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Magno: An Application for Early Detection of Dyslexia

Implementing Role-Based Access Control and Enhancing Pupil Follow-Up

Master's thesis in Computer Science
Supervisor: John Krogstie
June 2023

Master's thesis

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Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Computer Science

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Abstract

Magno is an application serving as a digital screening tool for dyslexia. Its primary goal is to facilitate early detection, limiting the negative impacts on individuals' educational achievements and overall well-being. This study aims to enhance and expand the functionality of Magno, with a focus on streamlining administrative tasks and improving security measures. The study addresses several research questions pertaining to role-based access control (RBAC), the implementation of additional features to support teachers in efficient pupil follow-up, the perceived usefulness of the enhanced application, and the potential challenges associated with its implementation. Based on a set of relevant requirements, design sketches are created and tested through qualitative interviews. Following, the functionality and features are implemented and evaluated through a quantitative usability questionnaire. The solution integrates distinct user roles, practical features for seamless pupil follow-up, and enhanced authentication and authorization mechanisms. Notably, the implementation results in a System Usability Scale (SUS) score of 92.8, indicating a higher level of usability compared to results from previous usability tests on Magno [1]. By combining the implementations and findings from this thesis with recommendations for further work, Magno will become a practical support tool for teachers, contributing to the overall goal of streamlining the dyslexia detection and intervention process in Norwegian schools.

Sammendrag

Magno er et digitalt screeningsverktøy for dysleksi. Applikasjonens formål er å tilrettelegge for tidlig deteksjon av dysleksi, og dermed begrense de negative konsekvensene på enkeltpersoners akademiske prestasjoner og selvfølelse. Denne masteroppgaven har som mål å videreutvikle Magno, med fokus på å effektivisere administrative oppgaver og styrke sikkerhetstiltak. Studien tar for seg flere forskningsspørsmål knyttet til rollebaserte tilganger, implementeringen av funksjoner for å støtte lærere i effektiv oppfølging av elever, opplevd nytteverdi av den forbedrede applikasjonen og potensielle utfordringer knyttet til anvendelsen av Magno i skolen. Basert på en rekke relevante systemkrav, blir designskisser utviklet og testet gjennom kvalitative intervjuer. Deretter blir funksjonaliteten implementert og evaluert gjennom en kvantitativ brukertest. Løsningen integrerer ulike brukerroller, praktiske funksjoner for effektiv oppfølging av elever og forbedrede autentiserings- og autorisasjonsmekanismer. Den oppdaterte applikasjonen har en bemerkelsesverdig System Usability Scale (SUS) score på 92,8, noe som indikerer en høyere brukervennlighet sammenlignet med resultater fra tidligere tester av Magno [1]. Ved å kombinere implementeringene og funnene fra denne masteroppgaven med anbefalinger for videre arbeid, vil Magno på sikt kunne bli et praktisk støtteverktøy for lærere, og bidra til det overordnede målet om å effektivisere prosessen med tidlig oppdagelse og oppfølging av elever med dysleksi i norske skoler.

Preface

The completion of this Master's was carried out during the Spring of 2023 at the Norwegian University of Science and Technology (NTNU) in Trondheim. The research was conducted under the Department of Computer Science. We would like to take this opportunity to express our gratitude to all those who have contributed to the completion of this master's thesis.

Firstly, we would like to thank our supervisor, John Krogstie, for his guidance and support throughout the research process. His insights and constructive feedback have contributed to the presented results and have been highly appreciated.

We would also like to express our gratitude to the teachers and special educators who generously dedicated their time and expertise to participate in this study. Their valuable insights, experiences, and collaboration have provided a rich foundation for understanding the challenges and opportunities surrounding dyslexia detection and intervention in primary schools.

Furthermore, we would like to extend our appreciation to our friend and developer, Jakob Lund Johannesen, for his technical advice and support. His expertise and insights have been truly helpful in the development work of this research project.

Lastly, a special thanks to our friends and family for their support and kindness, which helped us complete our master's degree at NTNU.

Katrine Norheim Holm and Vår Sørensen Sæbøe-Lassen

Trondheim, 11. juni 2023

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Acronyms

API Application Programming Interface.

HTTP Hypertext Transfer Protocol.

JWT JSON Web Token.

M neurons Magnocellular Neurons.

MVC Model-View-Controller.

P neurons Parvocellular Neurons.

PEOU Perceived Ease of Use.

PU Perceived Usefulness.

RAUT Remote Asynchronously Usability Test.

RBAC Role-Based Access Control.

RSUT Remote Synchronously Usability Test.

SUS System Usability Scale.

TAM Technology Acceptance Test.

UI User Interface.

UX User Experience.

1. Introduction

This chapter gives an introduction to the Master's thesis. Section 1.1 gives a motivation for why the research performed is important and valuable to its environment, elaborating on the situation of dyslexia detection and intervention in Norwegian schools. Section 1.2 goes into detail about the problem statement, giving the specific context for this research and the goals and research questions it aims to fulfill and answer. Lastly, Section 1.3 outlines the content of this thesis.

