ACIT5900

MASTER THESIS

in

Applied Computer and Information Technology (ACIT)

May 2023

Universal Design

Accessibility of digital teaching materials.

Identifying barriers faced by students with visual impairment in digital teaching materials

Stephen Simei Kimogol

Department of Computer Science

Faculty of Technology, Art and Design

OSLOMET

Accessibility of digital teaching materials.

Identifying barriers faced by students with visual impairment in digital teaching materials.

Stephen Simei Kimogol

http://www.oslomet.no/
Printed: Oslo Metropolitan University

Preface

Understanding the impact of accessibility on the experiences of people with disability has been my interest since I started this master's program. Furthermore, I work at Statped - the department of Teaching aids, as a developer. Therefore the motivation for choosing this topic was to learn more about how students with visual impairment interact with digital teaching materials and the accessibility barriers they face.

First, I want to thank my supervisor Norun Christine Sanderson for her invaluable guidance and support both during this thesis's writing and the work that preceded it.

I would also like to thank all the participants for their time and willingness to share their experiences with digital learning materials. This work would not have been possible without their contribution.

I want to thank also my colleagues at Statped for the discussion, for helping with the recruitment of the participants, and especially Ida, for testing the accessibility of my online questionnaire with different assistive technologies.

I also thank my friend Bishar Ali for his support and for proofreading my thesis.

Finally, I could not have undertaken this journey without my wife, Martha. Thank you for caring for our beautiful daughters Jeiso and Deraso and for your support and encouragement throughout the master's program and thesis writing process.

Stephen Simei Kimogol
Oslo, May 2023

Abstract

Information and communication technology has revolutionized all sectors and all aspects of human life. In the education sector, technology enhances the learning experience and access to learning materials, and it is also widely considered an enabler for more inclusive education. Digital learning materials are increasingly used in learning at all education levels, including secondary school. However, recent studies show that digital learning materials are not accessible to students with visual impairment in Norway. The overarching goal of this thesis is to identify the accessibility barriers faced by high school students with visual impairment in digital learning materials. Using semi-structured interviews and online questionnaire, this study investigated the accessibility barriers faced by students with visual impairment. The results reveal that students with visual impairment face several accessibility barriers that could impede their learning. The identified barriers are related to navigation issues on both the content and the secondary tools, usability barriers, incompatibility with assistive technologies, missing alternative text and inaccessible videos, and the lack of digital skills. These results indicate that the current digital learning materials are not universally designed. This means that students with visual impairment will spend more time and energy navigating and operating these resources rather than using them for actual learning. Consequently, greater attention is needed to understand these students' needs to make digital learning materials accessible.

Sammendrag

Informasjons- og kommunikasjonsteknologi har revolusjonert alle sektorer og alle aspekter av menneskelivet. I utdanningssektoren forbedrer teknologi læringsopplevelsen og tilgangen til læremateriell, og det er også ansett som en muliggjører for mer inkluderende opplæring. Digitalt læremateriell brukes i økende grad i undervisningen på alle utdanningsnivåer, inkludert videregående skole. Nyere studier viser imidlertid at digitalt læremateriell ikke er tilgjengelig for elever med synshemming i Norge. Det overordnede målet med denne oppgaven er å identifisere tilgjengelighetsbarrierene i digitalt læremateriell for videregående skoleelever med synshemming. Ved å bruke semistrukturerte intervjuer og online spørreskjema, undersøkte denne studien tilgjengelighetsbarrierene som elever med synshemming møter. Resultatene viser at elever med synshemming møter flere tilgjengelighetsbarrierer som kan hemme læringen deres. De identifiserte barrierene er relatert til navigasjonsproblemer både i innholdet og de sekundære verktøyene, brukervennlighetsbarrierer, inkompatibilitet med hjelpeteknologier, manglende alternativ tekst og utilgjengelige videoer, og mangel på digitale ferdigheter. Disse resultatene indikerer at dagens digitale læremidler ikke er universelt utformet. Dette betyr at elever med synshemming vil bruke mer tid og energi på å navigere og betjene disse ressursene i stedet for på faktisk læring. Det er derfor behov for å rette større oppmerksomhet mot å forstå behovet til disse elevene for å kunne gjøre digitalt læremateriell tilgjengelig.

Contents

Preface i

Abstract ii

Sammendrag iii

List of Acronyms vii

1 Introduction 1

2 Background 2

2.1 Digital teaching materials 2

2.1.1 Adapted digital teaching materials 7

2.2 Disability 7

2.2.1 Disability models 7

2.2.2 Visual impairment and Use of ICT 10

2.2.3 Human rights, legislation, and standards 14

2.3 Theoretical framework 17

2.3.1 Universal design 17

2.3.2 Universal design for learning 24

2.3.3 Cognitive models 26

2.4 Related work 29

3 Methodology **34**

3.1 Methods 34

3.2 Data collection 35

3.2.1 Participants 35

3.2.2 Interview 36

3.2.3 Online questionnaire 36

3.3 Data analysis 37

3.4 Ethical considerations 38

4 Results 41
4.1 Results from the interviews . . . 41
4.1.1 Types of Digital teaching Materials (DTMs) . . . 41
4.1.2 Navigation . . . 42
4.1.3 Barriers related to images, videos, and secondary resources 44
4.1.4 Usability and task completion . . . 45
4.1.5 Compatibility barriers . . . 45
4.1.6 Digital skills and Training . . . 47
4.2 Questionnaire results . . . 47

5 Discussion 49
5.1 Barriers . . . 49
5.1.1 Navigation . . . 49
5.1.2 Usability . . . 51
5.1.3 Compatibility problem . . . 52
5.1.4 Images and videos . . . 53
5.1.5 Secondary tools . . . 54
5.1.6 Digital skills . . . 55
5.2 Accessibility barriers implications - school and beyond . . . 56
5.3 Limitations . . . 57

6 Conclusion 58
6.1 Future work . . . 59

References 60

A Sikt: Assessment of processing of personal data 75

B Information letter to students (in Norwegian) 78

C Information letter to teachers (in Norwegian) 81

D Interview guide 84

E Online questionnaire 87

List of Figures

2.1 Digital teaching materials model. Source (Gilje et al., 2016; Gilje, 2021). 5
2.2 Digital teaching materials tiers. Source (Marcus-Quinn & Hourigan, 2022). 6
2.3 Disability Gap model. Source (Fuglerud, 2014) 9
2.4 WHO classification of severity of vision impairment. This classification is based on visual acuity. Source (World Health Organization, 2019b) 11
2.5 Refreshable braille 14
2.6 Accessibility pyramid 20
2.7 Levels of accessibility. Source (Guglielman, 2010) 21
2.8 WCAG structure 22
2.9 A comparison between Accessibility and Usability. Source (Foley, 2011) 24
2.10 Overlap between UDL and assistive technology 26
3.11 Taguette - enables coding and highlighting of text 39

List of Acronyms

DTM Digital Teaching Materials

UN United Nations

VI Visual Impairment

CRPD Convention on the Rights of Persons with Disabilities

ICT Information and Communications Technology

WAD Web Accessibility Directive

WHO World Health Organization

AT Assistive Technology

WCAG Web Content Accessibility Guidelines

EAA European Accessibility Act

CUD Center for Universal Design

CAST Center for Applied Special Technology

UD Universal Design

UDL Universal design for learning

FEIDE Federated Identity for education

HCI Human Computer Interaction

ICF International Classification of Functioning, Disability and Health

ICD International Classification of Diseases

1 Introduction

Inclusive education is vital for the achievement of equality and rights of education for people with disability, as enshrined in the United Nations (UN) Convention on the Rights of Persons with Disabilities (CRPD) (United Nations, 2008). United Nations' sustainable goal four aims to "ensure inclusive and equitable quality education," and outcome target 4.5 aims to ensure equal access to education for vulnerable groups, including persons with disability (United Nations, 2015). Digital inclusion strengthens equality by ensuring everyone gets the digital literacy needed for education and employment (Rohatgi et al., 2020). The use of Information and Communications Technology (ICT) in all aspects of education has tremendously increased recently (Nīmante et al., 2022). Research has shown that technology can contribute to inclusion and provides new opportunities for participation for everyone (Foley & Ferri, 2012; Warschauer, 2004). However, technology can also lead to exclusion if the solutions used are not universally designed (Seifert et al., 2021).

According to the Norwegian government's action plan 2021-2025, universal design is viewed as an innovative strategy to plan and shape society and increase equality and inclusion (Kulturdepartementet, 2021). The action plan states also that the education act committee has proposed a change from adapted learning to universal education and individually tailored education. This requires that Digital Teaching Materials (DTM) (from here called DTM) are universally designed. Accessibility is necessary for DTMs as students can not comprehend and learn from materials they cannot interact with (M. F. Rice & Ortiz, 2021). As such, accessibility is necessary to ensure that all students have access to the same information and have similar interactions with the content (M. F. Rice & Ortiz, 2021). Despite the importance of accessibility, recent reports indicate that most DTMs in Norway do not meet the current legal requirements (Oslo Economics, 2022) and have shortcomings that could create barriers for students with disabilities, particularly those using assistive technologies (Funka, 2021).

In light of the above findings, this thesis attempts to investigate the accessibility of DTMs by identifying the barriers faced by students with Visual Impairment (VI) when using these resources. Furthermore, the study seeks to understand these barriers from the perspectives of the students with VI and teachers of students with VI.

The study will seek to answer this central research question:
What accessibility barriers do high school students with visual impairment face in digital teaching materials?
The following questions were formulated to guide the data collection process:

- What challenges do students face when using digital teaching materials from publishers?
- What are the barriers in relation to digital teaching materials developed by teachers and other supplementary digital resources and tools used for learning?

The rest of this thesis is structured as follows. First, I give background information, definitions, theoretical underpinnings of the study, and an overview of related work in section 2. Then, in the section 3, I discuss the methodological approach and ethical considerations. In section 4, I present the findings, discuss the findings in section 5, and lastly, in section 6, I give the conclusion and recommendations for future research.

2 Background

In section 2.1, I will discuss different definitions of DTMs, and briefly introduce disability and how people with visual impairment interact with ICT in section 2.2. Finally, I will discuss theoretical frameworks and related work in section 2.3 and 2.4.

2.1 Digital teaching materials

There has been a digital transformation in all sectors of society, and education is no exemption. Advanced technology is increasingly used to facilitate learning (Foley & Ferri, 2012). Furthermore, the COVID-19 pandemic has accelerated the increased use of ICT in education (Maatuk et al., 2022; Nimante et al., 2022; Tadesse & Muluye, 2020). This digital transformation has also changed the use of teaching materials (Gilje, 2021). The transformation from print-based to digital formats came with new affordances and restrictions on teaching and learning. In terms of time and space, it made it easy to communicate and access information and learning is no longer constrained to school walls (Berthelsen & Tannert, 2020). Using interactive digital learning materials promotes experiential learning as interactive interfaces and videos enable students to respond and create knowledge (Knight, 2015).

Several terminologies related to DTMs are used in the literature and digital learning materials and digital teaching aids are used interchangeably. For instance, in a report commissioned by the Directorate for the Ministry of Education and Research, the Norwegian term *digitale læremidler* has been translated to digital teaching aids (Ramboll, 2015). A framework developed by the Norwegian Centre for ICT in Education addresses this issue and defines terms such as digital learning resources, digital resources, and digital learning materials (Kelentrić et al., 2017). According to this framework, digital resource is the general term encompassing digital technologies used in education (including computers, software, and interactive boards.), digital learning resources, and digital learning materials. Digital learning resources are information or content created for other reasons but can be used by teachers for learning purposes (Kelentrić et al., 2017). Examples are videos, newspapers, or other web-based content. Concerning DTMs, the definition given in this framework is

"a combination of digital tools, services and content specifically developed for use in schools and subjects. Typical examples include publishers' textbooks in digital format, websites associated with textbooks, animation, films, and learning games created for educational purposes" (Kelentrić et al., 2017).

In a report by the Norwegian Directorate for Administration and ICT(Difi), DTMs and digital resources are viewed as education tools designed for learning that utilize ICT to foster learning. The report also differentiates between DTMs and digital learning platforms, which it views as a system for managing users and organizing e-learning content in a folder-like system (Difi, 2017). Despite these definitions, the report states that the participants had difficulty distinguishing digital products

(DTMs from digital learning platforms) when answering the survey.

The categorization of teaching materials and learning resources was visualized by (Gilje et al., 2016; Gilje, 2021) as shown in figure 2.1. The horizontal axis shows the relationship between semantic (aids that mediate meaningful content) and functional teaching aids (no semantic content but a tool), while the vertical axis represents whether the aid has a built-in didactic purpose or not (Gilje, 2021). The authors also differentiate between primary text, i.e., content originally developed specifically for teaching, and secondary text, i.e., content not originally developed specifically for teaching. Moreover, primary tools, i.e., tools originally developed specifically for teaching, and secondary tools, i.e., tools that were not originally developed specifically for teaching. From this visualization, DTMs can be seen as primary tools (See figure 2.1). The above differentiation between primary and secondary text also corresponds to the definition found in the regulations of the Education Act, which defines teaching aids as "teaching aids mean all printed, non-printed and digital elements that have been developed for use in training. They can be stand-alone or form part of a whole, and alone or together cover competence targets in the Curriculum Agency for Knowledge Promotion." (Kunnskapsdepartementet, 2010).

The definition currently used in the regulation on universal design of ICT solutions is more focused on online-based tools. Paragraph §3e of the universal design regulation defines digital teaching materials as "online tools that can be used in educational work, and which have been developed with the intention of supporting learning activities" (loosely translated from Norwegian) (Forskrift, 2019). This definition does not state whether DTMs are apps, learning platforms, or websites. However, this implies that regulation only applies to digital teaching materials that require internet access. This definition is problematic and creates a degree of uncertainty around the terminology. Due to the uncertainty, a project initiated by the association of parents with blind children to highlight the current situation recommended broadening the definition of digital teaching materials to include resources that do not require an internet connection (Foreldre til blinde barn, 2022).

DTMs and digital learning resources are considered artifacts that aid learning and gaining knowledge in a specified subject. Petersen and Ulk (2010) argues that

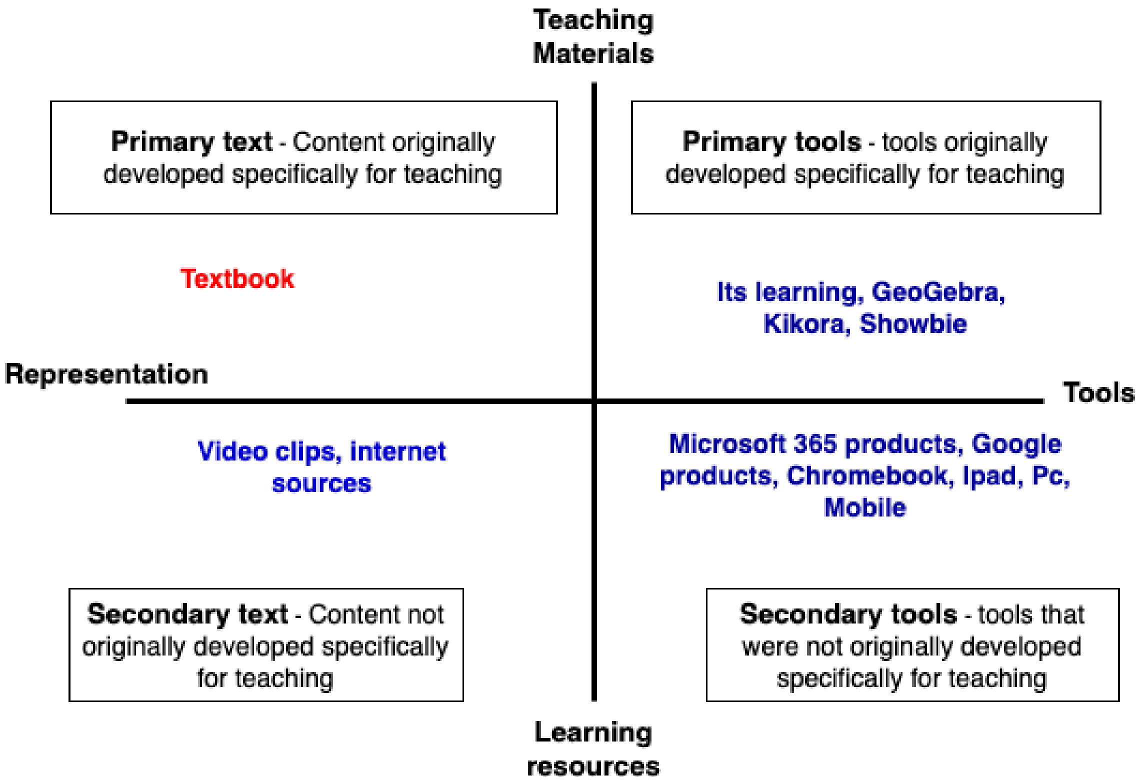

Figure 2.1: Digital teaching materials model. Source (Gilje et al., 2016; Gilje, 2021).

DTMs are generally viewed as tools or didactic learning programs. The first view states that DTMs are tools, digital products, and formats - the second view sees it more as a product or learning process within which learning takes place and a medium for learning.

Marcus-Quinn and Hourigan (2022) observed that during the COVID-19 pandemic, three content-producing cultures emerged. The top tier is the DTMs that have been produced by education companies, where a fee is required to access them, and accessibility is built into the resources. The second tier is the resource produced by teachers. The authors observed that these resources have challenges associated with them in terms of quality and how they are produced. The last tier is the resources that teachers source online. The authors argue that accessibility of the materials in all these three tiers varies, and it will continue to be so until a set of standards for such digital content is developed.

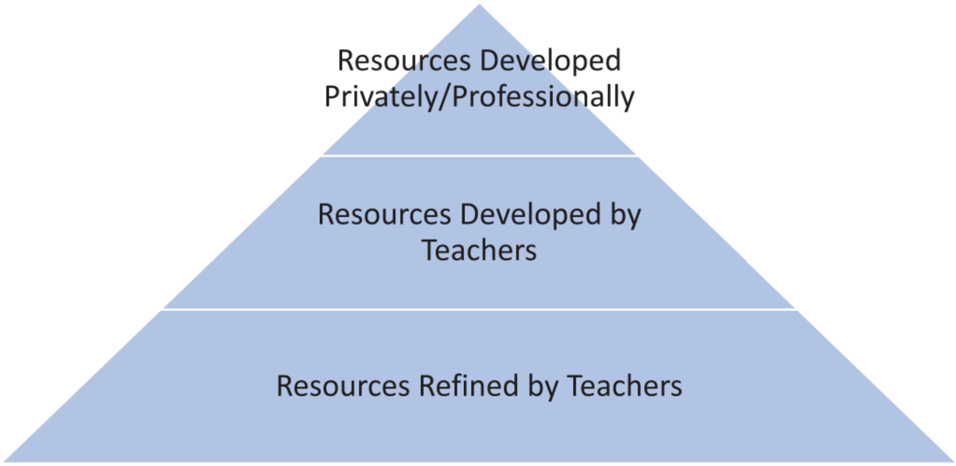

Figure 2.2: Digital teaching materials tiers. Source (Marcus-Quinn & Hourigan, 2022).

Transformation of DTMs is required so that they can fully utilize the affordances of digital technologies. However, reducing the barriers created by this transformation is not a trivial task (Kieserling & Melle, 2019). Further, in the definition given by the regulation on the universal design of ICT, it is clear that many resources that are developed by teachers and which might not require internet access are not covered by the definition. This raises questions regarding the accessibility of this content and whether they comply with the accessibility requirements. Another important issue is whether the teachers who develop or refine learning materials are obliged to develop accessible materials or whether they do it as best practice.

In order to get a broader understanding of accessibility barriers faced by students with VI in DTMs, the definition by Kelentrić et al. (2017) covers all the different tiers of digital learning materials referred by Marcus-Quinn and Hourigan (2022) (see figure 2.2). However, it emphasizes tools and products that are specifically developed for educational purposes, thus leaving out secondary tools(see figure 2.1). As such, in this thesis, DTM will be used in its broadest sense to refer to all forms of digital tools and resources used for learning.

