other e-learning websites have defined that many of the ILM still has many accessibility limitations.

As discussed in section 2.1.2, the use of ICT in education is one of the main skills that needs to be learned by Norwegian students. They have been using ICT in school from the very early age. Access to faster broadband internet, access to laptop, desktop and use of interactive learning materials has made Norwegian education more supportive to implement ICT tools and become more learner centered education. The students in upper secondary level were able to use GeoGebra from the beginning of the first level. From literature review, this research has found that Norway has changed from two track model to one track inclusive education which is in the favor of including all children. The target group of the research is beneficial to all the students worldwide even though the study targeted students in a high school in Norway, it's application can be worldwide, wherever GeoGebra is used. The issues identified can also be helpful for successful implementation of universally design interactive learning materials.

Referring to 2.2.1. Upper secondary schools in Norway have two types of program as described in section. According to the type of program taken by students, they are able to choose one of the mathematics subjects from the very first year. According to the student's choice from the first year, the mathematical curriculum courses is separated in second and third year based on their priority of program selection. The use of GeoGebra and other type of software are recommended by Norwegian ministry for the digital exam. The school chosen for this research has been using GeoGebra as supportive tool for mathematics.

The students involved in the research interview were not with disability however problems described in the interview are related to accessibility and usability problems. As described in section 2.1.2. both accessibility and usability are interlinked , the barriers faced by the students as they described in the interview session were found to be violations of WCAG 2.0 guidelines (Velleman & Abou-Zahra, 2014) and doesn't follow some of the user interface design principles of Jacob Nielsen (Nielsen, 2012). The heuristic evaluation of the GeoGebra website has also

confirmed the issues identified. The barriers described are discussed in section 4.1.3 are discussed below.

**Lack of error indication and feedback on the state of a task:**

According to the first principle of user interface design, the websites need to keep the user informed about the current process level, and provide appropriate notification in real time. The system should be responsive according to the action of user like searching, giving inputs etc. The students have described that they were unable to find updates on the progress of their tasks until they find final error result. If there is task in progress there is requirement of the notification because without notification the students may find it difficult to complete their tasks. The participant found the input task confusing because he had selected different tools but due to lack of identification for different task which was in process and similarity of the background color he found error in completion of task. The participants described that it is teacher's responsibility and requires to guide students during the task but according to good user interface design, the system needs to give enough instructions to the users so that it is able to complete task independently or with help of GeoGebra proceed further in the task.

**Complexity and Confusion in using icons of buttons, and symbols:**

In the second usability principle, it is specified that the system should support user's requirement. For example: language, symbols, phrases and concept similar to user's background. There should be understandable meaning or symbolic representation, icons or names used according to the task that's will be performed. The contents found in the webpage should be arranged in sequential and normal order. The students found the inputting task by selecting the buttons were difficult and complicated. The students said that they avoid solving complicated questions with GeoGebra because they make many errors and face difficulty. The most difficult subjects were defining functions, equations and writing syntax as they require to search for exact buttons in the on-screen keyboard.

**Issue with lack of predictability in task:**

The third usability principle describes the end users should have overall control over the system. So, the system should be able support redo and undo command in the user's task if there is any occurrence of error. The users should be able to exit any

time if the user accidentally press wrong functions during the task. The students had described that sometimes GeoGebra doesn't work as predicted. Lack of error notification makes it much harder. The participants had specifically identified CAS to be not working as predicted sometime and mostly find error in it. They said that they need to strictly follow every specific command for getting correct result.

As the fourth principle describes that the user should be able to easily use website without any hesitation. The system's symbols, word, situation and actions are predictable. a student said that in Norway, they normally use commas instead of dots. Therefore, errors related to those symbols is expected among Norwegian students. General platform standards like authorizing user to change control button or settings should be supported by the system. So, relating this principle to GeoGebra, there are some issues identified by students regarding the on-screen keyboard.