1.1. Motivation

Within the field of education, the ability to read and write holds a key position, serving as fundamental building blocks for learning. As children begin their educational journey, the first years of school offer the opportunity for them to develop these essential literacy skills. While the majority of children acquire these skills quickly, certain children encounter difficulties with letters and words. Some of these children may experience these difficulties as a result of dyslexia.

Dyslexia is a complex neurodevelopmental disorder characterized by unexpected underperformance despite adequate intelligence, sufficient educational environment, and normal eyesight and hearing [10]. According to Dysleksi Norge [11] 5% of the Norwegian population is diagnosed with dyslexia. However, what is particularly concerning is the prevalence of undiagnosed cases, with 49% of those with dyslexia remaining undiagnosed until they reach the 8th grade or later [12]. Additionally, there is a high chance that some individuals with dyslexia never receive a diagnosis. The late detection of dyslexia reduces the efficiency of support mechanisms, which is shown to have a significant impact on young children in the first years of primary school [13]. Beyond the more immediate educational implications, the late identification of dyslexia can have long-term consequences on individuals' overall well-being [5].

However, early detection and intervention have been shown to reduce the challenges and consequences caused by undetected dyslexia [14]. By identifying the specific manifestations and underlying causes, educational institutions can take targeted and tailored measures to meet the pupil's challenges effectively [15]. Importantly, the optimal period for intervention efficacy is during the first or second grade of primary school, when children develop essential literacy skills such as phonological awareness and reading automatization [16]. In contrast, the impact of intervention diminishes by approximately 70% when implemented between the first and fifth grades [13]. Hence, early detection and intervention of dyslexia are paramount.

1.2. Problem Statement

Several screening and diagnostic tests are currently employed in Norwegian schools to facilitate the detection and diagnosis of dyslexia. However, due to their reliance on reading proficiency, many of these tests cannot be taken until the child has attained a certain level of reading skill. Consequently, researchers have conducted studies aiming to develop screening tools capable of predicting future reading difficulties before a child learns to read. One such tool is Magno, which is based on the magnocellular theory of dyslexia.

Magno comprises a set of screening tests designed to evaluate visual processing abilities. Previous projects [1][17] have demonstrated the promising effectiveness of Magno as a screening tool.. The application is intended for use by teachers and special educators involved in dyslexia detection, equipped with features that provide an overview of pupils' results, enabling teachers to follow up with pupils at risk of dyslexia.

Despite Magno's potential, certain functionalities and safety measures still need to be improved before it can be introduced and effectively utilized in schools. Valuable insights obtained from interviews with special educators performed in the specialization project of the fall of 2022 [18] emphasized that the the goal of the detection process is not necessarily establishing a diagnosis, but identifying difficulties and implementing early interventions. Therefore, the development of a follow-up tool capable of allowing teachers to store relevant pupil information, assess the risk of dyslexia, and track pupils' reading and writing levels, is of the highest importance. Given that the implementation of the application involves the entry of personal pupil data, ensuring secure data storage and prohibiting unintended access is essential.

1.2.1. Goals and Research Questions

In light of the motivation and problem statement, the aim of this Master's thesis is to enhance and expand the functionality of Magno, with a specific emphasis on improving the security and utility. The primary focus will be on incorporating features that facilitate efficient pupil follow-up and establishing a secure platform that supports role-based access control(RBAC). This involves specifically dividing responsibilities between a basic user role and an administrator role while ensuring that the extended functionality remains practical and user-friendly for teachers and special educators.

These enhancements are implemented with the intention of implementing Magno as a screening tool in Norwegian schools in the future, with the ultimate goal of streamlining the process of dyslexia detection and intervention for young pupils.

To gain an in-depth understanding of how these goals can be reached, this thesis aims to answer the following research questions.

RQ1 How should additional features be implemented to achieve role-based access control, limiting unwanted access to pupil data and facilitating role-based task management?

RQ2 How should additional features be implemented to achieve a system that facilitates tasks related to detecting dyslexia and following up pupils in primary school?

RQ3 How do the additional features affect Magno's usability?

RQ4 What are the potential challenges of implementing Magno in schools?

1.3. Report Outline

This paper consists of nine chapters. Chapter 2 outlines the research methodology, including the design research guidelines that have been followed and the employed research process with a focus on the development process and evaluation methods. In Chapter 3, the findings from the literature review conducted in the specialization project are presented, with a specific focus on dyslexia and related theories. Additionally, aspects of web design and relevant quality attributes will be presented. Chapter 4 describes the prior work related to the Magno project, including insights gained from the specialization project serving as the foundation for this thesis. Chapter 5 provides an overview of the methods and tools employed throughout the development process.

Moving forward, Chapter 6 delves into the design phase, detailing the work accomplished and presenting the performed evaluation of the design along with the results. Chapter 7 focuses on the implementation phase, offering an updated list of requirements and showcasing the system's new implementations, all of which have been developed in accordance with the identified requirements. Additionally, the results of the usability test conducted to evaluate the implementations will be presented. Chapter 8 provides an evaluation and discussion of the obtained results from the performed evaluations and highlights other important contributions of the performed work. In Chapter 9, a conclusion answering the research questions is presented, along with recommendations for future work.