2.1.1 Adapted digital teaching materials

In Norway, Statped [1] - a directorate under the Ministry of Education that offers special education services. Statped develops, adapts, and produces teaching materials for sign language, blind, and children with low vision children (from here called Statped books) (Statped, 2022). The Norwegian Library of Talking Books and Braille (NLB)[2] produces adapted learning materials for higher education.

2.2 Disability

This thesis does not aim to present and discuss an in-depth history and different views on disability. However, some discussions on disability are necessary to understand the contextual background of the thesis. Therefore, in this section, I will present a general overview of disability and the disability model, visual impairment, and a brief discussion on how persons with VI interact with ICT. According to the world health organization, 15 % of the population lives with some form of disability, and it is estimated that this number will double to 1.5 billion people by 2050 (World Health Organization, 2011). It is also estimated that at least 2.2 billion people live with vision impairment or are blind, and half of these cases could have been prevented or "yet to be treated" (Barreto & Hollier, 2019). As of 2018, it is estimated that 320,00 people live with visual impairment in Norway[3].

2.2.1 Disability models

The perceptions of disability have changed over time. M. E. Begnum (2020) listed over 15 models used to understand disability. The author categorized these models into four broad approaches: disability as an act of God, illness or victimhood, disability as multifaceted, disability as contextual, and disability as embodied experience. Initially, an outdated view that was held by many was that disability was a punishment, karma, moral fault, or illness (M. E. Begnum, 2020; Shakespeare et al.,

[1] https://www.statped.no
[2] https://www.nlb.no/eng
[3] https://www.blindeforbundet.no/oyehelse-og-synshemninger

2006). Post-enlightenment views of disability focused on medical deficit (Shakespeare et al., 2006). Commenting on disability J. Grue (2011), argues that the medical model is an “ideological framework that reduces every aspect of disability to bodily impairment, prescribes only medical treatment and normalization as appropriate interventions, and denies agency to disabled people while reserving power for medical professionals” (J. Grue, 2011). This perspective reduces disability to individual bodily deficits that need treatment and rehabilitation. One of the problems with this model is that it gives medical professionals the right to decide on what is best for an individual with a disability, denying the individual possibility to do anything about their impairment.

The social model, which became popular in the 70s and 80s, has been influential in linking civil rights movements and political activism and advocating for the equality and rights of persons with disability (Owens, 2015). This model deviates from the medical model, highlighting the interaction between persons with disability and society. As such, disability is a socially constructed phenomenon, and disability is a complex collection of conditions that are socially constructed (M. E. Begnum, 2020). Therefore, disability is created in society through a lack of awareness and understanding of the needs of disabled people. Compared to the medical model, this model changed the perspective from individual deficit to social barriers that discriminate; as such, it is not the individual that is wrong but the design (M. E. Begnum, 2020). Examples of disabling design are - if a person with a visual impairment receives emails in inaccessible applications, similar to if they receive mail in regular print instead of braille print. Therefore, people’s perceptions are changed by designing and building a more inclusive society. This model’s focus on society has been instrumental in the human rights movements of the 1970 and 1980s and the subsequent laws that guaranteed the rights of people with disability. Further, this model has influenced the World Health Organization (WHO) International Classification of Functioning, Disability and Health (ICF) biopsychosocial model, which takes into consideration the interaction between an individual’s health conditions and the contextual factors (World Health Organization and others, 2013). One important perspective that ICF acknowledges is that disability is a continuum and a universal experience that can be permanent, temporary, or continuous experience

(World Health Organization and others, 2013).

Another model that has become popular in Scandinavia is the relation or Nordic model or the gap model (M. E. Begnum, 2020). This model is similar to the social model as it also focuses on the relationship between people and the environment. Disability, in this case, arises where there is a “mismatch between the person’s capabilities and the functional demands of the environment” (Tøssebro, 2004). This mismatch creates a gap between individual abilities and societal or environmental expectations. This model also differentiates between physical impairment, i.e., the loss of body parts, damage or abnormality of one’s body function, and disability, which is a result of an individual’s encounter with an environment that does not accommodate the needs of the individual’s impairment (Edvardsen & Gjærum, 2021). Figure 2.3 illustrates the disability gap model which Fuglerud (2014) drew based on the white paper on Dismantling of Disabling Barriers (Sosialdepartementet, 2003). Fuglerud (2014) argues that barriers are “the physical and social conditions that limit participation in the community .” In this thesis, barriers are viewed as the features of DTMs and tools that not only limit their accessibility to students with VI but also limit their participation in learning.

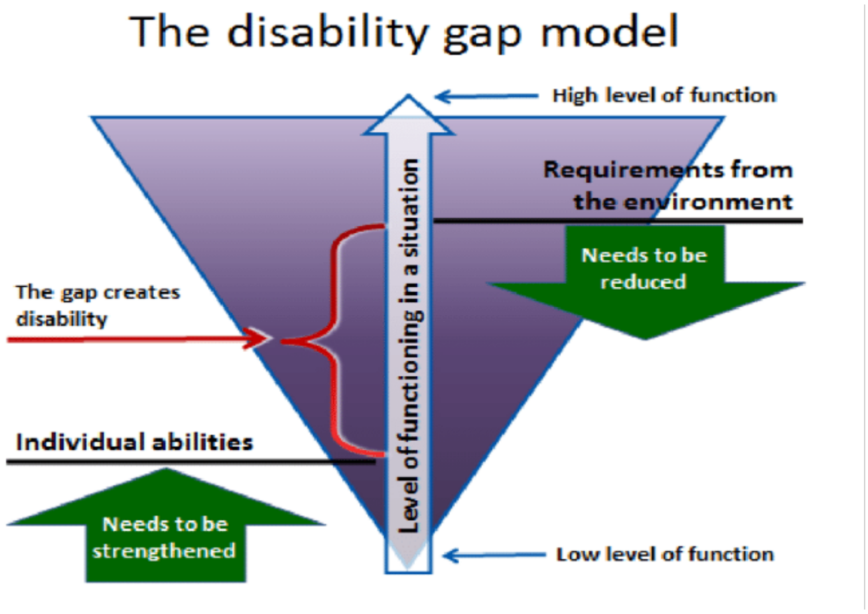

Figure 2.3: Disability Gap model. Source (Fuglerud, 2014)

2.2.2 Visual impairment and Use of ICT

Visual impairment

Visual impairment is an umbrella term that describes the loss of vision across a wide spectrum. In literature, numerous terms are interchangeably used to describe visual impairment, including visually handicapped, visually disabled, blind, low vision, sightless, and non-sighted (Andreas Kleynhans & Fourie, 2014; Bolt, 2005). The use of these terms has changed as the perceptions of disability changed, as described in section 2.2.1. Like many other impairments, VI impairment was interpreted based on the models of disability that emphasized individual impairment. However, this has changed as the focus turned to society that is disabling, especially from the social disability model (Bolt, 2005). According to Bolt (2005), the appropriate and respectful terms are “visual impairment and people with impaired vision.” In this thesis, I will adopt visual impairment, and students with visual impairment will be used when referring to participants in this study.

According to the International Classification of Diseases (ICD), vision impairment is classified based on visual acuity (World Health Organization, 2019a). Visual acuity refers “to the capability of the eye to resolve two point sources of light that may be located close to each other” (Barreto & Hollier, 2019). The severity of visual impairment is categorized into two groups: distance vision impairment and near vision impairment[4]. Distance vision impairment includes mild vision, moderate vision, and severe and blindness. Distance visual acuity assesses a person’s ability to recognize details on a vision chart from a fixed distance and is written as fraction (World Health Organization, 2019b). For example, 6/12 means an individual can read a letter on a vision chart at 6 meters, while a person with normal vision will read it at 12 meters (see figure 2.4). Although visual acuity-based severity measure is one of the most used in population-based surveys, other vision features such as field of vision, contrast sensitivity and colour vision are also measured in a clinical assessment (World Health Organization, 2019a).

While some people are born blind, others develop visual impairment through conditions that cause a progressive decline in vision and, in some cases, ren-

[4]https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment

der one completely blind. Some eye conditions that cause vision impairment include cataracts, corneal opacity, diabetic retinopathy, refractive error, glaucoma, trachoma, and age-related vision loss (World Health Organization, 2019b).

Category	Visual acuity in the better eye	
	Worse than:	Equal to or better than:
Mild vision impairment	6/12	6/18
Moderate vision impairment	6/18	6/60
Severe vision impairment	6/60	3/60
Blindness	3/60	
Near vision impairment	N6 or M 0.8 at 40cm	

Figure 2.4: WHO classification of severity of vision impairment. This classification is based on visual acuity. Source (World Health Organization, 2019b)

Visual Impairment and Use of ICT

According to Nicolau and Montague (2019), multiple approaches to interacting with computers have been proposed since the inception of research in human-computer interaction. Assistive Technology (AT) is an umbrella term that describes all software and hardware that help people with disabilities accomplish tasks they could not do and foster independent living (Nicolau & Montague, 2019). As Hersh and Johnson (2008) noted, AT helps "to overcome the gap between what a disabled person wants to do and what the existing social infrastructure allows them to do." Mostly AT uses a sensory substitution approach where "input from one sensory modality can be augmented with input from another sensory modality" (Choi et al., 2019). Several approaches have been developed to facilitate blind users' interaction with computers, and they mainly focus on other sensory channels (Barreto &

Hollier, 2019). These are mainly tactile and auditory channels. Some ATs currently used for non-visual web browsing are screen readers, speech recognition, alternative keyboards, braille displays, and refreshable braille (See figure 2.5) (Lazar et al., 2007). Screen readers are software applications that read out loud what is displayed on the screen (Lazar et al., 2007). It utilizes text-to-speech technology to read the text displayed to the user serially and also aids in navigation using a keyboard or touch screen (Ramakrishnan et al., 2017). Screen readers also offer shortcuts that are navigation commands that enable interaction with a computer without a mouse (Bigham et al., 2008). For the touch screen, the elements that the finger touches are announced, the double tab for selection, and swiping fingers across the screen to scroll content on the screen. With relation to the web, screen readers generally have web mode that enables them to navigate based on the structure of the Document Object Model (DOM) and not necessarily on the visual layout (Nicolau & Montague, 2019) and this direct interaction with DOM also improves access to dynamic content (Bigham et al., 2008).

There are several screen reader options depending on the operating system they support and their cost. JAWS and Windows-Eye are commercial products that support Windows operating systems, while NVDA is a free alternative for Windows. Apple products - computers (OSX) and iOS use VoiceOver. ChromeVox is the alternative for Chrome and ChromeOS. Android also has a screen reader called TalkBack. Because most screen readers are commercial or platform-dependent and require installations, Bigham et al. (2008) developed an on-the-go screen reader called WebAnywhere that could be used on any platform, as the name suggests. It runs on any computer or terminal that produces sound.

People with VI navigate through the content of the user interface, primarily using the keyboard and screen reader in a serialized manner. This serialized navigation creates several challenges for people with VI according to Buzzi et al., 2012. First, the serialization of content creates an overload of vocal information. Secondly, the user has no overview of the whole interface, third screen readers can mix content and structure and lastly, screen readers can announce content incorrectly depending on how the HTML is coded. Additionally, screen readers only read text content. Therefore, all visual elements such as images, graphs, and other illustrations must be coded correctly in the HTML using the alt tag (Barreto & Hollier, 2019). Regarding braille displays, some limitations identified in the literature are that the displays have limited character, usually a single line of 20 to 40 characters (Leonardis et al., 2018).

For individuals with low vision impairment, techniques used to help them interact with the interface are generally related to the magnification of graphical elements (Barreto & Hollier, 2019). Barreto and Hollier (2019) argues that magnification reduces the functional demands on the person's visual acuity. However, there is a trade-off, as magnification reduces the possibility of seeing the whole interface. Thus, the user has to interact with elements on the screen sequentially, increasing the cognitive load (Barreto & Hollier, 2019).

Traditionally, learners are viewed as passive recipients of information transmitted through the textbook (Knight, 2015). However, this has changed with the advent of Web 2.0 technologies, facilitating two-way collaborative communication. Furthermore, digital technologies in learning are used either as practical aids, in the form of content, or as a means of developing new learning through digital production (Berthelsen & Tannert, 2020). Although this is a welcomed development, the pervasiveness of graphic user interface in present-day systems and websites places significant demand on the visual channel of the user's perceptual system that is beyond the capabilities of many web users (Harper & Yesilada, 2019). Visual presentations, content spatial location, content pattern, and presentational similarity help sighted users navigate and interact with content. However, these visual cues presented on the interface cause usability problems if they are not made accessible (Harper et al., 2009; Ramakrishnan et al., 2017). As such, Alonso et al. (2008) argues that designing an interface that considers the needs of blind people demands some specific usability requirements. These include task adequacy - in that task should not involve eye-hand coordination or controlling several visual items because blind users interact with the interface serially. Also, the presentation of information should take into account that blind users use other senses to perceive information, and input methodology should support keyboard-only access or its equivalent, like speech input and refreshable braille display.

Technological artifacts and their design can embody the power that can limit the opportunities presented to people (Winner, 1980). One of the poignant examples of the power of technological artifacts is Robert Moses' design of low-hanging bridges in New York to achieve a certain social effect, i.e., to limit access to a public beach for people with low incomes and people of color who used public buses as the buses they use could not go under the bridges due to the height of the bridges (Winner, 1980). Similarly, the adoption of technology in learning that does not consider the needs of all students can easily disenfranchise students with visual disabilities and limit their possibility to actively participate in learning and feel included and supported by the technology used at school. In the following section, I will discuss legislation that has been put in place in different countries and standards that have been developed to ensure that people with VI are not disenfranchised.

Figure 2.5: Refreshable braille

2.2.3 Human rights, legislation, and standards

The Universal Declaration of Human Rights by the United Nations in 1948 was a key landmark in recognizing that all people have some political, civil, social, and economic rights despite individual differences (Rioux & Carbert, 2003). Almost 30 years later, the United Nations Declaration on the Rights of Disabled Persons specifically focused on disabled people was passed in 1975 (United Nations, 1975).

However, the most consequential is the United Nations Convention on the Rights of Persons with Disabilities (CRPD) of 2008 (United Nations, 2008). CRPD currently has 164 signatories and 184 ratification/accessions [5]. Compared to the United Nations Declaration on the Rights of Disabled Persons, CRPD is a binding convention that requires member states that have ratified it to ensure that they protect and promote the rights of people with disability. For this master thesis, article 9 on accessibility and Article 24 on education are relevant. Article 9 emphasizes that member states should ensure that people with disability get access to ICT and the Internet, while Article 24 advocates for inclusive education at all levels. Accessibility is pivotal for human rights as it is considered a precondition for one to enjoy other rights such as education, as without it, they are unachievable (Lawson, 2017).

As Rioux and Carbert (2003) noted, although human rights is an international concern, the legislation and practice happen locally. In the United States, Section 504 and the rehabilitation act of 1973, and the Americans with Disability Act of 1990 are some of the human rights laws that had a significant impact on the rights of people with disability. This legislation also strengthened the development of universal design as they required that needs of people with disability are taken into consideration in the design of products and environments (Ostroff, 2011; Pisha & Coyne, 2001).

In Norway, Anti- Discrimination and Accessibility Act prohibits any form of discrimination. Further, there is a persistent political view that the universal design of ICT will facilitate inclusive Norway (M. E. N. Begnum, 2016) as indicated by the governments action plan: Sustainability and equal opportunities – a universally designed Norway (2021–2025) (Kulturdepartementet, 2021). The universal design of ICT was incorporated into the Anti-Discrimination and Accessibility Act prohibiting discrimination on the basis of disability in 2008 (amended in 2013 to Equality and Anti-Discrimination Act)[6]. This act required that all new and public websites had to be accessible by 2018 and 2021, respectively. On 1 February 2023, the Web Content Accessibility Guidelines (WCAG) 2.1 standard became part of Norwegian law;

[5]https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html

[6]https://lovdata.no/dokument/NLE/lov/2017-06-16-51

thus, all public websites must conform to this requirement (WCAG will be discussed in detail in section 2.3.1). In Norway, the Authority for Universal Design of ICT[7] is the authority that is tasked with ensuring that websites and applications conform to the regulations on the Universal Design of ICT. However, the Directorate of Digitization is the supervisory authority in the area of universal design of ICT. Recently several cases have been reported in the media where the authority has issued daily fines to institutions whose websites have failed to conform with the WCAG requirements. A case reported by Aftenposten[8] indicates that Oslo municipality was fined because the DTMs used in one of the schools were not accessible.

Several efforts have also been made at the European level. The Web Accessibility Directive (WAD) (EU Commission, 2016) is a European Union initiative to build an inclusive society where all can participate digital economy and society. This directive has three main requirements: web accessibility statements for each website and app, a feedback mechanism, and regular monitoring. EN 301 549 standard is another effort that is aimed at harmonizing accessibility standards (ETSI, 2019). The first version of EN 301 549 referred to WCAG 2.0 while the subsequent versions have incorporated WCAG 2.1[9]. The introduction of WAD into Norwegian means that EN301 549 and WCAG2.1 are a reference point for all technical requirements and evaluations [10]. Some of the sections in EN301 549 relevant to visual impairment and this thesis include capital four on functional performance (support for ICT usage without vision), chapter 9 on the web, and chapter 10 on non-web documents. Because Chapter 10 covers non-web documents, this will like to impact the requirements for the accessibility of DTMs. Currently, the definition by Forskrift (2019) requires that DTMs have an internet connection for the law to cover them. Students will hugely benefit from this as using accessible e-books will improve their participation in learning (Marcus-Quinn, 2022). Besides the WAD initiative, the European Accessibility Act (EAA) is another initiative that is aimed

[7]https://www.uutilsynet.no/english/authoritys-tasks/904

[8]https://www.aftenposten.no/oslo/i/8J5joG/petter-15-er-blind-men-faar-ikke-verktoeyene-han-trenger-paa-skolen-en-systemsvikt

[9]https://digital-strategy.ec.europa.eu/en/policies/web-accessibility-directive-standards-and-harmonisation

[10]https://samarbeid.digdir.no/digital-postkasse/wad-viktige-standardar-pa-norsk/901

at reducing barriers caused by different rules among the member state and thus facilitating trading and better accessible products and services across the region (CRD, 2019). EAA is expected to be part of Norwegian law in 2025[11].

2.3 Theoretical framework

In this section, I will discuss the theoretical framework that underpins this thesis. First, I will discuss universal design and other concepts such as accessibility and usability. Then I will discuss universal design for learning and how it provides equal opportunities to all students. Lastly, I will discuss how cognitive models have been used to understand the design of user interfaces.

2.3.1 Universal design

As the perception of disability changes over time, and the interaction between environment and individual becomes central, approaches to accommodate the needs of different groups also become prominent to the delight of the people with disability (Ostroff, 2011). The emergence of universal design was driven by governments' efforts through legislation and market response to a change in demographics (Ostroff, 2011). The paradigm change happened in different parts of the world, and as such different terminologies are used to describe it; however, the similarities of these terminologies are more prominent as they "transcend national laws, policies, and practices" (Ostroff, 2011). Terminologies such as universal design, inclusive design, barrier-free design, and design for all emerged and are used interchangeably in the literature (M. E. Begnum, 2020; Nygaard, 2017; Ostroff, 2011; Persson et al., 2015).

Universal Design (UD) is associated with Ronald Mace and a group he led at the Center for Universal Design (CUD) at North Carolina State University. They defined Universal design as "the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" (Story, 2001).

[11] https://www.uutilsynet.no/tilgjengelighetsdirektivet-eaa/eus-tilgjengelighetsdirektiv-eaa/268

To further explain the concept of universal design and guide the development of usable products and environment, CUD developed seven principles(Story, 2001). These principles are:

- Principle 1: Equitable Use
- Principle 2: Flexibility in Use
- Principle 3: Simple and Intuitive Use
- Principle 4: Perceptible Information
- Principle 5: Tolerance for Error
- Principle 6: Low Physical Effort
- Principle 7: Size and Space for Approach and Use

Another definition that is very close to the definition by CUD is the one in the UN Convention on the Rights of Persons with Disabilities (CRPD) in Article 2. It defines UD as:

”the design of products, environments, programs and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. “Universal design” shall not exclude assistive devices for particular groups of persons with disabilities where this is needed.”