According to the fifth principle, the system needs to have a simple design so that there is less requirement of instructions that likely to be required. Eliminating the error possibility or testing them, giving users a confirmation request for a change is always necessary in the system. As the students has described, GeoGebra is not predictable and needs to incorporate proper instructions. The simple design of the CAS toolbar can resolve much of the students' problems.

### **Issue of flexibility for beginners:**

The sixth usability principle defines that the objects for manipulation, signs, actions and options to select contents used in a website should be understandable, simple and predictive. The users would not need to recall the information from one part of dialogue to another part. The instruction and error message needs to be clear, should be easily retrievable and appropriate. According to the students, they described that they required to remember the commands and whole task from before in order to conduct task with GeoGebra. The students had described that the GeoGebra doesn't allow to modify the toolbar and help button to according to their preferences.

The seventh principle describes that the system should support both beginner level and expert level users. The shortcuts, accelerators usually cannot be seen by users. So, the system should adjust the speed of interaction time and task completion time according to the user's requirement. The shortcut for commands and buttons for



conducting the task should be well informed to the students before beginning of the task. The student felt that due to lack of experience and practice they were not able to use the GeoGebra tools easily but following the eight principle, whether a user is beginner or expert level, it should be entertaining all the users equally.

**Issue with instructions to solve error:**

According to the eighth principle of usability for interface design, the instruction or the contents in a website should be relevant and avoid rarely used or unnecessary ones. The user should not be distracted by the website dialogue if it is not required. Though the students are satisfied with the website design and colors used for the website, there is requirement of relevant instruction for guiding the correct steps in the task. A useful short clip or message pop up can help to follow the steps when the students are proceeding in the task.

The ninth principle describes that the message of error needs to be understandable and simple. There should be problem identification in the instructions and quick hint, suggestion or guide to recover from the error easily. If there is error in typed command, user should be able to edit and repair only the error part so that they don't have to type all again. The students are found to be restarting the task as the error cannot be found or identified. Lack of proper instructions for solving error can create possibility of error occurrence. The dynamic geometric system like GeoGebra needs to focus more on the access to good user interface design usable for the students.

It is necessary for the system to help or support the users and provide the important documents according to the tenth usability principle. All the information or contents available in the system should be easily searchable, giving emphasis to the task of user, and provide short list of steps needed to accomplish them. The research has found that there is a manual for GeoGebra but doesn't seem to help much. Students with non-disability have faced many usability barriers which can clearly be seen as accessibility issues for students with impairments. The accessibility evaluation will further elaborate the side of accessibilities issues. The issues identified here can be more problematic during exam sessions. The school and responsible departments needs to arrange the proper evaluation of any digital tool before implementation and including them in the curricular and exam. As use of the GeoGebra is countered to

add marks for the exam, the issues identified is one of the necessity to be resolved immediately.

### 5.2. Does GeoGebra conform to the Guidelines set by WCAG 2.0?

From the heuristic evaluation of ten selected pages of GeoGebra, it is found that in overall, the pages did not meet altogether 22 success criteria under Level A and Level AA of WCAG 2.0. This outlines that the GeoGebra interactive learning materials is not completely accessible as it only meets 6 success criteria from level A and level AA. The overview of the result according to the success criteria is provided in the table (See Table 5-1: Overview of numbers of not met, not applicable, and successfully achieved success criteria of the evaluated pages of GeoGebra.) below.

Table 5-1: Overview of numbers of not met, not applicable, and successfully achieved success criteria of the evaluated pages of GeoGebra.

Success Criteria	Not Met	Not Applicable	Successfully Achieved
A	16	7	2
AA	6	3	4

**Success Criteria Level A:** The majority of the criteria from level A were not met by the evaluated webpages. One of the commonly failed criteria was non-text content. In multiple pages the controls or inputs do not have labels that describe their purposes. Especially in the main application webpage of GeoGebra, the buttons as the controls do not have alternative text describing its purpose. Some of the image do not convey any information however they contain some kind of the alternative text. Similarly, some of the images lacked “alt” attributes.