2. Research Methodology

This chapter provides an overview of the research methodology employed in this project. To address the defined goals and research questions, the research included developing and evaluating extensions and improvements to Magno by following design science methodologies and guidelines. Design research aims to develop new artifacts that help people fulfill needs, overcome problems, and grasp new opportunities, producing not only artifacts but knowledge about them, their use, and their environment [19]. The evaluation of artifacts is crucial in the design science theories and helps improve the product and design process through iterative cycles of building and evaluation [9]. Following principles from design science research, a new version of Magno was provided along with knowledge about the application's performance. Section 2.1 will describe how the design research guidelines were followed in this project. Thereafter, Section 2.2 will outline the research process, encompassing the development process, along with the evaluation methods and data generation methods utilized.

2.1. Design Research Guidelines

Hevner et al. [9] have developed a set of guidelines for conducting and evaluating good design science research that we aim to follow in this project. Descriptions of how this research adheres to the guidelines are listed in Table 2.1. A complete list of the guidelines formulated by Hevner et al. [9] can be found in Appendix A.

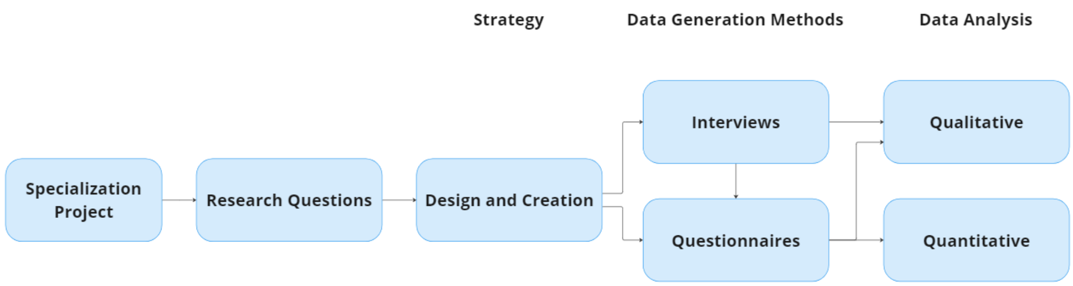
Guideline	**Description**
Guideline 1: Design as an Artifact	This research produces a viable artifact: an instantiation of the application Magno.
Guideline 2: Problem Relevance	The research aims to develop an artifact that improves and streamlines tasks related to dyslexia detection and follow-up for teachers and special educators in schools, which has proved highly relevant through previous research.

Guideline 3: Design Evaluation	The utility, quality, and efficacy of the artifact are rigorously and repeatedly demonstrated through several forms of evaluation methods, including qualitative interviews and a usability questionnaire.
Guideline 4: Research Contributions	The research provides clear and verifiable contributions in the form of a viable artifact and knowledge about its performance, highlighting how the produced artifact improves and streamlines the work of teachers and special educators in the context of dyslexia detection and intervention.
Guideline 5: Research Rigor	The research relies heavily upon applying agile, best-practice development methodologies and rigorous evaluation methods in the form of usability testing to ensure the artifact's performance.
Guideline 6: Design as a Search Process	The research follows an iterative process, where the development is divided into phases, and the outcomes of each phase are evaluated. In this way, the development follows a produce/test cycle utilizing feedback from teachers and special educators (end-users) in the search for an effective solution to the defined problem.
Guideline 7: Communication of Research	The results of the research will be presented in a manner comprehensible for non-technology-oriented audiences through tables, illustrations, and concise answers to the research questions.

Tabell 2.1.: Desciptions of the Adherence to the Design Research Guidelines [9]

2.2. Research Process

The research process is based on Oate's model of research processes [2] and practices from design science research [19]. Figure 2.1 presents an overview of the research process employed in this project. As a preparation for the master thesis, a literature review and case study was conducted during the specialization project. The primary objectives of the specialization project were to investigate the dyslexia detection process in Norwegian schools and explore potential enhancements and extensions to Magno's functionalities, aiming to make it a more effective tool for teachers and special educators in the dyslexia detection and follow-up process. The outcomes of the specialization project formed the foundation for the research questions addressed in this thesis. The following sections describe the process employed as part of the design and creation strategy while giving a brief description of the evaluation and data generation methods and forms of analysis.