Commenting on these two definitions Fuglerud (2014) argues that the inclusion of assistive devices in the definition by CRPD is to reduce the gap that arises due to the mismatch between a person’s ability and the demands from the society or the environment (see figure 2.3). The author further argues that the definitions emphasize equitable solutions and usability for everyone rather than special solutions. The inclusion of AT also highlights the understanding that UD is not a single solution that solves all issues for all, and it must be considered in combination with solutions developed for specific groups (see figure 2.6)(Nygaard, 2017).

With regards to the applicability of seven universal design principles in ICT, Fuglerud (2014) discusses in her Ph.D. dissertation that UD principles were developed in the context of the physical environment. The author argues, however, that some principles apply to ICT. These are Principle 2: Flexibility in Use, Principle 3: Simple and Intuitive Use, and Principle 4: Perceptible Information. Because ICT is information and communication-intensive, it causes high cognitive load; ICT solutions must be easy to comprehend and interpret (principle 3) and offer flexibility (principle 2) in how they present content to aid perception (principle 4).

Accessibility and usability are two terminologies that are used together when discussing UD. Next, I will explain how these two relate to each other and their applicability in the context of this thesis.

Accessibility

Accessibility is linked to UD (Halbach & Fuglerud, 2016), and it is considered as a “precondition” for universal design (M. E. Begnum, 2020). However, UD is broader and focuses on equal opportunities for all users to participate in society, while accessibility is considered pragmatic as it can be achieved through adaptation or specific solutions among other approaches (Fuglerud, 2014). The accessibility pyramid shown in the figure also reflects Goldsmith, 2001 ’s view of the bottom-up approach that stipulates that a design should consider the needs of everyone, but it can also be adapted to the needs of people with disability - this is regarded as a change from designing for people with disabilities as a distinct user group ((Goldsmith, 2001) as cited in (Ostroff, 2011).

Historically, making products and services accessible was about adapting products developed for one audience to another audience (Powlik & Karshmer, 2002). Web accessibility concerns itself with making the web more accessible to more people (Henry, 2006). Several definitions of accessibility have been proposed in the literature. In an effort to develop a unified definition for web accessibility Petrie et al. (2015) analyzed 50 definitions drawn from books, articles, standards, and guidelines. The unified definition derived from this analysis describes web accessibility as “all people, particularly disabled and older people, can use websites in a range of contexts of use, including mainstream and assistive technologies; to achieve this, websites need to be designed and developed to support usability across these contexts” (Petrie et al., 2015).

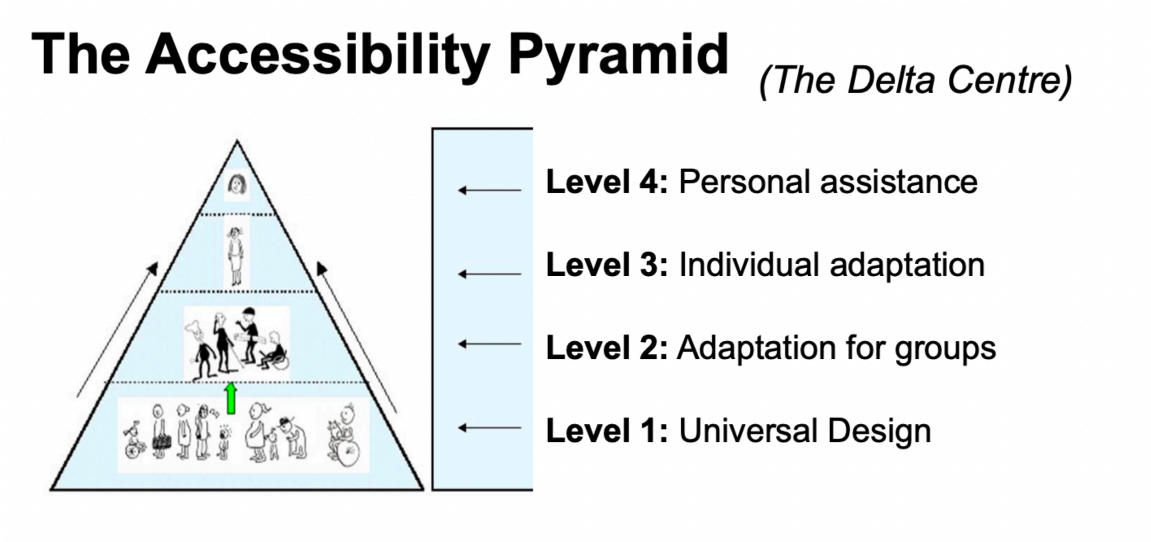

Figure 2.6: Accessibility pyramid

Another common definition used in literature is from International Organization for Standardization (ISO) (ISO, 2011), which defines it as "extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use."

Concerning DTMs M. F. Rice and Ortiz (2021) argues that "digital instructional materials are accessible when they adhere to applicable legal standards, and users can open, view, and interact with digital material". According to Guglielman (2010), accessibility in e-learning is viewed from two perspectives: Technical accessibility, which entails access to e-learning platforms (signing in and navigation), and pedagogical accessibility, which focuses on access to contents, tools for interactions and collaboration, and learning activities. Figure 2.7 indicates that the technical aspect is low level while the pedagogical is high level of accessibility.

With regards to the web, World Wide Web Consortium (W3C) launched the Web Content Accessibility Guidelines (WCAG) that has become *de facto* standard for web accessibility (Lewthwaite, 2014). As a result, many countries, including Norway, have incorporated it into their laws.

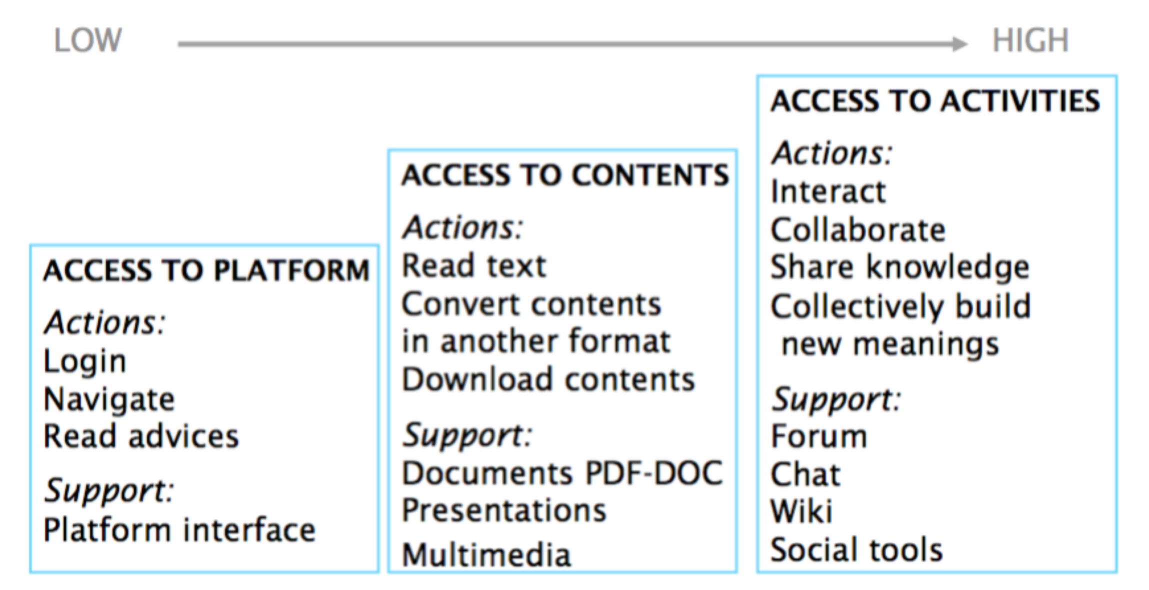

Figure 2.7: Levels of accessibility. Source (Guglielman, 2010)

Web Content Accessibility Guidelines (WCAG)

Although web accessibility first appeared in 1995 (Story, 2001), guidelines to promote it was published by the Access Board (an independent U.S government agency) and were first included in the U.S Rehabilitation Act amendments in 1998, and these guidelines were adopted by W3C a year later (Shneiderman & Plaisant, 2005). Since then, the guidelines have gone through several iterations, with the latest being the 2.2 version. These guidelines were developed to help developers with ways to make the web accessible.

These principles are:

- **Perceivable**: It is about providing alternative text for non-text content and providing captions, presenting content in different ways that are also supported by AT while ensuring that it is not losing meaning and making it easier to see and hear content.

- **Operable**: Making it possible to use the content keyboard only, giving users enough time and not using content that might cause seizures. Aid users to navigate and find content quickly.

- **Understandable**: Make it easy to read and understand text, ensure that content appears and operates in predictable ways, and help users from making and correcting mistakes.

- **Robust**: Compatibility with user agents such as browsers, mobile, and AT both current future.

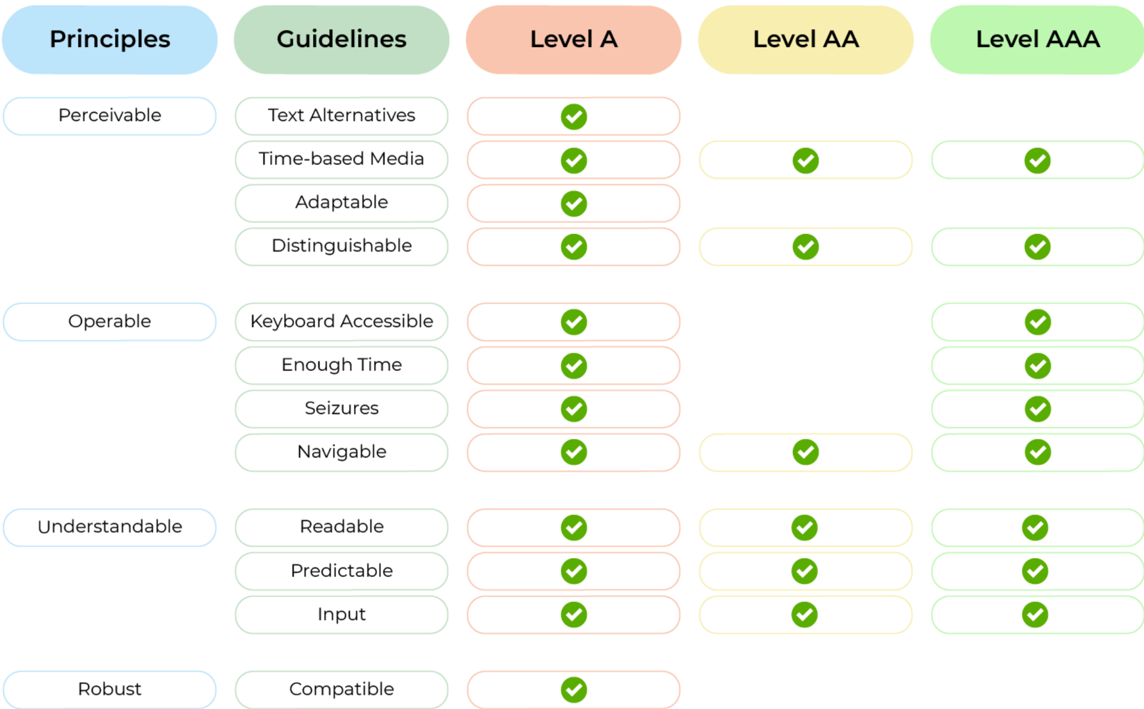

Figure 2.8: WCAG structure

All four principles have guidelines and testable criteria with corresponding conformance levels (A, AA, AAA with the latter being the highest). Figure 2.8 illustrates the WCAG structure. Automatic testing, manual testing, user testing, and hybrid testing are some of the methods used to evaluate the accessibility of a website. Because manual testing is difficult and cumbersome (Abascal et al., 2019), several automatic testing tools have been developed, and studies such as (Alsaeedi, 2020; Frazão & Duarte, 2020; Ismailova & Inal, 2022; Vigo et al., 2013) have looked into their performance. Critics of automatic testing argue that accessibility tests based on this method simplify the universal design, do not take into consideration the experience of people with disability, and in general, fail to consider the complexity of disability (M. E. Begnum, 2020; Lewthwaite, 2014). Further, it is argued that designers' attention is taken away from users as the focus is on accessibility tools, standards, guidelines, and compliance (Seale et al., 2006; Takagi et al., 2003).

Usability

Another terminology that is commonly used with accessibility is usability. According to ISO, usability is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" (ISO, 1998).

In this definition, three keywords are worth highlighting: effectiveness, efficiency, and satisfaction. Effectiveness is achieved if a user performs a task and accomplishes the goal. It is an important criterion that determines efficiency and satisfaction (Leporini & Paternò, 2004). Nielsen (2012) argues that usability is a "quality attribute" that can be defined by five components. These are learnability, efficiency, memorability, errors (number of errors, severity, and how quickly a user can recover), and satisfaction.

Usability is aimed at making the web user experience more efficient and satisfying. Technical accessibility is a precondition for usability; however, if a website passes all technical evaluation and conform to different guidelines for accessibility, it can still be difficult for people to accomplish the task they wanted to do (Leporini & Paternò, 2004). Therefore, it is important to note also that technological artifacts should not be evaluated on whether they are in use but on how well they work for the people who need them (Powlik & Karshmer, 2002). Further, to bridge the gap between accessibility and usability, it is essential to not only base tests on technical guidelines but also to understand how people with impairment use products and how those products work with their assistive technologies (Theofanos & Redish, 2003). Figure 2.9 summarises the relationship between accessibility and usability (Foley, 2011).

The discussion from this section indicates that the term Universal design em-

Usability	Accessibility
Broadest Audience	
“Look & Feel”	Validation Tools
Efficiency of Use	Standards
“User-friendly”	Access to Content
User-based Design	Assistive Technology Users with Disabilities
Subjective Satisfaction	Legal Requirements
Error Frequency & Severity	

Figure 2.9: A comparison between Accessibility and Usability. Source (Foley, 2011)

bodies several concepts that are interdependent. Although UD is about making products and the environment usable by all people, it can only be achieved if the products are accessible. However, technical accessibility alone can not guarantee usability. As such, products have to be both accessible and usable for them to benefit all people. Like universal design that acknowledges there is ”one population, comprised of individuals representing diverse characteristics and abilities” (Iwarsson & Ståhl, 2003), publishers, designers, and other producers of DTMs should embrace this diversity in class so that many students can benefit from them.

2.3.2 Universal design for learning

Universal design for learning (UDL) was inspired by the improvement in accessibility of the physical environment after the introduction of universal design principles. The principles of UDL were developed at the Center for Applied Special Technology (CAST) after the Individuals with Disabilities Education Act was reauthorized in 1997 in the United States as the concerns about access to the curriculum were raised (Edyburn, 2005). The framework enables instructors to design educational curricula that give all individuals equal opportunities to learn despite their disabilities and break the “one-size-fits-all” (Edyburn, 2005) by offering flexibility in the presentation of instructional materials, response, and engagement (Courey et al., 2013). The principles of UDL put emphasis on three aspects of pedagogy: Multiple means of representation of information (enable various ways of acquiring knowledge), multiple means of expression of knowledge, and multiple means of engagement in learning (Edyburn, 2005; D. H. Rose et al., 2005). These principles are based on three systems in the neuroscience of learning: a recognition system, a system that tells how to do things, and an effective system that helps decide what is vital and drives motivation for learning (Courey et al., 2013). CAST has developed a framework into a guideline that includes three principles, nine guidelines, and 31 checkpoints (CAST, 2011).

Multiple means of representation is about different ways in which materials are presented to students, such as physical books or digital content. Digital content offers several ways in which students with different abilities interact with it, like interacting with content using text-to-speech or tactile input using refreshable braille. Offering only physical books will not offer such options for students. Hence, it is important to consider how the student best perceives information and their diverse learning needs (Kieran & Anderson, 2019). Contemporary technology allows interaction and customization to meet student needs and facilitate multiple modes of expression and engagement (D. Rose, 2000). For example, students can interact and manipulate data dynamically and fathom processes and results. Concerning assessment, D. Rose (2000) argues that UDL application enhances assessment accuracy. However, suppose they are not designed well or presented in formats that are not accessible to students. In that case, this not only limits the assessment accuracy but also reduces students' performance (score) despite their knowledge of the subject in question. The same is true for digital teaching aids, as students will struggle to grasp the content if they struggle with navigating through the tool in which the DTMs is represented.

UDL views barriers students face as an environmental problem such as curriculum, instruction materials, or assessment used (Kieran & Anderson, 2019). This approach strengthens the need to develop solutions that target "limitations in the curriculum rather than limitations in the student" (D. H. Rose et al., 2005). This view is similar to the perception of disability fronted by the disability gap model discussed earlier. The barriers arise when the teachers and developers of these environmental factors do not consider the students' abilities.

Technology plays a vital role in the implementation of UDL and can be used in cohorts with AT to reduce barriers faced by students with disabilities. UDL and

AT technologies can be viewed as two interventions that reduce barriers. UDL reduces barriers for everyone, while AT reduces barriers for individuals with disabilities. Figure 2.10 illustrates this relationship and overlaps these two approaches. Digital teaching materials offer flexibility that is not possible with traditional print formats. For example, the multimodal nature of digital materials supports principle 1 on multiple forms of representing information e.g., text-to-speech features and text descriptions and captions of media for students who are blind. Although digital teaching materials offer many advantages, their success hinges on their design and compatibility with assistive technologies.

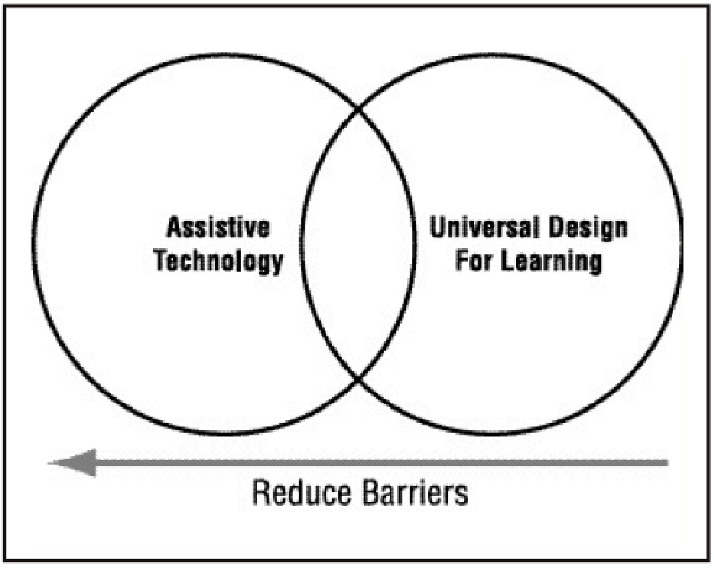

Figure 2.10: Overlap between UDL and assistive technology

2.3.3 Cognitive models

Cognitive models have been used to evaluate human performance. For example, in human-computer interaction, models such as Goals, Operators, Methods, and Selection (GOMS) have been used to evaluate human performance when performing a computer-based task, and the results of the test is used to guide in the design of user interface (Yuan et al., 2020). Further, the cognitive approach is one of the models suggested by Eberts (1994) HCI design. Cognitive approaches borrow theories of psychology to understand human brain cognitive processes. Some of the models based on the cognitive approach are metaphoric design (use of metaphors and analogies to facilitate the learnability and memorability of a user interface), attention and workload models (focusing on a single task at a time by considering the user's attention span and workload, e.g., amount of information passed to sensory systems), and human information processing model (how information is processed on short-term and long term memory) (Cuevas, 2004).

For a successful human-computer interaction, three subsystems are involved: the perceptual system (that receives sensory information from the computer), the motor system (which does the controlling actions), and the cognitive system (which binds the first two first subsystems) ((Card, 1983) as cited in (Barreto & Hollier, 2019)). If the interface objects and actions have a logical structure that is easily anchored to familiar tasks, the structure is relatively stable in human memory (Shneiderman & Plaisant, 2005). For blind users who navigate through the levels of hierarchy within a page, it should not be complicated as they are not able to see where they are on a page and find where to go next (Alonso et al., 2008). Visual elements can cause visually complex pages that, if not made accessible, can cause information overload reducing the possibility of task completion (Harper et al., 2009).