The evaluation showed that many of the inputs elements did not have the labels attribute describing the objectives of the input functions. The instructions about what is expected from the end-users were provided inside the input field as placeholders. Once the end-user starts typing something, the information in the placeholder disappears. This can present barrier to the people with short-term memory or people with visual disability.

The other commonly identified issue in multiple webpages were the inaccessibility of the interface elements with keyboard only. The main application CAS was completely inaccessible with keyboard only. The other strange thing was that the Help Page of GeoGebra can be accessible with keyboard, however it was difficult to distinguish the visibility of the focus elements, since, the focus visibility was not assigned at all.

The repetitive blocks like header and footer were available in multiple evaluated webpages. However, no any mechanism was provided to skip those repetitive block of contents, as a result, user have to navigate from the beginning of the webpage through the menu bar to the main content.

Another important criterion not met by the evaluated pages was description of the purpose of the link. In many places, the purpose of the link was unclear. For example, in the download page, users were provided the link to download the offline software for the different platform. The link text was provided as “Mac”, “Windows”, “Chrome OS”, and “Linux” which can be confusing to the user. Furthermore, there are different shapes without name that serves as the link which is difficult to understand the purpose without activating it.

Another most common issue identified was that the majority of the input elements in different pages do not have any labels describing its purpose. As a result, it is difficult for the visual impaired people to identify the purpose of the input element. Similarly, the robust attribute of the evaluated pages is poor as it is found that many of the webpages contains duplicate ID's, the major region of the webpages is not landmarked, and many of the interface elements do not have attributes like name, role, and value describing the properties of the elements.

**Success Criteria Level AA:** The minimum contrast ration of 4.5:1 between the foreground text color and background color was mostly violated. Many of the buttons which serve as important functions in the webpages had contrast issue and did not meet the minimum ratio assigned by WCAG 2.0. Moreover, the color assigned to the visibility of the focus in relation to the background color was very low in contrast. In some places, it was very difficult to distinguish where the focus is.

There was the failure of success criteria 2.4.5 because there was no other option to let the end-user navigate from one page to another page inside the website so, there is the requirement of mechanism resulting in multiple ways of navigation.

Furthermore, concerning the visibility of the focus, as discussed earlier, the color chosen to provide the visibility of the focus was poor.

## 6. Conclusion

The implementation of interactive learning materials in education institutes is rapidly growing, supporting teachers in their traditional teaching methods of subjects like science, mathematics and others. Moreover, helping students to learn the subjects more effectively and efficiently. One of the popular learning management system is GeoGebra. In Norway, GeoGebra has been the important part of the teaching-learning process of mathematics and currently, it is also being used in examinations.

Despite the popularity of interactive learning like GeoGebra, little is known regarding their conformance to the needs of universal design and/or their accessibility.

Universal design of the LMS is important to provide every student the chance to equally participate in the learning process. Furthermore, in Norway, the old or new ICT system directed to the end-users are required to satisfy the WCAG 2.0 success criteria AA by 2021.

As a result, this study evaluated GeoGebra. The fundamental goals of this research were to study the end-user's experience of using GeoGebra and to evaluate the GeoGebra against WCAG 2.0 success criteria A and AA. For the study, two different qualitative methodologies were used.

To study the experience of user using the GeoGebra, semi-structure interview was done with the second and third year students from a higher secondary school from Norway. In addition, heuristic evaluation was done to find out to what extent GeoGebra follows the WCAG 2.0 criteria. Heuristic evaluation of ten selected webpages from GeoGebra was done in two different platforms by two master students from Universal Design of ICT in Oslo and Akershus University of Applied Science. The data from the semi-structured interview was analyzed based on Interpretative phenomenological analysis (IPA).

From the result, it was found that although the students find the GeoGebra as a very helpful application in learning mathematics, their response outlines that there are lots of things that need to be improved. Furthermore, from the heuristic evaluation it was found that the majority of the success criteria level A and AA were not met by the evaluated webpages. Out of 38 total level A and AA success criteria, the evaluated

pages did not meet 22 success criteria, 10 were not applicable, and only 6 were met. This clearly indicates that the GeoGebra in general is not accessible to people with disabilities.