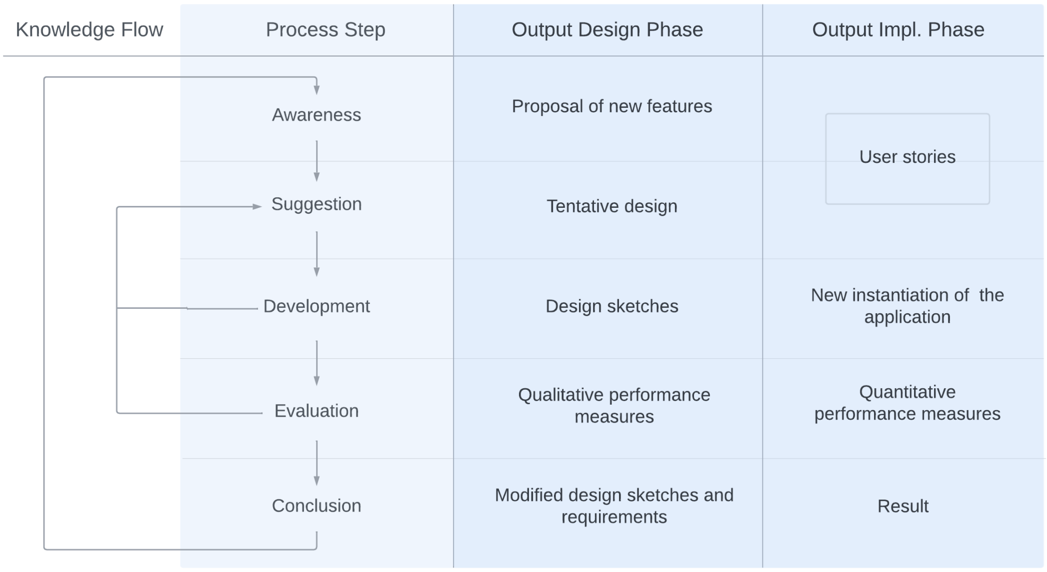
Figur 2.1.: Research Process based on Oate's Model [2]

2.2.1. Development Process: Research Strategy and Data Generation Methods

As seen in Figure 2.1, the research strategy employed in this project is *design and creation*. The design and creation strategy is typically used when the research requires producing a new element of a system or a system as a whole [2]. As suggested by Oates, the design and creation strategy should consist of an iterative process involving five steps: awareness, suggestion, development, evaluation, and conclusion [2]. Furthermore, the same steps are taken in the framework for reasoning in the design cycle, extended by Vaishnavi to apply the cycle specifically to design science research [4][3].

This project utilized an iterative development process consisting of two main phases: a *design phase* and an *implementation phase*. Each phase iteratively applied the five steps, facilitating continuous refinement and improvement throughout the project. The process is based on the general design cycle, shown in Appendix B. Figure 2.2 illustrates the development process, showing the output of each step in both phases.

The design phase aimed to create design sketches representing the system requirements. As the evaluation method, a series of qualitative interviews were conducted to assess the usefulness and ease of use of the intended functionality. The feedback gathered in these interviews provided valuable insights into the expected performance of the new functionality and guided the modification of some design sketches. Furthermore, changes were made to the requirements, and user stories were formulated as the foundation for the implementation phase. The goal of the implementation phase was to implement all intended functionality, fulfilling the system requirements. To evaluate the implementations, remote usability testing was utilized to receive further feedback and validate the results from the design phase. This comprehensive testing process performed at several stages in the development process allowed for a detailed assessment of the implemented functionality and features, aligning with the guidelines in design-science research [9]. The applied usability testing methods will be described in detail in Chapter 5.



Figur 2.2.: Development Process with the Outputs of All Process Steps Based on the Framework for Reasoning in Design Research [3][4]

3. Background Theory

This chapter provides the necessary background theory on dyslexia and web design. Section 3.1 gives an explanation of dyslexia, encompassing various theories for the underlying causes and the significance of early detection and intervention. Section 3.2 explores elements of web design and discusses essential quality attributes relevant to the problem statement of the thesis.

3.1. Dyslexia

The term "dyslexia" was introduced by Rudolf Berlin in 1887, but it took over a century for professionals to develop precise definitions [20]. In recent years, there has been a rapid advancement in the scientific comprehension of dyslexia. As a result, researchers have revised definitions and classifications and identified neuropsychological correlations and neurobiological factors of the deficiency [14]. Despite the progress in understanding dyslexia, there still remains a level of uncertainty among researchers due to varying theories and definitions. The following sections will cover the definitions of dyslexia, theories about its causes, and why early detection is necessary. The majority of this chapter is repurposed from the specialization project.

3.1.1. Defining Dyslexia

Dysleksi Norge [15] is a Norwegian organization for people with reading and writing difficulties, math difficulties, and language difficulties. Their definition of dyslexia is translated from Norwegian as follows:

Dyslexia is a specific learning disability that makes it difficult to acquire functional reading and writing skills. Typical characteristics are, therefore, extensive difficulties with word decoding and spelling, in addition to difficulties with other language-related skills. The most common are difficulties with phonological processing, rapid naming, and phonological short-term memory. Some also have difficulties with processing speed and automation capabilities. The difficulties differ from the person's other cognitive skills [15].

The definition provided by Dysleksi Norge draws inspiration from the definitions provided by the IDA (International Dyslexia Association), the BDA (British Dyslexia Association), and the Rose Report on the teaching of reading skills in primary schools.

The IDA's definition of dyslexia was established in 2002 and states the following:

Dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede the growth of vocabulary and background knowledge [21].