With regards to the design of DTMs and their use in a learning context, it is important to consider cognitive load, mainly intrinsic cognitive load (load caused by the content itself), extraneous cognitive load (the process that increases cognitive load but they do not help with the understanding of content), and germane cognitive load (understanding the content and creating new schemes in the memory) (Kieserling & Melle, 2019). Because of high information density and complexity in the representation (Kieserling & Melle, 2019), it is vital that designers reduce irrelevant content and elements that cause extraneous cognitive load such that learners can use their mental resources on the content that is truly essential for their learning (Kieserling & Melle, 2019; Whitenton, 2013). This is especially important for people with VI, as they must split their cognitive energy between using the screen reader software and the browser and interacting with the content (Theofanos & Redish, 2003). Several strategies have been suggested in the literature on reducing cognitive load. First, avoiding clutter by segmenting content into meaningful chunks of information makes it easier to comprehend (Ramakrishnan et al., 2017). Second, building on the existing mental model, i.e., using designs that are familiar to users, reduces the need for learning structure of the site and offloading tasks by reducing elements that force users to read or remember some text, thus freeing up mental resources that can be used on essential task (Whitenton, 2013).

According to Bundsgaard and Hansen (2013), DTMs should reduce unnecessary cognitive and bodily processes and foster students' cognitive and collaborative processes. Some of the features that can cause unnecessary cognitive load are if the content is inaccessible to students using, e.g., formats that do not support reading caused by poor contrast or the possibility to change the font size or not support assistive technologies used by the student. Moreover, content irrelevant to teaching aims, such as redundant details and images that draw student attention but do not yield any learning benefits, should be reduced.

Digital learning resources "carry a high risk of cognitive overload" due to elements such as images, sounds, navigation, and text (Marcus-Quinn & Hourigan, 2022). Moreover, blind users have to listen to content before they establish if it is essential or establish if the content is what they are looking for, thus "blind users typically go through reams of irrelevant content before they find what they need, thereby suffering from information overload" (Ramakrishnan et al., 2017). Ramakrishnan et al. (2017) argues further that screen readers are oblivious to semantics and boundaries of HTML elements; thus, screen reader has to read them sequentially and navigate at the syntactic level instead of the semantic level, which can lead to mixing up of content from different element thus confusing and disorienting the user. In a learning context, where students have to follow lectures and navigate through a page becomes a challenge if the page and its contents are poorly designed. Therefore, optimal learning materials can only be developed once the needs of different students are established (Marcus-Quinn & Hourigan, 2022).

2.4 Related work

While the use of technology in education is not new and has been studied to a greater extent, the studies on aspects such as identifying barriers faced by students with VI are relatively few. Moreover, fewer studies have studied this topic in the context of the recent European regulations. As such, in this section, I will identify dominating tendencies within the topic of digital learning materials. First, I will explain the different affordances and opportunities digital learning materials offer. I will also discuss findings from some of the recent reports on the awareness of the accessibility of DTMs, and lastly, I will focus on the findings from previous studies on ICT accessibility barriers for VI in general and also in relation to DTMs.

Berthelsen and Tannert (2020) developed a framework that is based on the notion of affordances offered by DTMs and how the affordances are integrated into learning designs. As a point of reference, this study analyzed digital learning materials used in six courses in Danish lower secondary schools (7th-10th grade). The courses were on a digital learning portal that covered all content of national curricula. The process of accessing content has several steps that authors argue are time-consuming, with no apparent learning potential limiting time for other activities. The study also identified several affordances: physical affordances, e.g., actions like typing, clicking, and mouse use. The other is a virtual affordance that includes navigating between web pages through hyperlinks, within-page navigation by scrolling, and view of media such as videos. The study found that only a few virtual affordances are made available within the DTMs, which do not fully utilize contemporary digital technologies' affordances. The authors argue that the current digitalization of learning materials copies the traditional learning designs. Thus, the process is not capitalizing on the inherent affordances offered by digital technologies. This tendency was also observed by (Meier, 2015) as a "merely digitizing the status quo" (Meier, 2015) as cited in (Berthelsen & Tannert, 2020). They argue further that digitalizing learning material is a challenging task and should take a user-oriented and pedagogical approach. The authors also raise another question on the role of teachers in DTMs as they are now reduced to facilitators of learning, giving them limited opportunity to compensate for inadequacies of learning materials.

In a study by Dini et al. (2007) that evaluated the accessibility of educational software, the authors agree that computer offers potential for inclusion, but a need to focus on usability and accessibility still remains because most of them are based on visual communication that can lead to accessibility problem for students with visual impairment. The study further identified that the student must have been trained to use a keyboard and mouse alternative shortcuts to use DTMs effectively.

Jensen and Moe (2014) discussed accessibility and multimodal interaction of DTMs. They identified three vital elements for the accessibility of digital learning materials. These include typography, layout, and navigation. Large fonts are easier to read, with a serif size of 12 being recommended. A clear layout directs the user's attention to the important content in the right order. The authors state that lack of clear order limits readers' understanding of content as the reader needs “to work cognitively to find a meaningful reading path” (Jensen & Moe, 2014). Navigation structure helps users move within the content and know where they are and easily identify where they would like to go. As such, it is important that the content is well organized and easily navigatable with keyboard shortcuts.

In 2010 there were barely enough DTMs produced by publishers (Oslo Economics, 2022). However, a survey by the Center for ICT in Education (IKT-senteret) in 2014 revealed that 6 out of 10 upper secondary school pupils use DTMs daily or weekly while only ten percent of pupils at lower secondary school pupils use them (IKT-senteret, 2014) as cited in (Gilje, 2021). Despite the increasing use of DTMs in schools, a survey commissioned by the Directorate for Children, Youth, and Families (Bufdir) to survey the status of the universal design of the DTMs used in primary schools showed that most of them do not meet the requirements for universal design (Oslo Economics, 2022). The qualitative analysis of this report indicates that although there is greater awareness of universal design due to the inclusion of ICT regulation into Norwegian law, the report shows there are still barriers and challenges to the development of universal DTMs. This is predominant with content that is built with HTML canvas (these are elements used to draw graphics, images, and animations on the web page). The problem is also common with unlicensed teaching aids, and these problems could be avoided if the universal design was part of the development of these resources. From the perspective of publishers/suppliers – two barriers were reported. First, high cost is associated with production as complying with all WCAG requirements is time-consuming, and second is the difficulty in interpreting universal design legislation. Another report by Funka (2021) shows that all digital learning resources [12] examined met neither legal requirements nor tested cognitive criteria (These include among others ease of finding where one is in the page, understandability of important information, easy to understand if an object is clickable or not and consistency - similar behavior for similar actions). The report states that these shortcomings create barriers for people with disability, which could especially exclude people who use AT.

The lack of universally designed DTMs has also been reported in the higher education sector. A report by Proba Research (2019) indicates that except for materials adapted by the Norwegian Library of Talking Books and Braille (NLB), few teaching aids are universally designed. The reports also indicate that higher education institutions have not built competence in universal design, both at the personnel level responsible for choosing teaching aids or tools like templates that can be used by staff. Sanderson et al. (2022) found similar results from a qualitative study on the knowledge of universal design and digital accessibility of faculty members in Norway and Poland. The result of this study shows that faculty members lacked an understating of accessibility barriers faced by students, expertise on how to make digital learning materials accessible for these students, and both lack of knowledge on legal requirements and the gap between legislation and implementation. In the same vein, M. F. Rice and Ortiz (2021) states that a lack of guidance on how to make DTMs accessible could potentially discriminate against students with VI and also frustrate teachers as they learn to teach with DTMs.

More recently, literature has emerged that offers insight into the recent EU accessibility act and digital teaching materials. Marcus-Quinn (2022) discussed in her essay the implications of the EU accessibility act and web accessibility directive on digital teaching and learning materials in Ireland. The author argues that the legislation currently focuses on websites and online services, but regulations will also

[12] This report categorizes digital learning resources as individual or supplementary tools with features that facilitate learning that acts as additional support for textbooks

impact teaching and learning materials in the future. Further, the author states a ”knowing-doing gap” in producing high-quality, accessible DTMs, which requires effort and experience, highlighting the need for adequate resources. Other studies have identified similar barriers. For example, Ştefan et al. (2021) identified several challenges that make it difficult for students to access digital content. These include a lack of awareness among the teachers and designers, inadequate training, and limited access to tools that make the creation of accessible content.

Griful-Freixenet et al. (2017) conducted a qualitative study on the perceived barriers and opportunities of the universal design for learning. Although the study focused on university students and general UDL principles, some opportunities and challenges discussed in the paper can be relevant to DTMs. The study found that the traditional approach of ’retrofitting’ materials to students’ needs proved to be inefficient. The study also found that the third principle on multiple means of engagement best met the perceived needs of engagement for students with disability.

With relation to the general use of ICT for people with VI, Fuglerud (2011) research in 2011 identified some of the barriers and challenges by people with VI. Some of the major challenges are registration and authentication and technical challenges, such as software updates affecting AT. Further, the study suggested a need for training on several levels, including the use of AT - which adds additional cognitive load, the use of AT in combination with other software, and how best to optimize the settings such that these two work seamlessly. A literature review by do Nascimento et al. (2019) identified accessibility barriers faced by people with severe vision impairment in web-based learning. The study describes three main barriers and how they can be overcome. First, the lack of information that helps users navigate through web-based learning platforms causes an extra cognitive load because students try to understand how the platform works and comprehend the content simultaneously. Some of the problematic components are navigation bars, menus, and a lack of suitable language that could easily be understood when produced by screen readers. Secondly, the content presented in images and graphics is inaccessible to people with VI due to a lack of alternative texts. The third relates to understanding the meaning of audio feedback and the relationship between sound and action. For example, events sound on link clicks that indicate an error. Understanding such sounds is only possible with prior knowledge. Other sounds may be associated with wrong actions and can be unpleasant. In addition, DTMs that are scanned formats of physical books are inaccessible with screen readers (Kharade & Peese, 2012).

The studies and reports reviewed in this section and section 2.1 have looked into several aspects of ICT use in education related to DTM. They portray a picture of barriers that students with VI face. These can be summarised as follows: First, there is the increased use of DTM, which include DTMs from publishers, DTMs from other sources and refined by teachers, and those created by teachers (Marcus-Quinn & Hourigan, 2022), which are all in some cases organized in secondary tools such as OneNote (Gilje, 2021). Further, there is a knowledge gap on producing high-quality accessible DTMs and a lack of understanding of accessibility barriers faced by students (Marcus-Quinn, 2022; M. F. Rice & Ortiz, 2021; Sanderson et al., 2022). Further, a report by Fuglerud et al. (2021) proposes more research to be done, among others, on digital barriers faced by people with VI. Therefore, an in-depth study on accessibility barriers faced by students with VI and creating awareness of their challenges is needed. This thesis aims to contribute to the literature by identifying the barriers faced by students with VI in DTMs.

3 Methodology

In section 3.1, I will discuss the choice of methodology, while in section 3.2, I will discuss the data collection process, starting with the selection and recruitment of informants, the design of the online questionnaire and interview questions, and how the data is collected. In section 3.3, I will explain the data analysis method and procedure, and finally, in section 3.4, I will discuss the ethical considerations.

3.1 Methods

Since Human Computer Interaction (HCI) aims to understand the important user perspectives in designing technologies to make them usable and collect data, socio-scientific methods have become the most used in HCI research (de Carvalho & Fabiano, 2021). However, compared to other fields, research in HCI is different and complex in three ways, according to Lazar et al. (2017a). First, they are few national and annual data sets, and secondly, longitudinal studies are rare; thus, researchers are required to collect their own data, which also limits the size of the data. This is mainly due to the rapid technology change, making a comparison of interface usage between decades irrelevant. Third, not just anybody is the right candidate to participate in the research because the "focus on the users, tasks, and environments, which means that not only must the users be representative in terms of age, educational experience, and technical experience, but also in terms of the task domain" (Lazar et al., 2017a). For example, if the focus is on severe motor disabilities and how they interact with the interface, then participants should have that impairment. In this thesis, the focus group is students with visual impairment. Therefore the participants are representatives not only in terms of age, i.e., high school students but also have experience in using DTMs and thus have experiences in the task at hand which is interacting with these materials. Under those requirements, recruiting participants is a difficult and slow process.

Further, there is an increasing awareness that the focus on the task alone can not be relied on to design and develop an effective system, and as such, there is a need to identify usability issues and how they are experienced and perceived by the users (Adams et al., 2008). Qualitative research methods are considered the most appropriate for investigations that aim to understand user experiences and perceptions (Adams et al., 2008). The use of the qualitative method is a well-established approach in HCI and it has been used by research such as (Hussain & Sanderson, 2022; Sanderson et al., 2022).

Because of the time limit and the expected difficulty in recruiting and conducting interviews with students with VI, an online survey was deemed suitable to reach students with different VI. Surveys are generally considered an effective method to quickly get a bigger picture of how users use a particular technology (Lazar et al., 2017a). In this thesis, the research question is to identify accessibility barriers faced by students with VI when using DTMs as such, a mixed method approach (qualitative and quantitative) is thought appropriate to gain insights into these barriers.

3.2 Data collection

3.2.1 Participants

The participants consisted of four students with VI in high school and two teachers of students with VI. All four students were blind, and one of the teachers was also blind. To protect the participants' identity and for confidentiality, interviewees were assigned a pseudonym P1, P2, P3, and P4, while for teachers, SP1 and SP2-VI (a teacher with visual impairment) were used. All the students and teachers were from the same school. Students with VI are a small group, and recruiting a sample representing all VI variations is a difficult task (Keates, 2006) as cited in (Fuglerud, 2014). Hence, five to ten participants is a generally accepted number (Lazar et al., 2017b). Moreover, all the participants have experience in the task domain, i.e. use of DTMs. Another aspect considered is user representative (at the individual or system level)- a practice recommended in the software development process (Fuglerud, 2014). This categorization can also be applicable in this research - students represent the individual level by sharing their subjective experiences, while teachers are user representatives at the system level as they understand the broader accessibility challenges faced by students with VI.

3.2.2 Interview

An interview guide was developed based on the literature studies (See appendix D). In an attempt to make each interviewee feel as comfortable as possible, I asked the students to choose the most convenient venue for interviews, i.e., an online (Teams) meeting or a physical interview. I interviewed three students at their school, while one was done online. I also conducted two interviews with teachers - one was physical and a telephone interview. A semi-structured interview was considered the best fit for this research as it allowed students to share their experiences, perceived barriers, and challenges of DTMs. All the interviews were semi-structured, and an audio recording was taken for later analysis, except one interview SP1 which was not recorded.

3.2.3 Online questionnaire

For the online questionnaire, I used a web-based survey tool, *nettskjema*[13], that was designed and developed by the University of Oslo. The tool has an inbuilt automatic universal design checker. The automatic evaluation gave no accessibility violations. Further, I sent the form to a person with VI who tested it with the refreshable braille and the most used screen readers, such as JAWS, VoiceOver, and NVDA. The questionnaire had both closed-ended questions with ordered responses and open-ended questions. Open-ended questions were used to give flexibility and freedom to answer the question in their own words (See appendix E). Because the potential respondents are not general high school students, I sent invitations to participate in the project and link to the questionnaire to schools and two organizations. For the school, I got the list of emails from Statped - these are schools that have ordered adapted books from them in the last year. I also sent the questionnaire link to Parents of blind children [14] and Norwegian blind association for Youth [15].

[13] https://nettskjema.no
[14] https://www.ftbb.no
[15] https://nbfu.no

3.3 Data analysis

As de Carvalho and Fabiano (2021) noted so clearly that "independent of how good a picture is, it does not speak for itself: it must be interpreted". With regard to the analysis and interpretation of qualitative data, several methods of data analysis have been developed, such as grounded theory, thematic analysis, discourse analysis, conversation analysis, and phenomenological analysis (Adams et al., 2008; de Carvalho & Fabiano, 2021). Compared to the other mentioned methods, thematic analysis is considered a more flexible and accessible approach, and this is mainly because it does not attach itself to any conceptual and theoretical framework (de Carvalho & Fabiano, 2021) and as such, it is intended for data analysis only than being a method for qualitative research which would have opened it to epistemological discussions on research theories (Braun & Clarke, 2012; Terry et al., 2017).

Thematic analysis "is a method for identifying, analyzing, and reporting patterns (themes) within data" (Braun & Clarke, 2006). Since thematic analysis "seeks to identify patterns of experiences both of processes and attitudes to those processes," it suits the analysis of HCI interactions according to Adams et al. (2008). Thematic analysis has six phases according to Braun and Clarke (2006), and these are as follows:

- Familiarizing yourself with data: This includes a transcription of data, for example, from the audio taken during the interviews, reading data, and identifying preliminary patterns and themes in the data.

- Generating initial codes: organizing data into meaningful chunks and coding potential themes. This is done by highlighting, taking notes, and copying parts of the transcripts that are relevant to a code.

- Searching for themes: This phase involves grouping and mapping codes and extracts into different sub-themes and themes.

- Review themes: This involves taking another look at the identified sub-themes and themes and separating them into distinct topics, validating them with the data and also recording missed or misplaced data, and coding them appropriately.

- Defining and naming themes: At this stage thematic map of the whole data set has been developed, and the focus turns to refinement and clear identification of the themes, their scope, and giving them working titles.

- Report production: The last stage is writing the report, describing and arguing the findings in relation to the overarching research question.

To analyze the qualitative data in the study, thematic analysis was done to gain insights into barriers faced by the participants. First, all the recorded interviews were transcribed. Then, the transcribed text was reread while listening to the audio to ensure it had been transcribed correctly and that the text was understandable. The interviews were conducted in Norwegian language and analysis was done on the transcribed text, but the excerpts used in results section were translated to English. Taguette[16], an open source tool with features such as highlighting, tagging, and tag-merging (Rampin & Rampin, 2021) was used to make the analysis of the qualitative data easy. Using this tool, the text was high-lightened, grouped into chunks, and tagged with codes. Taguette made it easier to sort all the statements and identify possible excerpts. Figure 3.11 illustrates how the text was highlighted and coded. Four iterations were done, and several codes and sub-codes were created and grouped in the early iterations of thematic analysis. For example, all aspects of the accessibility of videos, images, and links from teachers were grouped into one category. Similarly, issues related to the use of DTMs in different contexts were grouped as another category and later refined to a theme on navigation as the analysis progressed. Aspects of different user agents and assistive technologies were grouped and assigned appropriate codes.

3.4 Ethical considerations

The data collection received approval from Norwegian Agency for Shared Services in Education and Research (SIKT). See appendix A. The interview guide and the

[16]https://www.taguette.org

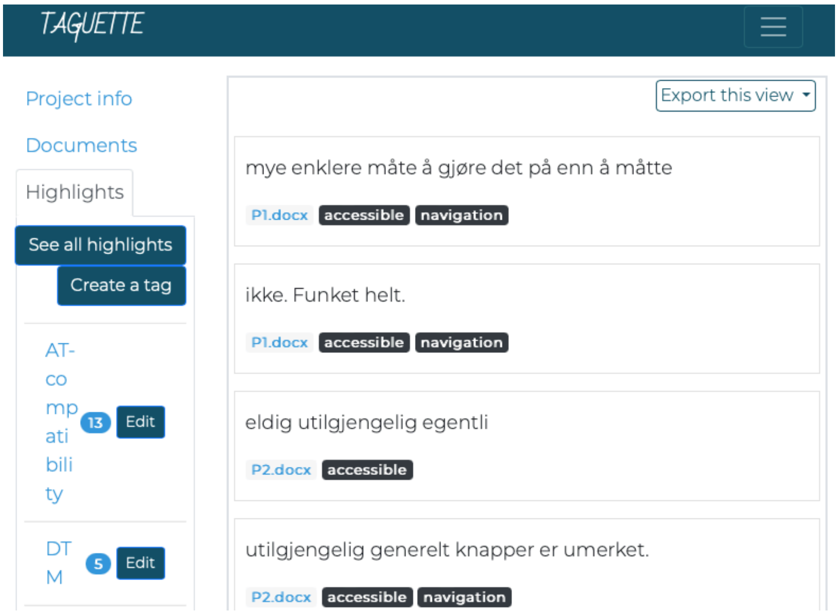

Figure 3.11: Taguette - enables coding and highlighting of text

online survey questions were also part of the application sent to SIKT. The recruitment and communication with the students were done through a teacher of the students with VI at the school. The participants were provided with information letters (see appendix B and C), and consent forms were sought before the interviews. The participants were also informed that participation was voluntary and that they could withdraw their consent anytime. The school also took the necessary steps to oversee and ensure students were heard, and their rights were not infringed; as such, one teacher was present during all student interviews.