#### Limitations of the Study and future work

This study could have yielded better results if there were participants with some form of learning disability. However, the research has tried to compensate for that conducted semi structured interview and heuristic evaluation method to see whether GeoGebra is designed for universal accessibility. The other limitation is that the heuristic evaluations were made by beginner experts. As part of future endeavor, more experienced evaluations can come up with more results. However, the findings of this research could be starting points.

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## 8. Appendix

### 8.1. Consent Form Sample for Semi structured interview

#### Interview Consent Form

##### 1. Project Title

Title: Evaluation of Interactive Learning Materials for Universal Design: Case of Geogebra in Norwegian Schools

##### 2. General Descriptions

Researcher's Name: Pooja Shrestha

Supervisor's Name: Wondwossen Beyene

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##### 3. Research Question

RQ 1). What is the experience of students regarding GeoGebra?

RQ 2). Does GeoGebra comply to WCAG 2.0 Guidelines?

##### 4. Purpose

The goal of this project is to contribute to making Interactive Learning Materials in the Case of Geogebra more universally designed. The use of electronic and interactive LMs has significantly increased in western countries. ICT facilitates successful implementation of curriculum not only limiting students to learn and practice but including in tutorials, recreations, games and applications. This paper will evaluate geogebra which has been used in higher secondary schools in Norway. As it is known that Geogebra has been implemented in curriculum by education ministry for more than 10 years that geogebra so the main aim of the thesis is to evaluate if they have followed universal design standards.

## 5. Participants

In order to take participate in this research, one need to be a student using geogebra in high school more than one years for mathematics.

## 6. Procedure

The interview will contain questions related to geogebra, involvement of user and information about their knowledge on geogebra. The participants are requested to give their genuine opinions. The interview will take 30 minutes for completion. The interview is volunteer activity and participant can withdraw at any time they like. Also, it is not obligation to participate in further studies after you completed interview. Participants can skip any question if they don't like to answer.

## 7. Risk and Benefits

There is no risk at all upon participating on this survey. It is to be clear that the research is not finding out the imperfection of the staffs but the issues in the procedure while they use geogebra. There will be various benefits of this research to higher secondary education of Norway and geogebra developers to accessible websites.

## 8. Voluntary Participation

Participation in this research is voluntary. You have the rights to withdraw from this research study anytime you like without any jeopardy. If in case you chose to withdraw from the research, the collected data will not be used in the any part of the research and will be destroyed.

## 9. Confidentiality

All the information collected will remain confidential and the participants will be anonymous. The data collected, the questionnaires use will remain in the private folder and nobody will have access in it accept the members that are involved in this project. After the completion of the project, the data will be handled according to the rules and regulations proposed by the Norwegian Data Law.



## 10. Consent

I have understood the objectives of this research and the points in this consent form. Furthermore, I have had questions answered satisfactorily and I will contact the researcher group if I have any further suggestion.

I have provided with the copy of this consent form.

Date:

Signature:

[For further information or if you have anything to add, please don't hesitate to contact in the above-mentioned e-mail address or mobile number.]

Thank you so much for the participation.

## 8.2. Interview Question Form

Table 8-1: Interview question form

Q1.	How long have you been using geogebra for mathematics?
Ans.	
Q2.	Did you use any ILM in other subjects, what is your impression of Geogebra comparing to that ILM, what feature they miss in geogebra comparing to that?
Ans.	
Q3.	What do you use geogebra for?
Ans.	

Q4.	Did it help you to understand mathematics well? How? Can you give example?
Ans.	
Q5.	How often do you use geogebra?
Ans.	
Q6.	Did you face any kind of problem while using geogebra or while learning to use it?
Ans.	
Q7.	What is your usual way to adapt to the difficulties, how do you make your way?
Ans.	
Q8.	Do you have any suggestion to make it more helpful for learning it in simpler way?
Ans.	