Furthermore, the Rose Report from 2009 is similar to the IDA's definition and states:

Dyslexia is a learning difficulty that primarily affects the skills involved in accurate and fluent word reading and spelling. Characteristic features of dyslexia are difficulties in phonological awareness, verbal memory, and verbal processing speed. Dyslexia occurs across a range of intellectual abilities. It is best thought of as a continuum, not a distinct category, and there are no clear cut-off points. Co-occurring difficulties may be seen in aspects of language, motor coordination, mental calculation, concentration, and personal organization, but these are not, by themselves, markers of dyslexia. A good indication of the severity and persistence of dyslexic difficulties can be gained by examining how the individual responds or has responded to well-founded intervention [22].

In 2010, the BDA adopted the Rose Report's definition and added the following part:

The British Dyslexia Association (BDA) acknowledges the visual and auditory processing difficulties that some individuals with dyslexia can experience and points out that dyslexic readers can show a combination of abilities and difficulties that affect the learning process. Some also have strengths in other areas, such as design, problem-solving, creative skills, interactive skills, and oral skills [23].

The definitions share several elements. Phonological processing, in particular, is highlighted as a central area of difficulty. This involves challenges in recognizing and manipulating the sounds of language, which can consequently impact reading and spelling proficiency. Furthermore, the definitions emphasize that dyslexia's impact on reading and writing skills is often unexpected in relation to the individual's other cognitive abilities.

The definitions also acknowledge the neurobiological basis of dyslexia, suggesting that it originates from underlying neurocognitive factors. Notably, the definition provided by the BDA distinguishes itself by acknowledging the visual and auditory processing challenges experienced by certain individuals with dyslexia and proposes this as a possible cause. Further elaboration on the biological explanations will be provided in the next section.

3.1.2. What Causes Dyslexia

Although research on dyslexia has made progress, the underlying biological and cognitive causes of dyslexia are still debated. Several theories have been proposed in the literature to explain the potential causes of dyslexia. The most prominent theories include the *phonological theory, visual theory, auditory processing theory, and cerebellar theory*, and finally, a general *magnocellular theory* that unifies all of these mentioned theories. While various versions of these theories exist in the literature, this section will elucidate each theory's most frequently referenced versions.

The Phonological Deficit Theory

The phonological deficit theory is considered the most widely accepted cause of dyslexia [24]. The theory explains that individuals with dyslexia experience challenges in reading due to a weakened ability to separate words into phonemes. Consequently, difficulties arise in the establishment, representation, storage, and retrieval of constituent sounds of speech. These challenges significantly impact the acquisition of reading skills [25]. Research conducted by Ramus et al. [25] utilizing brain-imaging techniques suggests that the disorder originates from a congenital dysfunction in the left hemisphere of the brain. Specifically, the studies indicate reduced activity in the insula region during phonological processing tasks. As the insula area is known to be involved in language transmission, the reduced activity may be a reason for the difficulty dyslexic individuals encounter in establishing phonological representations [24].

However, the Phonological theory has faced criticism for its perceived incompleteness. One argument presented by Stein [26] suggests that relying solely on a phonological basis is insufficient in distinguishing dyslexia from other reading difficulties that may arise due to factors like inadequate education or lack of parental support. This claim is substantiated by the observation that difficulties in reading stem from an inability to effectively divide words into their individual sounds and match them with corresponding letters. As a result, most children with reading difficulties exhibit some phonological challenges [26]. Additionally, there are no discernible differences in phonological abilities between dyslexic individuals and other children facing reading issues [26]. Furthermore, Stein [27] argues that there are dyslexic individuals who do not exhibit any phonological struggles, indicating that a phonological deficit should not be a prerequisite for diagnosis. Another criticism lies in the theory's inability to explain why dyslexics experience visual problems [27], as well as sensory and motor disorders [25]. Thus, researchers have explored pathophysiological visual and auditory mechanisms as potential causes for children's phonological difficulties.

The Visual Theory

The visual theory explains that dyslexia is caused by a deficiency in visual processing. Before phonological processing skills can be developed, the ability to analyze text visually is required. An important aspect of this process involves the identification of individual letters and their correct sequencing. These skills depend on the visual system, which at a biological level, can be divided into two distinct pathways: the magnocellular and parvocellular pathways (magno - larger and parvo - smaller in Latin) [25].

The pathways have different roles and properties. The magnocellular pathway consists of large magnocellular (M) neurons that specialize in processing rapidly moving visual stimuli [28]. In fact, the transmission of signals through neurons tends to be faster as the size of the neuron increases [26]. These motion-sensitive neurons are responsible for delivering signals when the visual system detects an object across a broader area. However, they primarily provide an approximation of its overall shape and location, lacking the ability to perceive fine details or colors. The identification of detail and color that enable object recognition is facilitated by the parvocellular (P) neurons [26][29]. Hence, the M and P pathways collaborate to detect and recognize objects.