With regards to confidentiality, all the audio recordings were saved on Oslomet Onedrive with two-factor authentication and were only accessible to the thesis supervisor and me. The recorded interviews were transcribed and anonymised, but the original audio files will be deleted at the conclusion of this thesis.

The online questionnaire was anonymous, and no written consent was required to be sent beforehand to participate. However, the respondents were informed that they agreed to participate in the survey by filling in and submitting the questionnaire.

Qualitative research embraces the researcher as part of the process of generating the findings through analysis (L. Haven & Van Grootel, 2019). However, Lazar et al. (2017a) argues that one shortcoming of qualitative data analysis is the subjective interpretation of data. As such, I was cognizant of this and my position as a Statped employee, and I strived to be impartial in my interpretations.

4 Results

High school students with visual impairments and the teachers of the visually impaired were interviewed about their experience of using digital teaching materials and the barriers and challenges they meet when using these technologies. The overarching goal of this study was to identify the challenges and barriers faced by students and the perspectives of the teachers of visually impaired on the barriers faced by students in DTMs.

4.1 Results from the interviews

As mentioned in section 3.1, thematic analysis is the chosen approach for analyzing the data from qualitative methods. In total six main themes were identified from the analysis, and these will be discussed below. In the discussion below, P1, P2, P3, and P4 refer to students, while SP1 and SP2-VI refer to teachers.

4.1.1 Types of Digital teaching Materials (DTMs)

The first theme that was identified from the common patterns in the data was the type of DTMs students use. Although this theme is not directly a barrier faced by students, it captures what participants view as DTMs, and from this understanding, their perceived barriers are derived. The students named several types of DTMs they use, which include adapted digital books from Statped (which are mainly in Docx format, HTML, and audio-books), resources developed by teachers such as PowerPoint slides, and links to other resources sent by teachers, digital dictionaries, and digital books from publishers. The categories of DTMs named by the participants are coherent with the discussion from section 2.1, where different tiers of DTMs were discussed. One observation is that all the participants used DTMs that Statped has adapted. As such, the students referenced and compared these materials when explaining their experiences. The teachers claimed that the current DTMs are mainly designed for the sighted. Hence, it often takes longer for students with VI to navigate and find the right page, the right chapter, or the correct information. Regarding the choice of learning materials and resources, the teachers argued that because of salient lessons learned over the years using DTMS, the school and teachers prefer to use books adapted by Statped. However, the students expressed that they would have wished to use the same DTMs and tools as their peers, but the current state of the DTMs and tools excludes them. Students expressed further that they not only need same content in the DTMs but also the same interaction experiences as their peers.

4.1.2 Navigation

Navigation of DTMs is one of the strong themes that emerged from the analysis. The students expressed that navigation of DTMs is one of the main barriers they face when using DTMs, as this demands high levels of concentration. This is because they move through the content sequentially. Some of the issues that made navigation difficult include unlabeled buttons and links that do not indicate where they lead to. This makes it hard for them to find where they are on the page and locate the resource or content they are looking for. These views emerged in conversations concerning navigating DTMs during lessons and group work. Concerning navigation during the lesson, one of the participants explained this as follows:

> It is such a messy set-up for me who uses tab and scrolls through everything, then it kind of gets so messy, so it requires a lot of concentration to get it done. It is the way you go through unnecessary buttons on websites, and it takes you a very long time to navigate past things you didn't necessarily need. It takes a lot more, and I have to scroll through everything when I return, while the others can press with the pointer and skip over. So, therefore, it takes much longer. P4.

The participant further explained that navigating during lessons can be challenging, and sometimes they choose not to use the resource because it will just be an exercise in futility. The interviewee said:

> It takes a very long time, so everyone else in the class has finished reading by the time I get to it, so sometimes I do not even bother to do it because I know I cannot do it. P4

Similar navigation issues were raised by students when participating in group work, as the comment from one of the participants illustrates:

> And in a context where we have to collaborate and answer some questions or make a presentation or something based on what we have read and in such contexts, I choose, I have always done that until now, the Statped books. And I could have chosen others that are online, but for me, in situations like that, it's about having enough time to finish reading before discussing and enough time to be able to think through... so in order for me to be able to contribute in a decent way, I like to choose the simplest solution for myself then as well. P3 - (the simplest solution student is referring to is the adapted books from Statped).

Because of the difficulty in navigation, students often go through the resources in advance mainly to familiarize themselves with the structure and not necessarily read the content. As such, the student requests teachers to send links earlier, and they appreciate it when they get sent links in advance.

> I just think it is a bit cumbersome in class because it takes a while to log in and find what you need. So, I really appreciate it when I get a message from the teacher in advance of a lesson; then, I can get it ready for the lesson. P3.

Another finding is related to a lack of consistency in the layout and presentation of the content. Talking about this issue one of the participants said: "And it's that things aren't somehow consistent... For example, we have a book that has headings for each page. Another book does not have that. And it's like different formats". P1

Navigation: secondary tools

Regarding secondary tools, SP1 argued that the students have to 'work themselves to death' to get content in the DTMs in secondary tools used at the school. For example, the school uses OneNote - Microsoft package [17] as a tool (secondary tool see figure 2.1) for organizing teaching materials and assignments. However,

[17] https://www.microsoft.com/en-ww/microsoft-365/onenote/digital-note-taking-app

the tool is not accessible to students with VI. The teachers argue that OneNote has a confusing structure, is difficult to navigate, and does not particularly work well with students AT. Therefore the school uses a folder system on OneDrive where students with VI access DTMs, adapted DTMs from Statped, and assignments.

4.1.3 Barriers related to images, videos, and secondary resources

Resources that contain only images without alternative text are problematic for students with VI, as described by one of the students: “Some teachers may only have pictures, which is a bit difficult for me. Then I’m like..You really should not have sent it ... Is it plain text? Thumbs up. Is it just pictures? No thanks”. P3.

Further, the students expressed that it stresses them when they get unfamiliar links. “Websites that we get links to, I experience a challenge in that I get a little stressed. How is it actually designed? Do the usual keyboard shortcuts work? In other words, I get a bit of unnecessary stress”. P3

Regarding videos, SP-VI explained the challenges faced by students and how this set higher demands for students with VI, and the consequence is that this might affect their grades. The teacher explained this as follows:

> For example, there may be videos that are in English, and they may be subtitled in Norwegian, but a visually impaired student will not see the subtitles on the video. You can also say that but most understand English quite well, but still, all the other students have the opportunity to see the translation and see the subtitles. But visually impaired students will not have that opportunity. And therefore, it seems much higher requirements are placed on the visually impaired student to master English. It is discrimination in that way.....most people understand English quite well, but we also have students with us who are not very good at English, and then you can risk that because you are not very good at English, then suddenly the grades in other subjects are affected because you do not see the subtitles on English videos and it is wrong in the way that you get a bad grade in history or social studies just because you do not catch these videos which are allowed to be part of the

> curriculum. SP-VI

4.1.4 Usability and task completion

Another theme that was identified is related to task completion and usability. Students have expressed that they would often ask for help when they find difficulty in navigating and finding content. They argue that they could find what they are looking for given ample time, but in, for example, a class setting, they would rather ask for help rather than waste time.

> It is not a rare occasion, and I would probably have managed to find it myself, but it is also about having time to read it before we go on. So I have to ask for help to avoid wasting all my time. P3.

Even though students might have access to other digital teaching materials and appreciate their importance, they prefer to use books adapted by Statped.

> I think it is also very much about getting used to it. After all, I have been used to Statped books for years. Since that's what I know, I'd like to use it, but I certainly see the advantage of learning digital books and how it works. P3

Time used to complete tasks such as finding content was another usability issue raised. Talking about this issue, one of the teachers for students with VI said:

> I would say that what is often the challenge is a lot about how much time you spend using these things, and it is probably often a challenge that a visually impaired student takes much longer to navigate forward, and also often on navigating and finding information. SP-VI

4.1.5 Compatibility barriers

Because most students with VI rely on assistive technologies, incompatibility or missing accessibility support for this equipment is a concern that all interviewees expressed.

> some are very inaccessible with a screen reader. It is generally inaccessible if buttons are not labeled.....If there is something like that element on the website that is not read out by the screen reader, for example, if there are buttons that are unlabelled or links that just say link. P2

In some cases, if the elements are coded incorrectly, navigation using the keyboard and the screen reader becomes difficult. This example from one of the participants illustrates this behavior. “For example, if I use tab in order (...to navigate), I only get the tabs symbol. It is not in the actual window”. P1.

Another example given by one of the teachers also shows how the screen reader does not seem to change the focus even though the focus has changed visually. The teacher stated that

> It was very difficult to jump to page numbers, you could search pages, and it worked fine. But when it jumped to the page, it only visually jumped to the page. But the screen reader did not jump or move the focus to the same place, so it looked like it moved to the right page, and it did visually on the screen. But for a screen reader user, you will not get there (to the desired book page). SP2-VI

The consequence of this is that students are forced to use other resources that they were not supposed to use, as this description from one of the students illustrates

> For example, we’re going to find out a word in Spanish instead of using Ordnett [18], so I would have used Google Translate or just look up words on the web, actually because I could not find it via Ordnett. P2.

Another issue expressed by a student was the use of drag-and-drop elements. The student explained that this is usually very inaccessible to ATs they use, and they had to get assistance from teachers or fellow students.

The compatibility of DTMs with phones and tablets is another issue that the participants raised. Students have expressed that some applications, such as Teams, are best accessible with phones, but digital books, such as those from Statped, are

[18] Ordnett is an online language and dictionary service https://www.ordnett.no

not easy to navigate on phones and tablets. One of the participants, when talking about this issue, said that " .....no, simply because I can't quite manage to search the page from mobile, so it's a bit boring to scroll to page 140 when you're on page one" P1

4.1.6 Digital skills and Training

The teachers raised the issue of having adequate digital skills related to the use of AT and digital teaching material. Lack of adequate skills can also hinder students' progress at school, and as such, the school starts offering training to students as early as possible as this statement from one of the teachers indicates

> It can be a very big challenge. So it is important to deal with it quickly when the students come to us because if they are not very good at it, then it will also be an obstacle in the subjects and you don't want that. SP-VI

One of the teachers explained that students are offered one-to-one training on the use of AT with DTMs and the specific platforms used in the school to get the most value from AT, like screen readers. They argue that some students need many follow-ups, and the kind of help varies too; some need help with key keyboard shortcuts both in Windows and programs. In some other cases, students need follow-up to become more confident in the programs and AT they use.

4.2 Questionnaire results

The overall response to the online questionnaire was poor. The questionnaire received five responses. This is, however, not a surprise because the target group is narrow. In addition, one of the respondents was a primary school pupil, thus not in the target group. Therefore, the results from four respondents will be discussed here. Of the four responses, two were blind, while the other were students with low vision impairment. The questionnaire analysis showed that students with low vision did not use adapted DTMs from Statped. Moreover, two of three blind respondents indicated they did not receive adapted DTMs in time.

Regarding navigation, three respondents answered that navigating through the DTMs they use is easy, while the other responded that it is difficult. However, in the open-ended questions, one of the respondents wrote that it is challenging to navigate DTMs because of the presence of many images that do not have alternative text. Moreover, three students answered that they occasionally ask for help navigating the DTMs.

On the question of how DTMs can be made more accessible - one student suggested that it should be easier to navigate with keyboard shortcuts, avoid drag-and-drop elements (an issue echoed by an informant in the interviews) and use alternative text. All four responded that they rarely require help to sign in to platforms where digital books are stored. Similar responses were also received from the interviews.

5 Discussion

In this section I will discuss the thesis findings against theories discussed in section 2.3 and previous research—the thesis aimed to identify the barriers faced by students with VI in DTMs. The prior section's analysis revealed that participants faced several obstacles. These include navigation issues concerning primary content, media usage and other learning resources, usability issues, compatibility, and digital skills. I have grouped these issues into six main areas. I will discuss the barriers identified in section 5.1. Then, in section 5.2, I will discuss the general impact of accessibility barriers, while in section 5.3, I will discuss the study's limitations.

5.1 Barriers

5.1.1 Navigation

Navigational barriers are one type that stands out, which the participants repeatedly mentioned in the interviews. Some of the main issues mentioned are inconsistent content layout and headings, link text without cues to where they lead, and unnecessary buttons that are timing consuming to navigate. Previous studies have shown that missing information or clue on where the user is may cause the VI user to lose navigation orientation, and it can cause extra cognitive load mainly because the VI users try to understand the structure of DTMs and simultaneously comprehend the content (do Nascimento et al., 2019). WCAG acknowledges these challenges and gives guidelines on simplifying the navigation of an interface in Principle 2 on operable and Principle 3 understandable in WCAG2.1 (World Wide Web Consortium, 2018). For example, success criteria[19] 2.4.1 on bypass block, 2.4.2 page titled, 2.4.3 on focus order, and 2.4.4 link purpose in context are some of the conformance level A[20] that must be met to guarantee minimal levels of navigation. Some success criteria in conformance level AA relevant to VI include 2.4.5 multiple means of locating content in a webpage, e.g., search instead of scrolling to get to the content quicker. 2.4.9 link purpose (link only) and 2.4.10 section headings are

[19] https://www.w3.org/TR/WCAG21/#navigable

[20] conformance means that requirements are met https://www.w3.org/WAI/WCAG21/Understanding/conformance

some of the conformance level AAA that help users with VI to aid the screen reader in describing the purpose of the link and easily understand the organization of content and the purpose of each section, respectively. The level AAA is not covered in the current Norwegian regulations.

Success criteria 3.2.3 Consistent navigation (AA) and 3.2.4 Consistent identification (AA) are some requirements that must be met to ensure that websites operate predictably. The benefit of consistency in the order in which elements appear is that users become comfortable using the resource as they can predict where to find content or what will come next when navigating it. Results from the qualitative data show further that if the content is not presented in a useful way, it demands high concentration levels from the students with VI. These results reflect those of (Kharade & Peese, 2012), who explained that cluttered web pages and inconsistent design between pages confuse the users. This challenge also justifies the students' choice of DTMs that Statped adapts, as they are familiar with them and thus comfortable using them. Although adapted DTMs meet their needs, it deprives them of the opportunity to use the same DTMs and tools and get the same interaction experiences as their peers. As described in section 2.3.3, to facilitate learnability and memorability, content has to have a logical structure anchored in the familiar task, segmenting content into chunks not to overload the working memory and reduce extraneous load. As such, navigational barriers in the DTMs increase the extraneous load, thus reducing the cognitive real estate students should have used to learn the content. Therefore, navigation barriers can hamper learning, limiting students' flexibility to read and repeat content easily. To enhance the effectiveness of DTMs in learning, Saarinen (2020) suggests some practical considerations, such as making it easy for students to go back and forth between the previously presented content strengthening the argument for the need for navigable DTMs.

Another task that students with VI struggled with was drag and drop tasks. Such tasks require the use of a mouse which demands hand-eye coordination. Again, this could not be achieved by students with VI using the AT at their disposal. Such a task can also be problematic for students with low vision if they experience difficulty locating the pointer on the screen. The success criteria of WCAG 2.1.1[21] on key-

[21] https://www.w3.org/TR/WCAG21/#keyboard

board access covers the needs of people with disabilities such as vision impairment. Technical evaluations done by (Funka, 2021) on DTMs in Norway show violations that touch some sections of the four WCAG2.1 principles. Some of the technical issues mentioned in evaluation can be related to the aspects of navigation identified in this thesis. For instance, consistent navigation, navigation requiring mouse.

5.1.2 Usability

Another important finding is related to the time used to find content and the satisfaction level, which affects the choice of DTMs and secondary tools. Whereas the sighted users could get the overview of the page 'at a glance' - VI have to go through the content sequentially, and if the page does not have rich clues for navigation and to identify essential sections quickly, then they would take a long time to go through the content. As Theofanos and Redish (2003) argued that "blind users are just as impatient as most sighted," and hence they would not like to hear everything but scan content by listening just enough to decide whether to continue to listen or not. Timely content access is crucial in a classroom setting as the students must get the content quickly. The implication is that students with VI could not fully utilize the DTMs in different contexts, such as group work and in class. Students argued that they had to choose Statped books or not use the available DTM as they knew they wouldn't go through the content in time. Other studies have also found that accessibility barriers are particularly relevant to education because these challenges impose obstacles to collaboration and interaction for students with VI (do Nascimento et al., 2019).

Further, there is a need to reduce the number of steps taken to find the content. This process typically starts with signing in and then looking for the content. In contrast to earlier studies (Fuglerud, 2011) that indicated that the first barrier VI meets is related to registration and authentication, the interview and questionnaire results revealed that most students do not have difficulty signing in to different DTMs and tools or platforms. A possible explanation for this might be using Federated Identity for education (FEIDE)[22] for signing in. Fuglerud (2014) has suggested a global

[22] https://www.feide.no

mechanism for registration as one of the approaches that could solve this challenge. Other studies have also suggested single sign-on as one of the strategies to reduce frustrations related to remembering different passwords for different platforms (M. F. Rice & Ortiz, 2021). From the results, this problem seems to have been addressed with the use of FEIDE. As will be further elaborated in section 5.1.3, the navigation of secondary tools is an even more significant barrier that students with VI face.

By and large, ease of use is a critical factor that also affects how students work and their productivity. For example, although working in groups is essential in school, students with VI sometimes request help from sighted peers or teachers to deliver assignments or navigate through DTMs though they wouldn't have wished for this. Such time-oriented aspects of task forces students to rely on others, reducing their participation and independence.

5.1.3 Compatibility problem

The participants in this thesis used screen readers and refreshable braille displays as their two main ATs. The results of this study show that students had difficulty using DTM because the content did not interact well with their AT. Compatibility with AT is a requirement of WCAG 2.1 guidelines, specifically principle 4, which requires content to be robust enough to be interpreted by various user agents and AT. Moreover, compatibility with AT is considered one of the requirements for universal design (Fuglerud et al., 2014). Previous research, such as a report by Mordal et al. (2020), indicated that students would not have possibly participated in school and potentially students would not have completed school without AT. Further, a report by Funka (2021) also indicates that accessibility barriers could exclude people who use AT. Previous studies have demonstrated that the VI have to split their attention between the content and AT - as Theofanos and Redish (2003) put it that VI have to use cognitive energy to understand "how to use the system that is helping you." Lazar et al. (2007) found that screen reader users waste about 30.4 percent of their time due to frustrations caused by a screen reader if the layout is poorly designed and incorrectly coded, forcing the screen reader to give wrong feedback. In addition, users with disabilities spent time optimizing their setup by adjusting features of AT such as screen reader speed, screen magnification setup, or colour settings if colour blind and also configuring browsers and settings operating systems to their needs (Lazar et al., 2017b). For students who are also still learning and are not advanced AT users, splitting attention could be more challenging and cause technology-related frustration. As such, the inaccessibility of DTMs and compatibility problems with AT increase the mismatch between the student's capabilities and the demands of the environment in two ways (See figure 2.3 for the relationship between environmental requirements and individual abilities). First, the DMTs' inaccessibility set high cognitive demands from students, thus, high environmental demand. Secondly, One way to reduce the mismatch is by using AT to strengthen the abilities of students with VI; however, in this case, DTMs incompatibility with AT has a negative impact as it demands more from the already strained capabilities of the student, thus further increasing the mismatch.

5.1.4 Images and videos

While DTMs facilitate the UDL principle of providing multiple means of representation, i.e., making content perceivable to diverse audiences by providing information in different modalities. Thus affordance of DTMs can not be utilized to its potential if the formats in which the content is presented are not accessible. Examining teachers' views and the students' experiences, the study finds that images, videos, and graphics remained inaccessible to students with VI despite their wide use. Images without alternative text are an area where students experienced it was difficult for them to perceive the information that images conveyed to them. This problem is prevalent with DTMs that teachers have created, e.g., PowerPoint slides/lecture notes. As identified by Marcus-Quinn and Hourigan (2022), there are three main tiers of digital teaching materials; resources developed by professionals, a resource developed by teachers, and resources refined by teachers (see 2.2). Marcus-Quinn and Hourigan (2022) argue that there is a massive diversity in the accessibility of these resources partly because teachers do not have the skills, time, or resources to create accessible documents.

Further, the example given by one of the teachers on challenges faced by students concerning videos is yet another illustration of how lack of accessibility creates a mismatch between students' abilities and the environmental requirements. The sighted users can see information conveyed visually and captions when they don't understand or hear what is being said in the video. However, the students with VI will not have that opportunity. Therefore they are expected to master that language to understand the content. In this case, the videos cause high environmental demands, and this causes a mismatch between the student's abilities and the requirements of the environment. Conveying the information through transcription or text alternatives offers VI the opportunity to perceive the content if the audio from the video is unclear. A recent report by Funka (2021) also found that most audio and video files in digital learning resources in Norway are presented without text. Videos without text could significantly impact flipped classrooms, a trend that has increased recently (Klingenberg et al., 2020). Flipped classroom requires that students watch video lectures independently, but the emphasis is placed on the discussion in class. For students with VI, if they do not have access to videos with text, this would reduce their chances of benefiting from such an instructional strategy.Although it will be a legal requirement that all video recordings must have visual interpretation (WCAG 2.1 success criterion 1.2.5 audio description for prerecorded videos) by February 2024, kindergartens, primary schools, and upper secondary schools are exempted[23]. Recently there have been cases of legal complaints regarding accessibility. McAlvage and Rice (2018) gives several examples of civil complaints about accessibility where students sued universities. Regarding DTMs, most complaints are related to a lack of alternative text, videos without captions, and inaccessible formats (M. R. Rose, 2018) as cited in (M. F. Rice & Ortiz, 2021).

5.1.5 Secondary tools

Of greater concern is the increased use of secondary tools to organize DTMs. The problem is not their usage per se but how well they serve students with VI. The secondary tools referred to in this discussion are tools that were not originally de-

[23] https://www.uutilsynet.no/webdirektivet-wad/eus-webdirektiv-wad/265#standarden_i_wad__en_301_549

veloped specifically for learning (see figure 2.1). Students with VI struggle with navigating these tools because of causes extra cognitive load caused by trying to understand the tool's structure and at the same time comprehend the content (do Nascimento et al., 2019). Insights from interviews show that secondary tool such as OneNote was one area that was found to be significantly associated with the accessibility and usability of DTMs. Teachers increasingly use resources from all three tiers (see 2.2) to make a portfolio that meets the needs of their students (Marcus-Quinn & Hourigan, 2022). As Gilje (2021) noted, they use secondary tools such as OneNote to organize these resources. The consequence of this is that even where the DTMs have been made accessible if they are tucked away in the depths of inaccessible secondary tools, then they are not helpful to students with VI. For example, the participants in this thesis used Onedrive to access DTMs from Statped and other resources because OneNote, which the school uses, was inaccessible. As Smith and Stahl (2016) argued that "unless students with disabilities are able to access and interact with curriculum materials, it makes little difference whether or not the materials have been proven to be academically effective." Thus all aspects of DTMs and secondary tools have to be accessible. This requires that schools become better informed and do due diligence by reviewing not only the accessibility statement of DTMs in their procurement process (M. F. Rice & Ortiz, 2020) but also the accessibility of secondary tools.

Synthesizing the discussion from the last three subsections (5.1.1 to 5.1.3), three main aspects need to be considered so as to understand and address the accessibility barriers by students. First is the navigation of DTMs that determine content comprehension, the second is the platform's structure, and third is the additional layers added by assistive technologies.

5.1.6 Digital skills

The participants in this study (students) are digital natives who may be familiar with digital tools, have adequate digital skills, and are technology savvy (Prensky, 2001). However, other studies indicate that being born in a digital world does not guarantee digital literacy (Arslantas & Gul, 2022). In this discussion, we are limiting digital literacy to a technical dimension - practical and operation skills related to using different user agents and assistive technologies. The teachers remarked that the lack of digital skills is a barrier that limits students' interaction with DTMs and other secondary tools that the students use at the school. Further, this limits their ability to interact, engage in learning, and demonstrate their knowledge independently. Lack of skills in keyboard shortcuts makes interacting and performing computing tasks challenging and generally results in them not getting the most value from AT at their disposal. The findings are in agreement with Fuglerud (2011), who observed that digital skills are one barrier faced by people with VI. The author argues further that AT creates an extra layer, i.e., additional cognitive and learning demands that require additional effort from the VI in using ICT solutions. Hence having skills on how to effectively use AT impacts how well students can use DTM. Further, studies have shown that having digital skills is vital in the digital age and, in many ways, paves the way to minimizing barriers they would have otherwise faced (Arslantas & Gul, 2022). Teachers' view that they start training as early as possible is vital and is also supported by Arslantas and Gul (2022), who argues that early introductions improve confidence, speed, and accuracy of usage.

5.2 Accessibility barriers implications - school and beyond

Current accessibility shortcomings of DTMs can have long-term detrimental effects that could potentially ramify far beyond school. This directly impacts the transition from high school to higher education, which could also affect the transition from higher education to employment, as higher education is considered an essential factor determining participation in working life (NOU 2001:22, 2001). Indeed recent studies have demonstrated that employment is lower among the People with VI compared to the general population in Norway (Brunes & Heir, 2022), similarly the percentage of people with disabilities in higher education is lower compared to the rest of the population (L. P. Grue & Finnvold, 2014; Proba Research, 2018), and even those in higher education have to put more time and effort than their sighted peers (Langørgen & Magnus, 2018). As mentioned earlier, reports by Mordal et al. (2020) show that students with VI would not have completed school without AT, and accessibility barriers could exclude people who use AT (Funka, 2021). Moreover, the compatibility of AT with DTMs is tightly interwoven with other barriers identified in this thesis. Consequently, students with VI would not perceive content as they experience difficulty navigating DTMs and secondary supporting tools and perceive the information presented in images and videos. As such, this would impact their academic progress and possibly hinder their transition to higher education and employment further down the line.

5.3 Limitations

This thesis has some limitations. First, it is about the number of respondents. VI is a heterogeneous group, and recruiting participants with different VI was difficult. Even though an online questionnaire was deemed an appropriate method to reach as many as possible, it received very few responses. As such, the results in this thesis have mainly focused on the qualitative data from the interviews with four blind students, one blind teacher, and one teacher for the visually impaired. Secondly, the challenges and barriers described here are subjective experiences of students and teachers. Therefore, these limitations impede the generalisability of these results.

6 Conclusion

Using digital learning materials has great potential to facilitate inclusive education. However, this potential currently is not fully achieved due to accessibility barriers. In section 1, the central question asked is: What accessibility barriers do high school students with visual impairment face in digital teaching materials? Moreover, the following questions were formulated to help with data collection.

- What challenges do students face when using digital teaching materials from publishers?
- What are the barriers in relation to digital teaching materials developed by teachers and other supplementary digital resources and tools used for learning?

The results of this study show that despite increased use, accessibility challenges faced by students indicate that DTMs are not universally designed. Furthermore, the result indicates that students face barriers in DTMs from publishers, DTMs developed or refined by teachers, and secondary tools and resources. Much of the disabling aspects of the DTMs identified in this thesis are attributed to navigation issues, usability issues, inaccessible images and videos, and incompatibility with AT. Further, some other barriers are navigation challenges in secondary tools where teachers organize DTMs and a lack of digital skills among the students. Issues such as inconsistent and cluttered content layouts, unnamed buttons, and links without text make students miss orientation and demand high concentration. In addition, tasks requiring eye-hand coordination and a lack of keyboard support make it hard for VI students to operate DTMs. These navigation issues cause increased cognitive load. This problem is exacerbated by cognitive load caused by navigation issues in secondary tools and the incompatibility with AT. Taken together, students took longer to find content and could not use the DTMs effectively and efficiently, impeding their learning.

Another challenge is missing alternative text and a lack of audio descriptions and transcription of videos. The missing alternative is prevalent in DTMs produced or refined by teachers. In addition, prerecorded video resources in English are problematic for students with VI as they can not see video captions which helps sighted students when they do not hear or understand what is being said. This requires them to have a good command of the English language. In addition, lack of digital skills is a factor that limits from using the DTMs effectively. This includes handling and using AT, optimizing configurations, and mastering keyboard shortcuts.

The barriers identified here call for greater efforts to make DTMs more accessible to students with VI. Designers, developers, and producers should not see accessibility as an afterthought in the development process. Further, addressing accessibility issues is not restricted to publishers; those in procurement should also understand the diversity of students and their needs and check the accessibility statements of DTMs and the tools they buy. Further, producers of DTMs should not only see accessibility through the lens of possible legal liabilities but focus on building universally designed DTMs that all students can use in spite of their abilities.

6.1 Future work

Future research can evaluate specific DTMs using automatic tools and user testing methods to identify accessibility barriers faced by students with VI. Further, investigating how students use DTMs and measure accessibility, usability, and task completion is another view that needs further exploration.

References

Abascal, J., Arrue, M., & Valencia, X. (2019). Tools for web accessibility evaluation. *Web accessibility: a foundation for research*, 479–503.

Adams, A., Lunt, P., & Cairns, P. (2008). A qualititative approach to hci research.

Alonso, F., Fuertes, J. L., González, Á. L., & Martínez, L. (2008). User-interface modelling for blind users. *Computers Helping People with Special Needs: 11th International Conference, ICCHP 2008, Linz, Austria, July 9-11, 2008. Proceedings 11*, 789–796.

Alsaeedi, A. (2020). Comparing web accessibility evaluation tools and evaluating the accessibility of webpages: Proposed frameworks. *Information*, *11*(1), 40.

Andreas Kleynhans, S., & Fourie, I. (2014). Ensuring accessibility of electronic information resources for visually impaired people: The need to clarify concepts such as visually impaired. *Library Hi Tech*, *32*(2), 368–379.

Arslantas, T. K., & Gul, A. (2022). Digital literacy skills of university students with visual impairment: A mixed-methods analysis. *Education and Information Technologies*, *27*(4), 5605–5625.

Barreto, A., & Hollier, S. (2019). Visual disabilities. *Web accessibility: A foundation for research*, 3–17.

Begnum, M. E. N. (2016). Views on universal design and disabilities among norwegian experts on universal design of ict. *Norsk konferanse for organisasjoners bruk av IT (NOKOBIT). Open Journal Systems: Bergen, Norway*.

Begnum, M. E. (2020). Universal design of ict: A historical journey from specialized adaptations towards designing for diversity. *Universal Access in Human-Computer Interaction. Design Approaches and Supporting Technologies: 14th International Conference, UAHCI 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part I 22*, 3–18.

Berthelsen, U. D., & Tannert, M. (2020). Utilizing the affordances of digital learning materials. *L1-Educational Studies in Language and Literature*, 1–23.

Bigham, J. P., Prince, C. M., & Ladner, R. E. (2008). Webanywhere: A screen reader on-the-go. *Proceedings of the 2008 international cross-disciplinary conference on Web accessibility (W4A)*, 73–82.

Bolt, D. (2005). From blindness to visual impairment: Terminological typology and the social model of disability. *Disability & Society*, *20*(5), 539–552.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77–101.

Braun, V., & Clarke, V. (2012). *Thematic analysis.* American Psychological Association.

Brunes, A., & Heir, T. (2022). Visual impairment and employment in norway. *BMC Public Health*, *22*(1), 648.

Bundsgaard, J., & Hansen, T. (2013). Kvaliteter ved digitale læremidler og ved pædagogiske praksisser med digitale læremidler. forskningsbaseret bidrag til anbefalinger, pejlemærker og kriterier i forbindelse med udmøntning af midler til indkøb af digitale læremidler [in norwegian] [qualities of digital teaching aids and pedagogical practices with digital teaching aids. research-based contribution to recommendations, benchmarks and criteria in connection with the disbursement of funds for the purchase of digital teaching aids.] *København. Undervisningsministeriet*.

Buzzi, M. C., Buzzi, M., Leporini, B., & Mori, G. (2012). Designing e-learning collaborative tools for blind people. *E-Learning-Long-Distance and Lifelong Perspectives (2012)*, 125–144.

Card, S. K. (1983). *The psychology of human-computer interaction*. Crc Press.

CAST. (2011). Universal design for learning guidelines version 2.0 [graphic organizer]. Retrieved March 28, 2023, from https://udlguidelines.cast.org/more/downloads

Choi, J., Jung, S., Park, D. G., Choo, J., & Elmqvist, N. (2019). Visualizing for the non-visual: Enabling the visually impaired to use visualization. *Computer Graphics Forum*, *38*(3), 249–260.

Courey, S. J., Tappe, P., Siker, J., & LePage, P. (2013). Improved lesson planning with universal design for learning (udl). *Teacher education and special education*, *36*(1), 7–27.

CRD, V. (2019). Directive (eu) 2019/878 of the european parliament and of the council of 20 may 2019 amending directive 2013/36. *EU as regards exempted entities, financial holding companies, mixed financial holding companies, remuneration, supervisory measures and powers and capital conservation measures*.

Cuevas, H. M. (2004). An illustrative example of four hci design approaches for evaluating an automated system interface. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *48*(5), 892–896.

de Carvalho, P., & Fabiano, A. (2021). Thematic analysis for interactive systems design: A practical exercise. *Proceedings of 19th European Conference on Computer-Supported Cooperative Work*.

Difi. (2017). *Kartlegging av digital læremidler og læringsplattformer i utdanningssektoren [in norwegian] [mapping of digital teaching aids and learning platforms in the education sector].* https://www.uutilsynet.no/andre-rapportar/kartlegging-av-digital-laeremidler-og-laeringsplattformer-i-utdanningssektoren/943

Dini, S., Ferlino, L., Gettani, A., Martinoli, C., & Ott, M. (2007). Educational software and low vision students: Evaluating accessibility factors. *Universal Access in the Information Society*, *6*(1), 15–29.

do Nascimento, M. D., Brandão, A. A., de Oliveira Brandão, L., & de MB Oliveira, F. C. (2019). Overcoming accessibility barriers for people with severe vision impairment in web-based learning environments: A literature review. *2019 IEEE Frontiers in Education Conference (FIE)*, 1–8.

Eberts, R. E. (1994). *User interface design*. Prentice-Hall, Inc.

Edvardsen, N. K., & Gjærum, R. G. (2021). The aesthetic model of disability. *Theatre and Democracy: Building Democracy in Post-war and Post-democratic Contexts*.

Edyburn, D. L. (2005). Universal design for learning. *Special Education Technology Practice*, *7*(5), 16–22.

ETSI, C., CENELEC. (2019). Cenelec: En 301 549 v3. 1.1-accessibility requirements for ict products and services. *European Telecommunications Stan-*

dards Institute. https://www.etsi.org/deliver/etsi_en/301500_301599/301549/03.01.01_60/en_301549v030101p.pdf

EU Commission. (2016). Directive (eu) 2016/2102 of the european parliament and of the council. https://eur-lex.europa.eu/legal-content/GA/TXT/?uri=CELEX:32016L2102

Foley, A. (2011). Exploring the design, development and use of websites through accessibility and usability studies. *Journal of Educational Multimedia and Hypermedia*, *20*(4), 361–385.

Foley, A., & Ferri, B. A. (2012). Technology for people, not disabilities: Ensuring access and inclusion. *Journal of Research in Special Educational Needs*, *12*(4), 192–200.

Foreldre til blinde barn. (2022). *Diskriminering av blinde elever i norsk skole. En erfaringsbasert forskningsrapport om hvordan systemet som skal ivareta barna våre svikter [in norwegian] [discrimination of blind pupils in norwegian schools. an experience-based research report on how the system that is supposed to look after our children is failing].* Retrieved February 16, 2023, from https://ftbb.no/pdf/2022-10-31-FTBB-Diskriminering-av-blinde-elever-i-norsk-skole_v1.pdf

Forskrift. (2019). *Forskrift om universell utforming av informasjons- og kommunikasjonsteknologiske (IKT)-løsninger [for-2023-01-17-87] [in norwegian] [regulation on universal design of information and communication technology (ict) solutions]*. Retrieved March 12, 2023, from https://lovdata.no/dokument/SF/forskrift/2013-06-21-732

Frazão, T., & Duarte, C. (2020). Comparing accessibility evaluation plug-ins. *Proceedings of the 17th International Web for All Conference*, 1–11.

Fuglerud, K. S. (2011). The barriers to and benefits of use of ict for people with visual impairment. *Universal Access in Human-Computer Interaction. Design for All and eInclusion: 6th International Conference, UAHCI 2011, Held as Part of HCI International 2011, Orlando, FL, USA, July 9-14, 2011, Proceedings, Part I 6*, 452–462.

Fuglerud, K. S. (2014). *Inclusive design of ict: The challenge of diversity.* (Doctoral dissertation). University of Oslo, Faculty of Humanitites.

Fuglerud, K. S., Fyhn, T., Halbach, T., Kjæret, K., & Olsen, T. A. (2021). Teknologi og inkludering av personer med nedsatt syn i arbeidslivet: Kunnskapsoppsummering [in norwegiam] [technology and inclusion of people with impaired vision in working life: Knowledge summary].

Fuglerud, K. S., Halbach, T., Skotkjerra, S. E., & NR, N. R. (2014). Challenges with assistive technology compatibility in universal design. *Assist. Technol. Res. Ser*, *35*, 55–59.

Funka. (2021). *Universell utforming i digitale læringsressurser [in norwegian] [universal design in digital learning resources].* Retrieved April 22, 2023, from https://www.funka.com/no/uu-i-digitale-l%7B%5Cae%7Dringsressurser

Gilje, Ø., Ingulfsen, L., Dolonen, J., Furberg, A., Rasmussen, I., Kluge, A., & Granumj, K. (2016). Bruk av læremidler og ressurser for læring på tvers av arbeidsformer [in norwegian] [the use of teaching tools and resources for learning across teaching methods] ark&app report.

Gilje, Ø. (2021). På nye veier: Læremidler og digitale verktøy fra kunnskapsløftet til fagfornyelsen [in norwegian] [new perspectives on teaching material and digital tools in the periode between two curriculum reforms]. *Norsk pedagogisk tidsskrift*, *105*(2), 227–241.

Goldsmith, S. (2001). The bottom-up methodology of universal design. *Universal design handbook*, *26*.

Griful-Freixenet, J., Struyven, K., Verstichele, M., & Andries, C. (2017). Higher education students with disabilities speaking out: Perceived barriers and opportunities of the universal design for learning framework. *Disability & Society*, *32*(10), 1627–1649.

Grue, J. (2011). Discourse analysis and disability: Some topics and issues. *Discourse & Society*, *22*(5), 532–546.

Grue, L. P., & Finnvold, J. E. (2014). Hjelp eller barrierer? en undersøkelse av betingelser for høyere utdanning for ungdom med nedsatt funksjonsevne [in norwegian] [help or barriers? an investigation of conditions for higher education for young people with disabilities].

Guglielman, E. (2010). E-learning and disability: Accessibility as a contribute to inclusion. *EC-TEL Doctoral Consortium*, 31–36.

Halbach, T., & Fuglerud, K. S. (2016). On assessing the costs and benefits of universal design of ict. In *Universal design 2016: Learning from the past, designing for the future* (pp. 662–672). IOS Press.

Harper, S., Michailidou, E., & Stevens, R. (2009). Toward a definition of visual complexity as an implicit measure of cognitive load. *ACM Transactions on Applied Perception (TAP)*, *6*(2), 1–18.

Harper, S., & Yesilada, Y. (2019). *Web accessibility: A foundation for research*. Springer.

Henry, S. (2006). Understanding web accessibility. *Web Accessibility*, 1–51.

Hersh, M. A., & Johnson, M. A. (2008). Disability and assistive technology systems. *Assistive technology for visually impaired and blind people*, 1–50.