According to the visual theory, certain individuals with dyslexia may encounter selective disruption in the magnocellular pathway, resulting in deficiencies in visual processing [25]. This theory finds support in several studies. For instance, a study conducted by Livingstone et al. [30] reveals that while the P neurons exhibit similarities between non-dyslexics and dyslexics, the M neurons in the dyslexic brain exhibit a reduced size and apparent disorganization compared to the non-dyslexic brain. Consequently, dyslexic individuals demonstrate reduced visual evoked potential for rapidly presented, low-contrast stimuli while maintaining normal responses to slower or higher-contrast stimuli. The visual processing deficiencies contribute to timing deficits in the process of letter sequencing. However, it is important to note that this impairment is relatively insignificant and not present in all dyslexics [31].

The Auditory Processing Deficit Theory

The process of reading encompasses not only the visual arrangement of letters in written words but also the auditory sequencing of phonemes in spoken words [26]. The auditory processing deficit theory states that individuals with dyslexia have a deficiency in rapid auditory processing, particularly in perceiving short or rapidly changing sounds [25]. According to this perspective, the auditory deficit directly contributes to the inadequate development of phonemic and phonological awareness, whereby phonological difficulties are considered secondary consequences of auditory deficits [28]. Evidence supporting this theory is derived from studies that reveal poor performance by certain dyslexic individuals on various auditory tasks, including frequency discrimination and temporal order judgment of pure tones [25]. Similar to the visual theory, researchers suggest that M neurons play a role in detecting frequency and speech amplitude variations, which form the basis of letter sounds in the auditory system [29][26]. Thus, in many aspects, they can be compared to their visual magnocellular counterparts, which will be covered in more detail in the section presenting the magnocellular theory.

The Cerebellar Theory

The cerebellar theory is based on the idea that reading disabilities arise from deficits in the cerebellum - the part of the brain at the back of the skull which coordinates and regulates muscular activity. One function influenced by the cerebellum is motor control, including speech articulation. According to Ramus et al. [25], reduced articulation can result in impaired phonological representations. Additionally, the cerebellum plays a role in the automatization of learned tasks, such as driving, typing, and reading. Reduced capacity of automatization may hinder the integration of graphemes and phonemes during the learning process [25]. Support for the cerebellar theory is garnered from evidence demonstrating dyslexics' poor performance in various motor tasks. Furthermore, brain imaging studies have also shown differences in cerebellar activation among dyslexics and non-dyslexics [25].

The Magnocellular Theory

Finally, the magnocellular theory is a general theory of dyslexia that integrates the auditory, visual, and cerebellar theories [31]. This theory suggests that the impairment of various magnocellular systems in the brain is the underlying cause of cognitive deficits leading to dyslexia [28]. Within the visual and auditory processing theories, it is proposed that dyslexics' deficient development of M neurons contributes to challenges in identifying both auditory and visual motion, which are processed in separate regions of the brain [29]. Furthermore, as the cerebellum receives massive timing signals from several magnocellular systems in the brain, it is also believed to be impacted by the general magnocellular defect [31]. By considering phonological impairments as secondary consequences, the general magnocellular theory provides a comprehensive explanation for the range of dyslexia symptoms, encompassing visual, auditory, tactile, motor, and ultimately, phonological deficits [25].

3.1.3. The Significance of Early Dyslexia Detection

This section will discuss why early detection of dyslexia is essential to limit the negative consequences of the deficiency.

Detection and Diagnosis of Dyslexia

According to Sousa's book *How the Brain Learns to Read* [10], a child's process of learning to read involves three stages:

1. *Pictorial Stage.* During this stage, the child's brain captures and identifies words through visual recognition while also adapting to the shape of letters [10]. The stage typically occurs in the latter part of the kindergarten period [15].

2. *Phonological Stage.* Here, the child begins to develop phonological awareness, which allows the brain to associate letters with individual sounds (phonemes). Additionally, the child develops phonemic awareness, which involves the ability to isolate phonemes to form new words [10].

3. *Orthographic Stage*. This stage is reached when the child achieves the ability to rapidly and precisely recognize words.

Children who are at risk of dyslexia are possible to identify already in the pictorial stage. However, an official diagnosis of dyslexia cannot be made until the phonological stage begins and reading skills are expected to have reached a certain level. In Norway, this normally happens during 2nd grade of primary school. Nevertheless, in order to receive a diagnosis in the 2nd grade, the pupil's difficulties must have already been detected through assessment tests conducted in the 1st grade [15].

Intervention of Dyslexia

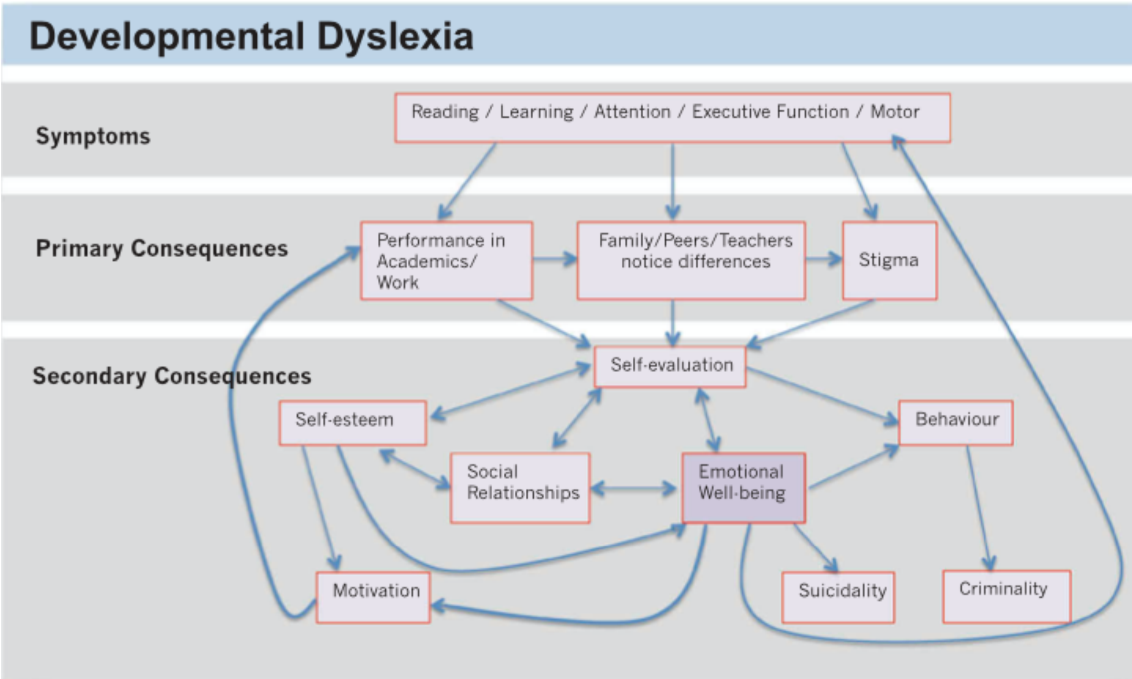
According to the literature discussed in Section 3.1.2, it is proven that dyslexia has neurological origins. Moreover, studies indicate a strong correlation between the disorder and genetic factors, with a 38-50% risk of a child developing dyslexia if one of their parents is affected [11]. However, research also acknowledges that environmental factors play a significant role in shaping and reducing the difficulties caused by dyslexia. In fact, the difficulties can be prevented for many children with early detection and intervention.

Irrespective of whether a formal diagnosis has been established, it is crucial to be aware of the challenges faced by pupils and provide necessary support from an early stage. The definitions presented in Section 3.1.1 mention that dyslexia can occur across a range of intellectual capacities and should be perceived as a continuum rather than a distinct category. Consequently, the difficulties experienced by individuals with dyslexia can vary depending on the underlying biological causes. Through early intervention, educators and specialists can implement effective strategies customized to the children's individual needs, enabling them to develop strong literacy skills and preventing potential academic challenges, despite the experienced obstacles. A widely cited study conducted by Foorman et al. [13] in 1997 demonstrates that the effectiveness of intervention diminishes as the child grows older. Specifically, the intervention has an approximate effectiveness of 80% when administered in the first or second grade and a mere 10%-15% when administered in the fifth grade or later [13]. These statistics highlight the significant repercussions of late detection and intervention.

Consequences of Late Detection

As children progress to higher grades in primary school, proficient reading and writing skills become increasingly necessary. Without adequate mastery of these skills, the syllabus can prove more challenging than intended, potentially leading to difficulties in keeping pace with their peers. Consequently, individuals may experience ongoing challenges in terms of academic skills, which can cause frustration, anxiety, and even behavioral disruptions as they try to cope with the academic demands [5].

In 2018, Livingston et al. [5] conducted a study examining the emotional ramifications of dyslexia. Through an extensive literature review encompassing over 100 journal articles, the researchers constructed a schematic diagram illustrating the primary and secondary consequences of dyslexia, as shown in Figure 3.1. The primary consequences encompass under-performance in academic and work settings, observed disparities by peers, family, or teachers, as well as the stigma associated with being different. These primary consequences can subsequently lead to negative self-evaluations and feelings of inadequacy. Moreover, individuals experiencing these emotions are at risk of developing challenges related to self-esteem, social relationships, behavior, motivation, and emotions, which Livingston et al. [5] categorize as secondary consequences of dyslexia. Over time, this can lead to disengagement from school, a lack of motivation, and a decreased interest in learning, further impacting their educational outcomes and limiting their opportunities for success in their careers. The negative effects of low self-esteem and challenges in social relationships may also affect their social life and all-over well-being.



Figur 3.1.: Primary and Secondary Consequences of Dyslexia [5]

The negative consequences of dyslexia underscore the significance of early detection and intervention. It is, therefore, advisable to initiate regular screenings for dyslexia at a young age, accompanied by comprehensive education and emotional support during the diagnostic process.