Hussain, A., & Sanderson, N. C. (2022). Challenges in implementing universal design of ict among teachers in higher education in norway. *Studies in Health Technology and Informatics*, *297*, 557–564.

IKT-senteret. (2014). *Kartlegging av digitale læringsressurser. rapport. oslo: Senter for ikt i utdanningen [in norwegian] [mapping of digital learning resources].*

Ismailova, R., & Inal, Y. (2022). Comparison of online accessibility evaluation tools: An analysis of tool effectiveness. *IEEE Access*, *10*, 58233–58239.

ISO. (1998). Ergonomic requirements for office work with visual display terminals (vdts), part 11: Guidance on usability. en iso 9241-11: 1998.

ISO. (2011). 26800: 2011: Ergonomics—general approach, principles and concepts. *International Organization for Standardization: Geneva, Switzerland*.

Iwarsson, S., & Ståhl, A. (2003). Accessibility, usability and universal design—positioning and definition of concepts describing person-environment relationships. *Disability and rehabilitation*, *25*(2), 57–66.

Jensen, B. W., & Moe, S. (2014). Accessibility in multimodal digital learning materials. *Universal Access in Human-Computer Interaction. Universal Access to Information and Knowledge: 8th International Conference, UAHCI 2014, Held as Part of HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014, Proceedings, Part II 8*, 337–348.

Keates, S. (2006). Pragmatic research issues confronting hci practitioners when designing for universal access. *Universal Access in the Information Society*, *5*, 269–278.

Kelentrić, M., Helland, K., & Arstorp, A.-T. (2017). Professional digital competence framework for teachers. *The Norwegian Centre for ICT in education*, *134*(1), 1–74.

Kharade, K., & Peese, H. (2012). Learning by e-learning for visually impaired students: Opportunities or again marginalisation? *E-learning and Digital Media*, *9*(4), 439–448.

Kieran, L., & Anderson, C. (2019). Connecting universal design for learning with culturally responsive teaching. *Education and Urban Society*, *51*(9), 1202–1216.

Kieserling, M., & Melle, I. (2019). An experimental digital learning environment with universal accessibility. *Chemistry Teacher International*, *1*(2).

Klingenberg, O. G., Holkesvik, A. H., & Augestad, L. B. (2020). Digital learning in mathematics for students with severe visual impairment: A systematic review. *British Journal of Visual Impairment*, *38*(1), 38–57.

Knight, B. A. (2015). Teachers' use of textbooks in the digital age. *Cogent education*, *2*(1), 1015812.

Kulturdepartementet. (2021). *Bærekraft og like muligheter – et universelt utformet Norge* [in norwegina] [sustainability and equal opportunities - a universally designed norway]. Retrieved April 28, 2023, from https://www.regjeringen.no/no/dokumenter/barekraft-og-like-muligheter-et-universelt-utformet-norge/id2867676/

Kunnskapsdepartementet. (2010). *Endr. i forskr til opplæringslova og privatskolelova [for-2010-06-30-1046] [in norwegian] [amendments to the provisions of the education act and the private schools act]*. Retrieved March 2, 2023, from https://lovdata.no/dokument/LTI/forskrift/2010-06-30-1046

L. Haven, T., & Van Grootel, D. L. (2019). Preregistering qualitative research. *Accountability in research*, *26*(3), 229–244.

Langørgen, E., & Magnus, E. (2018). ‘we are just ordinary people working hard to reach our goals!’disabled students’ participation in norwegian higher education. *Disability & Society*, *33*(4), 598–617.

Lawson, A. (2017). Accessibility of information, technologies and communication for persons with disabilities–contribution to the council of europe strategy on the rights of persons with disabilities, council of europe, 2017.

Lazar, J., Allen, A., Kleinman, J., & Malarkey, C. (2007). What frustrates screen reader users on the web: A study of 100 blind users. *International Journal of human-computer interaction*, *22*(3), 247–269.

Lazar, J., Feng, J. H., & Hochheiser, H. (2017a). *Research methods in human-computer interaction*. Morgan Kaufmann.

Lazar, J., Feng, J. H., & Hochheiser, H. (2017b). Working with research participants with disabilities. In *Research methods in human-computer interaction* (pp. 493–522). Morgan Kaufmann.

Leonardis, D., Claudio, L., & Frisoli, A. (2018). A survey on innovative refreshable braille display technologies. *Advances in Design for Inclusion: Proceedings of the AHFE 2017 International Conference on Design for Inclusion, July 17–21, 2017, The Westin Bonaventure Hotel, Los Angeles, California, USA 8*, 488–498.

Leporini, B., & Paternò, F. (2004). Increasing usability when interacting through screen readers. *Universal access in the information society*, *3*, 57–70.

Lewthwaite, S. (2014). Web accessibility standards and disability: Developing critical perspectives on accessibility. *Disability and Rehabilitation*, *36*(16), 1375–1383.

Maatuk, A. M., Elberkawi, E. K., Aljawarneh, S., Rashaideh, H., & Alharbi, H. (2022). The covid-19 pandemic and e-learning: Challenges and opportunities from the perspective of students and instructors. *Journal of computing in higher education*, *34*(1), 21–38.

Marcus-Quinn, A. (2022). The eu accessibility act and web accessibility directive and the implications for digital teaching and learning materials. *Routledge Open Research*, *1*(30), 30.

Marcus-Quinn, A., & Hourigan, T. (2022). Digital inclusion and accessibility considerations in digital teaching and learning materials for the second-level classroom. *Irish Educational Studies*, *41*(1), 161–169.

McAlvage, K., & Rice, M. (2018). Access and accessibility in online learning: Issues in higher education and k-12 contexts. from" olc outlook: An environmental scan of the digital learning landscape". *Online Learning Consortium*.

Meier, E. (2015). Beyond a digital status quo: Re-conceptualizing online learning opportunities. *Occasional Paper Series*, *2015*(34), 2.

Mordal, S., Buland, T., Midtgård, T. M., Wendelborg, C., Wik, S. E., & Tøssebro, J. (2020). Betydningen av hjelpemidler og tilrettelegging for funksjonshemmede barn og unges mestring og deltakelse i skolen [in norwegian] [the importance of assistive technologies and adaptation for disabled children and young people's coping and participation in school]. *SINTEF-rapport*, *647*. Retrieved April 20, 2023, from https://www.nav.no/no/nav-og-samfunn/kunnskap/forskningsrapporter-og-evalueringer-finansiert-av-nav/rapporter-navs-tiltak-og-virkemidler/betydningen-av-hjelpemidler-og-tilrettelegging-for-funksjonshemmede-barn-og-unges-mestring-og-deltakelse-i-skolen

Nicolau, H., & Montague, K. (2019). Assistive technologies. *Web Accessibility: A Foundation for Research*, 317–335.

Nielsen, J. (2012). *Usability 101: Introduction to usability*. Retrieved April 16, 2023, from http://www.nngroup.com/articles/usability-101-introduction-to-usability/

Nīmante, D., Kalniņa, D., & Baranova, S. (2022). Towards an inclusive digital learning environment in higher education: Opportunities and limitations gleaned from working students' remote learning experiences during covid-19. In *Inclusive digital education* (pp. 213–226). Springer.

NOU 2001:22. (2001). *Fra bruker til borger. En strategi for nedbygging av funksjonshemmende barrierer* [in norwegian] [from user to citizen. a strategy for breaking down disability barriers]. https://www.regjeringen.no/contentassets/1e18b045dd9346849813392b34c9cdc1/no/pdfa/nou200120010022000dddpdfa.pdf

Nygaard, K. M. (2017). What is universal design-theories, terms and trends.

Oslo Economics. (2022). *Universell utforming av digitale læremidler – en analyse av status og relevante tiltak. rapport utarbeidet til barne-, ungdoms- og familiedirektoratet [in norwegian] [universal design of digital teaching aids – an analysis of status and relevant measures. report prepared for the directorate for children, youth and families]*. https://osloeconomics.no/wp-content/uploads/2022/01/OE-rapport-2021-69-Universell-utforming-av-digitale-laeremidler-i-grunnskolen.pdf

Ostroff, E. (2011). Universal design: An evolving paradigm. *Universal design handbook*.

Owens, J. (2015). Exploring the critiques of the social model of disability: The transformative possibility of arendt's notion of power. *Sociology of health & illness*, *37*(3), 385–403.

Persson, H., Åhman, H., Yngling, A. A., & Gulliksen, J. (2015). Universal design, inclusive design, accessible design, design for all: Different concepts—one goal? on the concept of accessibility—historical, methodological and philosophical aspects. *Universal Access in the Information Society*, *14*, 505–526.

Petersen, M. A., & Ulk, R. (2010). Digitale læremidler, antropologi og et kvalitativt udgangspunkt i brugerne [in danish] [digital teaching aids, anthropology and a qualitative starting point in the users]. *Læremiddeldidaktik*, *3*(2), 4–9.

Petrie, H., Savva, A., & Power, C. (2015). Towards a unified definition of web accessibility. *Proceedings of the 12th International Web for All Conference*, 1–13.

Pisha, B., & Coyne, P. (2001). Smart from the start: The promise of universal design for learning. *Remedial and special education*, *22*(4), 197–203.

Powlik, J. J., & Karshmer, A. I. (2002). When accessibility meets usability. *Universal Access in the Information Society*, *1*, 217–222.

Prensky, M. (2001). Digital natives, digital immigrants part 2: Do they really think differently? *On the horizon*.

Proba Research. (2018). *Barrierer i høyere utdanning for personer med nedsatt funksjonsevne. utarbeidet for barne-, ungdoms- og familiedirektoratet [in norwegian] [barriers in higher education for people with disabilities. prepared for the directorate for children, youth and families]*.

Proba Research. (2019). *Universell utforming av ikt med vekt på læremidler i uh-sektoren. utarbeidet for nlb og universell [in norwegian] [universal design of ict with an emphasis on teaching aids in the he sector. prepared for nlb and universal]*. https://proba.no/rapport/universell-utforming-av-ikt-med-vekt-pa-laeremidler-i-uh-sektoren/

Ramakrishnan, I., Ashok, V., & Billah, S. M. (2017). Non-visual web browsing: Beyond web accessibility. *Universal Access in Human–Computer Interaction. Designing Novel Interactions: 11th International Conference, UAHCI 2017, Held as Part of HCI International 2017, Vancouver, BC, Canada, July 9–14, 2017, Proceedings, Part II 11*, 322–334.

Ramboll. (2015). *Evaluering og behovsundersøkelse av læremidler med statstilskudd [in norwegian] [evaluation and needs survey of teaching aids with state subsidies]*.

Rampin, R., & Rampin, V. (2021). Taguette: Open-source qualitative data analysis. *Journal of Open Source Software*, *6*(68), 3522.

Rice, M. F., & Ortiz, K. R. (2020). Perceptions of accessibility in online course materials: A survey of teachers from six virtual schools. *Journal of Online Learning Research*, *6*(3), 245–264.

Rice, M. F., & Ortiz, K. R. (2021). Evaluating digital instructional materials for k-12 online and blended learning. *TechTrends*, *65*(6), 977–992.

Rioux, M., & Carbert, A. (2003). Human rights and disability: The international context.

Rohatgi, A., Bundsgaard, J., & Hatlevik, O. E. (2020). Digital inclusion in norwegian and danish schools—analysing variation in teachers' collaboration, attitudes, ict use and students' ict literacy. *Equity, equality and diversity in the Nordic model of education*, 139–172.

Rose, D. (2000). Universal design for learning. *Journal of Special Education Technology*, *15*(4), 47–51.

Rose, D. H., Hasselbring, T. S., Stahl, S., & Zabala, J. (2005). Assistive technology and universal design for learning: Two sides of the same coin. *Handbook of special education technology research and practice*, 507–518.

Rose, M. R. (2018). *It's all in the design: The importance of making courses legally accessible.* Retrieved April 16, 2023, from https://www.qualitymatters.org/sites/default/files/presentations/its_all_design_the_importance_making_courses_legally_accessible.pdf

Saarinen, A. (2020). *Equality in cognitive learning outcomes: The roles of educational practices.* (Doctoral dissertation). University of Helsinki.

Sanderson, N. C., Kessel, S., & Chen, W. (2022). What do faculty members know about universal design and digital accessibility? a qualitative study in computer science and engineering disciplines. *Universal Access in the Information Society*, *21*(2), 351–365.

Seale, J., Boyle, T., Ingraham, B., & Roberts, G. (2006). Designing digital resources for learning. In *Contemporary perspectives in e-learning research* (pp. 139–151). Routledge.

Seifert, A., Cotten, S. R., & Xie, B. (2021). A double burden of exclusion? digital and social exclusion of older adults in times of covid-19. *The Journals of Gerontology: Series B*, *76*(3), e99–e103.

Shakespeare, T., et al. (2006). The social model of disability. *The disability studies reader*, *2*, 197–204.

Shneiderman, B., & Plaisant, C. (2005). *Designing the user interface: Strategies for effective human-computer interaction*. Pearson Education Inc.

Smith, S. J., & Stahl, W. (2016). Determining the accessibility of k-12 digital materials: Tools for educators. *Journal of Special Education Leadership*, *29*(2), 89–100.

Sosialdepartementet. (2003). Nedbygging av funksjonshemmende barrierer: Strategier, mål og tiltak i politikken for personer med nedsatt funksjonsevne [dismantling disabling barriers: Strategies, goals and measures in politics for people with impairments]. oslo, norway: Sosialdepartementet.

Statped. (2022). *Årsrapport 2022 [in norwegian] [annual report 2022]*. Retrieved May 1, 2023, from https://www.statped.no/globalassets/om-statped/arsrapporter/2022/statped_-arsrapport-2022.pdf

Ştefan, I. A., Hauge, J. B., Sallinen, N., Ştefan, A., & Gheorghe, A. F. (2021). Accessibility and education: Are we fulfilling state of the art requirements? *The*

International Scientific Conference eLearning and Software for Education, *1*, 579–587.

Story, M. F. (2001). Principles of universal design. *Universal design handbook*, *2*.

Tadesse, S., & Muluye, W. (2020). The impact of covid-19 pandemic on education system in developing countries: A review. *Open Journal of Social Sciences*, *8*(10), 159–170.

Takagi, H., Asakawa, C., Fukuda, K., & Maeda, J. (2003). Accessibility designer: Visualizing usability for the blind. *ACM SIGACCESS accessibility and computing*, (77-78), 177–184.

Terry, G., Hayfield, N., Clarke, V., & Braun, V. (2017). Thematic analysis. *The SAGE handbook of qualitative research in psychology*, *2*, 17–37.

Theofanos, M. F., & Redish, J. (2003). Bridging the gap: Between accessibility and usability. *interactions*, *10*(6), 36–51.

Tøssebro, J. (2004). Introduction to the special issue: Understanding disability.

United Nations. (1975). Declaration on the rights of disabled persons. *Official records of the General Assembly, Thirtieth Session*, (s34).

United Nations. (2008). *Convention on the rights of persons with disabilities*. Retrieved March 20, 2023, from https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities/optional-protocol-to-the-convention-on-the-rights-of-persons-with-disabilities.html

United Nations. (2015). *Transforming our world : the 2030 Agenda for Sustainable Development, 21 October 2015, A/RES/70/1.* Retrieved April 15, 2023, from https://www.refworld.org/docid/57b6e3e44.html

Vigo, M., Brown, J., & Conway, V. (2013). Benchmarking web accessibility evaluation tools: Measuring the harm of sole reliance on automated tests. *Proceedings of the 10th international cross-disciplinary conference on web accessibility*, 1–10.

Warschauer, M. (2004). *Technology and social inclusion: Rethinking the digital divide*. MIT press.

Whitenton, K. (2013). Minimize cognitive load to maximize usability. *Nielsen Norman Group*, *22*.

Winner, L. (1980). Do artifacts have politics? In *Computer ethics* (pp. 177–192). Routledge.

World Health Organization. (2011). *World report on disability 2011*.

World Health Organization. (2019a). International classification of diseases 11. 2018.

World Health Organization. (2019b). World report on vision.

World Health Organization and others. (2013). How to use the icf: A practical manual for using the international classification of functioning, disability and health (icf). *Exposure draft for comment. Geneva: WHO*, *13*.

World Wide Web Consortium. (2018). Web content accessibility guidelines (wcag) 2.1: W3c recommendation 05 june 2018.

Yuan, H., Li, S., Rusconi, P., Yuan, H., Li, S., & Rusconi, P. (2020). Cognitive approaches to human computer interaction. *Cognitive Modeling for Automated Human Performance Evaluation at Scale*, 5–15.

A Sikt: Assessment of processing of personal data

Sikt

Notification form / Accessibility of digital learning materials: Identifying barriers i... / Assessment

Assessment of processing of personal data

Reference number	Assessment type	Date
831358	Standard	17.02.2023

Project title
Accessibility of digital learning materials: Identifying barriers in digital learning materials

Data controller (institution responsible for the project)
OsloMet – storbyuniversitetet / Fakultet for teknologi, kunst og design / Institutt for informasjonsteknologi

Project leader
Norun Christine Sanderson

Student
Stephen Simei Kimogol

Project period
01.02.2023 - 01.09.2023

Categories of personal data
General
Special

Legal basis
Consent (General Data Protection Regulation art. 6 nr. 1 a)
Explicit consent (General Data Protection Regulation art. 9 nr. 2 a)

The processing of personal data is lawful, so long as it is carried out as stated in the notification form. The legal basis is valid until 01.09.2023.

Notification Form

Comment
ABOUT OUR ASSESSMENT
Data Protection Services has an agreement with the institution where you are carrying out research or studying. As part of this agreement, we provide guidance so that the processing of personal data in your project is lawful and complies with data protection legislation.

PARENTAL CONSENT
The project will gain consent from the parent for the processing of personal data about children under the age of 16. Our assessment is that the project facilitates for consent in compliance the necessary requirements under art. 4 (11) and 7, in that it will be a freely given, specific, informed, and unambiguous statement or action, which will be documented and which the registered/parent can withdraw.

FOLLOW YOUR INSTITUTION'S GUIDELINES
We have assessed that you have a legal basis to process the personal data, but remember that it is the institution you are employed/study at that decides which data processors you can use and how you must store and secure data in your project. Remember to use suppliers that your institution has an agreement with (e.g. for cloud storage, online questionnaires, video calls, etc.)

Sikt

Notification form / Accessibility of digital learning materials: Identifying barriers i... / Assessment

Assessment of processing of personal data

Reference number	Assessment type	Date
831358	Standard	17.02.2023

Project title
Accessibility of digital learning materials: Identifying barriers in digital learning materials

Data controller (institution responsible for the project)
OsloMet – storbyuniversitetet / Fakultet for teknologi, kunst og design / Institutt for informasjonsteknologi

Project leader
Norun Christine Sanderson

Student
Stephen Simei Kimogol

Project period
01.02.2023 - 01.09.2023

Categories of personal data
General
Special

Legal basis
Consent (General Data Protection Regulation art. 6 nr. 1 a)
Explicit consent (General Data Protection Regulation art. 9 nr. 2 a)

The processing of personal data is lawful, so long as it is carried out as stated in the notification form. The legal basis is valid until 01.09.2023.

Notification Form

Comment
ABOUT OUR ASSESSMENT
Data Protection Services has an agreement with the institution where you are carrying out research or studying. As part of this agreement, we provide guidance so that the processing of personal data in your project is lawful and complies with data protection legislation.

PARENTAL CONSENT
The project will gain consent from the parent for the processing of personal data about children under the age of 16. Our assessment is that the project facilitates for consent in compliance the necessary requirements under art. 4 (11) and 7, in that it will be a freely given, specific, informed, and unambiguous statement or action, which will be documented and which the registered/parent can withdraw.

FOLLOW YOUR INSTITUTION'S GUIDELINES
We have assessed that you have a legal basis to process the personal data, but remember that it is the institution you are employed/study at that decides which data processors you can use and how you must store and secure data in your project. Remember to use suppliers that your institution has an agreement with (e.g. for cloud storage, online questionnaires, video calls, etc.)

We presuppose that the project will meet the requirements of accuracy (art. 5.1 d), integrity and confidentiality (art. 5.1 f) and security (art. 32) when processing personal data.

NOTIFY CHANGES
If you intend to make changes to the processing of personal data in this project it may be necessary to notify us. This is done by updating the Notification Form. On our website we explain which changes must be notified: https://sikt.no/en/notify-changes-notification-form

FOLLOW-UP OF THE PROJECT
We will follow up the progress of the project at the planned end date in order to determine whether the processing of personal data has been concluded.

Good luck with the project!

B Information letter to students (in Norwegian)

Vil du delta i forskningsprosjektet ”Tilgjengelighet av digitale læremidler: Kartlegge barrierer i bruk av digitale i digitalt læremidler”

Hei! Har du lyst å være med i et forskningsprosjekt? Vi ønsker å finne ut utfordringer og barrierer elever møter når de bruker digitale læremidler.

Formål I dette prosjektet vil vi finne ut hvordan elever med synshemming bruker digitale læremidler og kartlegge utfordringer og barrierer elevene møter.

Vi har lyst å snakke med deg om digital læremidler. Vi håper du vil være med!

Vi vil for eksempel stille deg spørsmål som: Hva er dine erfaringer når det gjelder bruk av digitale læremidler? Hvilke barrierer møter du i forhold til navigasjon av tabeller og lister i digitale læremidler.

Dette prosjektet er et forskningsprosjekt fra Oslomet

Hvem leder forskningsprosjektet? Forskeren heter Stephen Simei Kimogol. Jeg er student ved Oslomet og går på andre år master graden min (Anvendt data- og informasjonsteknologi – Universell utforming av IKT). Jeg jobber også som utvikler i Statped divisjon for læremidler og læringsressurser.

Det er også en forsker fra Oslomet med i prosjektet. Hun heter Norun Christine Sanderson.

Hvorfor får du spørsmål om å delta? Vi spør deg om å være med fordi du er elev ved videregående skole.

Vi vet enda ikke hvem du er eller hva du heter, men din kontaktperson (institusjon) gir deg dette brevet fra oss.

Hvis du har lyst å være med i forskningsprosjektet, må du/foresatte skrive under på siste ark i dette brevet, og da vil vi ta kontakt med deg.

Hvis du ikke har lyst å være med, tar vi ikke kontakt med deg.

Hva betyr det for deg å delta? Hvis du har lyst å delta i forskningsprosjektet, vil vi ha et individuelt intervju med deg. Et intervju er en samtale der vi stiller deg forskjellige spørsmål. Spørsmålene vil handle om digitale læremidler.

Stephen vil være med under intervjuet, og vi vil gjøre lydopptak av intervjuet. Intervjuet vil ta ca. 45 minutter.

Det er frivillig å delta Det er frivillig å delta i prosjektet. Det betyr at du kan velge selv om du har lyst å være med eller ikke. Ingen andre kan velge dette for deg. Det er bare du som kan samtykke. Samtykke betyr at du sier at du synes noe er greit.

Hvis du vil delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Det betyr at det er lov å ombestemme seg, og det er helt i orden. All informasjon om deg vil da bli slettet.

Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller om du først sier «ja» og så «nei». Ingen vil bli sur eller lei seg, og det vil ikke ha noe å si for skolen din.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger Vi vil bare bruke informasjonen om deg til å finne ut tilgjengelighet av digital læremidler Vi vil ikke dele din informasjon med andre. Det er bare forsker Stephen Simei Kimogol som har tilgang til informasjonen. Vi passer på at ingen kan få tak i informasjonen som vi samler inn om deg. Vi lagrer all informasjon på en sikker datamaskin. Vi sletter lydopptak fra intervjuet når vi har skrevet ned alt som vi har snakket om. Vi passer på at ingen kan kjenne deg igjen når vi skriver forskningsartikler. Vi vil for eksempel finne opp et annet navn når vi skriver om deg. Navnet og kontaktopplysningene dine vil jeg erstatte med en kode som lagres på en egen navneliste adskilt fra øvrige data. Denne navnelisten vil være beskyttet med passord og kryptert. Det anonymiserte datamaterialet vil lagres i samsvar med kravene ved OsloMet til lagring av forskningsdata. Vi følger loven om personvern.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet? Opplysningene anonymiseres når prosjektet avsluttes, noe som etter planen er 01.09.2023 Alle personopplysninger og lydopptak vil da bli slettet.

Dine rettigheter Du har rett til å se hvilken informasjon som vi samler inn om deg. Du kan også be om at informasjonen slettes, slik at den ikke finnes lenger. Dersom det er noe informasjon som er feil, kan du si ifra og be forskeren rette opp i det. Du kan også spørre om å få en kopi av informasjonen av oss. Du kan også klage til Datatilsynet dersom du synes at vi har behandlet informasjonen om deg på en uforsiktig måte eller på en måte som ikke er riktig.

Hva gir oss rett til å behandle personopplysninger om deg? Vi behandler informasjon om deg bare hvis du sier at det er greit og du skriver under på samtykkeskjemaet.

Hvor kan jeg finne ut mer? Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med: • Stephen Simei Kimogol på mobil: 41395962 eller på epost: s361647@oslomet.no • Prosjektansvarlig for OsloMet: Norun Christine Sanderson på epost: nsand@oslomet.no eller på telefon: 67 23 86 73. • Personvernkontakt ved Fakultet for Teknologi, Kunst, og Design: Cecilia Roberts på epost: Cecilia.Roberts@oslomet.no eller på telefon: 67 23 85 56. • Vårt personvernombud ved OsloMet: Anne Bjørtuft på epost: Anne.Bjortuft@oslomet.no eller på telefon: 67 23 54 21. Du kan også kontakte personvernombudet på epost: personvern@oslomet.no.

Sikts personverntjenester har gitt oss råd om hvordan vi skal gjøre dette forskningsprosjektet. Dersom du har spørsmål til Sikt som handler om dette prosjektet, kan du kontakte dem på e-post (personverntjenester@sikt.no) eller telefon 73 98 40 40.

Med vennlig hilsen,

Stephen Simei Kimogol

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet 'Tilgjengelighet av digitale læremidler: Kartlegge barrierer i bruk av digitale i digitalt læremidler' og har fått anledning til å stille spørsmål. Jeg samtykker til:

• å delta i intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

———- (Signert av prosjektdeltaker, dato)

C Information letter to teachers (in Norwegian)

Vil du delta i forskningsprosjektet ”Tilgjengelighet av digitale læremidler: Kartlegge barrierer i bruk av digitale i digitalt læremidler”?

Hei! Har du lyst å være med i et forskningsprosjekt? Vi ønsker å finne ut barrierer elever møter når de bruker digitale læremidler.

Formål I dette prosjektet vil vi finne ut hvordan elever med synshemming bruker digitalt læremidler og kartlegge utfordringer og barrierer elevene møter.

Vi har lyst å snakke med deg om digital læremidler. Vi håper du vil være med!

Vi vil for eksempel stille deg spørsmål som: Hva er dine erfaringer når det gjelder bruk av digitale læremidler (fra forlagene og det du lager selv)? Hvilke typer/formater digital læremidler bruker du per nå – og for hvert fag?

Dette prosjektet er et forskningsprosjekt fra Oslomet

Hvem leder forskningsprosjektet? Forskeren heter Stephen Simei Kimogol. Jeg er student ved Oslomet og går på andre år master graden min (Anvendt data- og informasjonsteknologi – Universell utforming av IKT). Jeg også jobber som utvikler i Statped divisjon for læremidler og læringsressurser.

Det er også en forsker fra Oslomet med i prosjektet. Hun heter Norun Christine Sanderson.

Hvorfor får du spørsmål om å delta? Vi spør deg om å være med fordi du er lærer på videregående skole.

Vi vet enda ikke hvem du er eller hva du heter, men din kontaktperson (institusjon) gir deg dette brevet fra oss.

Hvis du har lyst å være med i forskningsprosjektet, må du skrive under på siste ark i dette brevet, og da vil vi ta kontakt med deg.

Hvis du ikke har lyst å være med, tar vi ikke kontakt med deg.

Hva betyr det for deg å delta? Hvis du har lyst å delta i forskningsprosjektet, vil vi ha et individuelt intervju med deg. Spørsmålene vil handle om digitale læremidler.

Stephen vil være med under intervjuet, og vi vil gjøre lydopptak av intervjuet. Intervjuet vil ta ca. 45 minutter.

Det er frivillig å delta Det er frivillig å delta i prosjektet. Det betyr at du kan velge selv om du har lyst å være med eller ikke. Ingen andre kan velge dette for deg. Det er bare du som kan samtykke. Samtykke betyr at du sier at du synes noe er greit.

Hvis du vil delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Det betyr at det er lov å ombestemme seg, og det er helt i orden. All informasjon om deg vil da bli slettet.

Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller om du først sier «ja» og så «nei». Ingen vil bli sur eller lei seg, og det vil ikke ha noe å si for skolen din.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger Vi vil bare bruke informasjonen om deg til å finne ut tilgjengelighet av digital læremidler Vi vil ikke dele din informasjon med andre. Det er bare forsker Stephen Simei Kimogol som har tilgang til informasjonen. Vi passer på at ingen kan få tak i informasjonen som vi samler inn om deg. Vi lagrer all informasjon på en sikker datamaskin. Vi sletter lydopptak fra intervjuet når vi har skrevet ned alt som vi har snakket om. Vi passer på at ingen kan kjenne deg igjen når vi skriver forskningsartikler. Vi vil for eksempel finne opp et annet navn når vi skriver om deg. Navnet og kontaktopplysningene dine vil jeg erstatte med en kode som lagres på en egen navneliste adskilt fra øvrige data. Denne navnelisten vil være beskyttet med passord og kryptert. Det anonymiserte datamaterialet vil lagres i samsvar med kravene ved OsloMet til lagring av forskningsdata.

Vi følger loven om personvern.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet? Opplysningene anonymiseres når prosjektet avsluttes, noe som etter planen er 01.09.2023 Alle personopplysninger og lydopptak vil da bli slettet.

Dine rettigheter Du har rett til å se hvilken informasjon som vi samler inn om deg. Du kan også be om at informasjonen slettes, slik at den ikke finnes lenger. Dersom det er noe informasjon som er feil, kan du si ifra og be forskeren rette opp i det. Du kan også spørre om å få en kopi av informasjonen av oss. Du kan også klage til Datatilsynet dersom du synes at vi har behandlet informasjonen om deg på en uforsiktig måte eller på en måte som ikke er riktig.

Hva gir oss rett til å behandle personopplysninger om deg? Vi behandler informasjon om deg bare hvis du sier at det er greit og du skriver under på samtykkeskjemaet.

Hvor kan jeg finne ut mer?

Hvor kan jeg finne ut mer? Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med: • Stephen Simei Kimogol tlf: 41395962 eller epost: s361647@oslomet.no • Prosjektansvarlig for OsloMet: Norun Christine Sanderson på epost: nsand@oslomet.no eller på telefon: 67 23 86 73. • Personvernkontakt ved Fakultet for Teknologi, Kunst, og Design: Cecilia Roberts på epost: Cecilia.Roberts@oslomet.no eller på telefon: 67 23 85 56. • Vårt personvernombud ved OsloMet: Anne Bjørtuft på epost: Anne.Bjortuft@oslomet.no eller på telefon: 67 23 54 21. Du kan også kontakte personvernombudet på epost: personvern@oslomet.no.

Sikts personverntjenester har gitt oss råd om hvordan vi skal gjøre dette forskningsprosjektet. Dersom du har spørsmål til Sikt som handler om dette prosjektet, kan du kontakte dem på e-post (personverntjenester@sikt.no) eller telefon 73 98 40 40.

Med vennlig hilsen,

Stephen Simei Kimogol

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet 'Tilgjengelighet av digitale læremidler: Kartlegge barrierer i bruk av digitale i digitalt læremidler' og har fått anledning til å stille spørsmål. Jeg samtykker til:

• å delta i intervju

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

——————————————————————————

——- (Signert av prosjektdeltaker, dato)

D Interview guide

The study will investigate the accessibility and usability of digital learning material by identifying the barriers faced by students with visual impairment when using these resources. The study will also seek to understand how accessibility and usability or lack of it partially or fully affect their learning process from teachers and students perspective.

The research questions: The study will seek to answer this central research question: 1. What are the barriers that high school student with visual impairment face when using digital learning materials? The following guiding question have been formulated to guide the data collection process:

1. What are the challenges that student face when using digital learning materials?
2. What are the barriers they face with relation to navigation, tables, list, and representations such as images and videos.
3. What are the challenges they face with subjects such as sciences and mathematics that have many formulas or equations. For example, using screen reader to read equations
4. Compatibility with other user agents they use such as screen readers and refreshable braille and challenges that arise with usage of digital learning materials which are inbuilt inside a certain software or platform?
5. What perspectives do teachers have on accessibility and usability of digital learning material and the effect it has on learning process. How does availability of universally designed digital learning materials or lack of it affect the choice of literature they use in teaching.

Interview guide: The interview will be semi-structured, and the question asked are open-ended questions.

Students

1. General experience of use digital learning materials

2. What types of digital learning do they use as of now – and for each subject e.g are they using Docx, HTML, ePUB, audiobooks with synthetic voice or with the human voice? What do they prefer and why?
3. Navigation: - Experiences with the use of navigation with screen reader and refreshable braille - what works well and what doesn't work so well. - Navigation of tables and lists.
4. Videos and Images – if the alternative text or image description given is satisfactory and related? If they get transcriptions for videos? If the audio files are compatible with their computers?
5. Experiences of books that are only found inside a certain platform – that is probably not downloadable? Does the platform affect their learning? Do they use more time learning the usage of that platform rather than concentrating on the content of the textbooks?
6. In-class experiences – how they interact with digital learning materials while following the teachers' instructions e.g., navigating to a page-specific page.

Teachers

1. General experience of use digital learning materials when teaching
2. Do they find all material from one book? And if they need to use material from different textbooks – how does the lack of universal design of these books affect their choices of lessons and content?
3. Do they provide lesson slides before class to students with visual impairment? Do they consider the accessibility of these files?
4. Do they get books in different formats from publishers? What is their experience on the level of universal design of these books? Do they prefer adapted books (tilrettelagt læremidler) from Statped and why?

E Online questionnaire

Nettskjema

Digitale læremidlers tilgjengelighet

Jeg heter Stephen Simei Kimogol og jeg studerer mastergrad i anvendt data- og informasjonsteknologi – Universell utforming av IKT ved Oslomet. Jeg jobber som utvikler i Statped - divisjon for læremidler og læringsressurser - avdeling læremidler syn. I dette prosjektet vil jeg finne ut hvordan elever som er blinde eller svaksynte bruker digitale læremidler og kartlegge utfordringer og barrierer elever møter. For å lære mer om dette, har jeg laget en spørreundersøkelse. Undersøkelsen består av 22 spørsmål for blinde og 25 spørsmål for svaksynte elever. Undersøkelsen er anonym, og det er frivillig å delta, og ved å fylle ut og sende inn dette nettskjemaet samtykker du til å delta i denne undersøkelsen.
Jeg håper du vil bruke litt av din tid til å svare på spørreundersøkelsen, slik at jeg får bedre innsikt i hvordan elever som leser punktskrift, bruker lyd, eller forstørring opplever digitale læremidler i videregående skole, og kan ta med eventuelle funn til avdeling læremidler syn.

Hvilket videregående trinn tar du?

Hvilken type synshemming har du?

Blind
Svaksynt

Er det noen fag der du ikke får digitale læremidler?

Ja
Nei

Hvis ja, vennligst spesifiser navnet på faget.

Bruker du digitale læremidler som Kikora, Itslearning eller Skolestudio på skolen?

Ja
Nei

Hvis ja, vennligst spesifiser navnet på verktøy.

Hvor lett synes du det er å bruke plattformen totalt sett?

Meget lett
Lett
Verken lett eller vanskelig
Vanskelig
Veldig vanskelig

Hvor ofte, om noen gang, får du hjelp til å logge deg på plattformen?

Aldri
Sjelden
Av og til
Jevnlig
Hver gang

Hvor ofte, om noen gang, får du hjelp til å navigere gjennom digitale læremidlene?

Aldri

Nettskjema

Digitale læremidlers tilgjengelighet

Jeg heter Stephen Simei Kimogol og jeg studerer mastergrad i anvendt data- og informasjonsteknologi – Universell utforming av IKT ved Oslomet. Jeg jobber som utvikler i Statped - divisjon for læremidler og læringsressurser - avdeling læremidler syn. I dette prosjektet vil jeg finne ut hvordan elever som er blinde eller svaksynte bruker digitale læremidler og kartlegge utfordringer og barrierer elever møter. For å lære mer om dette, har jeg laget en spørreundersøkelse. Undersøkelsen består av 22 spørsmål for blinde og 25 spørsmål for svaksynte elever. Undersøkelsen er anonym, og det er frivillig å delta, og ved å fylle ut og sende inn dette nettskjemaet samtykker du til å delta i denne undersøkelsen.
Jeg håper du vil bruke litt av din tid til å svare på spørreundersøkelsen, slik at jeg får bedre innsikt i hvordan elever som leser punktskrift, bruker lyd, eller forstørring opplever digitale læremidler i videregående skole, og kan ta med eventuelle funn til avdeling læremidler syn.

Hvilket videregående trinn tar du?

Hvilken type synshemming har du?

Blind

Svaksynt

Er det noen fag der du ikke får digitale læremidler?

Ja

Nei

Hvis ja, vennligst spesifiser navnet på faget.

Bruker du digitale læremidler som Kikora, Itslearning eller Skolestudio på skolen?

Ja

Nei

Hvis ja, vennligst spesifiser navnet på verktøy.

Hvor lett synes du det er å bruke plattformen totalt sett?

Meget lett

Lett

Verken lett eller vanskelig

Vanskelig

Veldig vanskelig

Hvor ofte, om noen gang, får du hjelp til å logge deg på plattformen?

Aldri

Sjelden

Av og til

Jevnlig

Hver gang

Hvor ofte, om noen gang, får du hjelp til å navigere gjennom digitale læremidlene?

Aldri

Sjelden
Av og til
Jevnlig
Hver gang

Hvor enkelt er det å navigere gjennom digitale læremidler mens du følger forelesningen?

Meget lett
Lett
Verken lett eller vanskelig
Vanskelig
Veldig vanskelig

Kan du navigere læremidlene med hurtigtaster?

Ja
Nei

Bruker du skjermleser?

Ja
Nei

Hvis ja, spesifiser eventuelt hvilken programvare du bruker. For eksempel JAWS

Bruker du leselist?

Ja
Nei

Er de digitale læremidlene tilgjengelige med de hjelpemidlene du bruker som leselist og skjermleser?

Hvor ofte, om noen gang, må læreren kopiere tekst fra det digitale læremidlet til et word-dokument fordi det er ikke tilgjengelig?

Aldri
Sjelden
Av og til
Jevnlig
Hver gang

Hvis det er animasjon eller video i de digitale læremidlene du bruker, er det noen tekst eller tale som forklarer dem?

Får du en forklarende tekst for bilder?

Ja
Nei

Hvis de digitale læremidlene setter tidsbegrensninger for enkelte handlinger, kan du enkelt forlenge eller avvikle disse tidsbegrensningene?

I de digitale læremidlene du bruker, er det mulig å øke skriftstørrelsen og justere konstrast for bedre leselighet?

Dette elementet vises kun dersom alternativet «Svaksynt» er valgt i spørsmålet «Hvilken type synshemming har du?»

Ja

Nei

I de digitale læremidlene du bruker, er det mulig å øke skriftstørrelsen med forstørringsprogramme som Zoomtext, Supernova og Magic?

Dette elementet vises kun dersom alternativet «Svaksynt» er valgt i spørsmålet «Hvilken type synshemming har du?»

Ja

Nei

I de digitale læremidlene du bruker, er det mulig å endre utseende og størrelse på markør og musepeker?

Dette elementet vises kun dersom alternativet «Svaksynt» er valgt i spørsmålet «Hvilken type synshemming har du?»

Ja

Nei

Bruker du læremidler tilrettelagt av Statped?

Ja

Nei

Får du tilrettelagt læremidlene fra Statped i tide?

Ja

Nei

Skriv et forslag her til hvordan et læremiddel etter din mening kan være mer tilgjengelig.