3.2. Web Design and Quality Attributes

Web-based technology plays a vital role in improving the effectiveness of several sectors, including educational institutions. Its impact extends beyond teaching and encompasses crucial aspects such as administration, data storage, knowledge management, and decision-making [32]. With the ever-increasing reliance on digital platforms, the significance of web design has grown exponentially. To ensure the success of web-based systems it is essential to design a system that meets both functional and non-functional requirements [33]. Functional requirements describe the services a system should offer, specifying expected responses to specific inputs and expected behavior in various situations [34]. Non-functional requirements, also known as quality attributes, define a web system's overall characteristics and properties beyond its functional aspects. They guide the design decisions and trade-offs made during the architectural process and ensure that the resulting system meets the desired quality standards. Common quality attributes include availability, interoperability, modifiability, performance, security, testability, usability, and more. In the following sections, relevant quality attributes for the problem statement of this master thesis will be presented.

3.2.1. Usability

Usability is a quality attribute in web design that focuses on delivering a positive user experience and facilitating ease of use for individuals interacting with a web application. It encompasses a range of factors, including how easily users can accomplish their desired tasks and the level of support the system provides during their interaction. Achieving high usability involves designing interfaces with consistent components, providing timely and relevant feedback to users, and implementing constraints that reduce potential errors and enable users to predict the system's behavior [35].

In the book *Software Architecture in Practice* [36], Bass et al. highlight the significance of prioritizing usability, as it has been proven to be one of the most cost-effective ways to improve a system's overall quality and the users' perception of that quality. By prioritizing usability as a quality attribute, the software system aims to enhance user engagement, increase user satisfaction and improve the system's overall performance.

To ensure that a web application meets the needs and expectations of its users, usability tests should be employed. These tests involve observing real users as they interact with the web application, providing valuable insights into user behaviors, identifying usability issues, and enabling informed design decisions to enhance the overall user experience [35]. By incorporating user feedback and iteratively refining the design based on usability testing results, developers can create user-friendly and efficient tools that maximize user productivity.

3.2.2. Security

As an attribute, security refers to the system's ability to protect data and information from unauthorized access while still providing authorized access to users [36]. O'Brien et al. [33] associate the security attribute with four principles:

1. *Confidentiality*, ensuring that access to information and services are granted only to authorized individuals or entities.
2. *Authenticity*, which is concerned with establishing trust in the identity of the sender of information. It involves verifying and validating the identity of the users through authentication mechanisms, digital signatures, and certificate-based systems.
3. *Integrity*, guaranteeing that information remains unaltered and accurate throughout its lifecycle by implementing measures such as data validation and secure data storage.
4. *Availability* ensures that the system is accessible and operational when needed.

To ensure that sensitive data and information are protected, evaluation of the security attribute is important. Evaluation of the security attribute may include conducting authentication and role-based access control testing to guarantee that only authorized users can access sensitive data and perform privileged actions. By conducting comprehensive security assessments and tests, developers can gain insight into vulnerabilities, validate security measures and make necessary improvements to enhance the overall security posture of the system [37].

3.2.3. Balancing Usability and Security

When prioritizing quality attributes in web design, it should be acknowledged that different quality attributes can present conflicting requirements and trade-offs. One notable conflict arises between security and usability, a topic extensively discussed in academic research [38]. This conflict stems from the inherent tension between protecting the system and its data while ensuring a user-friendly and intuitive experience. As Bonneau et al. [39] put it: "It is generally easy to provide more of one by offering less of the other".

On the one hand, security measures encompass practices including complex passwords, authentication, encryption, and strict access controls. Although these security measures enhance protection, they can also introduce challenges and friction for users, potentially reducing the user experience. For instance, users may struggle to remember intricate passwords or experience delays due to encryption protocols [39]. On the other hand, usability often includes simplicity, clear instructions, and a minimal number of steps to complete tasks. However, prioritizing usability without implementing adequate security measures can expose the system to potential attacks and compromise sensitive data. Finding the right balance between the attributes is thus highly important. As emphasized in a literature review by Nwokedi et al. [40], failure to achieve a balanced trade-off between usability and security can negatively affect the system's end-users, who the system is primarily designed to provide assistance.

Several researchers have provided empirical evidence of the trade-off between usability and security. For instance, Gunson et al. [41] conducted a research study investigating user perceptions of single-factor and two-factor authentication methods in automated telephone banking. The results showed significant differences between the two methods, with two-factor being perceived as offering higher levels of security. However, this gain in security was accompanied by significantly lower perceptions of usability and increased time consumption [41]. To mitigate the trade-off between usability and security, employing techniques and measures that facilitate users in making secure choices becomes crucial. By providing clear instructions and explanations in the user interface, users can better understand the importance of security measures and adopt them effectively. Additionally, incorporating user feedback through iterative usability testing allows for the identification of pain points, understanding of user perspectives, and refining the delicate balance between security and usability.

4. Related Work

Magno was started as a project at NTNU in the year 2015. Since then, multiple iterations through Master's theses at NTNU have been performed to develop and customize Magno for various environments. To gain in-depth knowledge about the screening tests of Magno, the refinements and improvements that have been made, and the environments Magno has been adapted to, previous work related to the development of Magno has been studied in detail. While some of the work is not included in the current application, this chapter will primarily focus on describing the iterations that have contributed to the current version of Magno. Section 4.1 to Section 4.4 will describe the results from these iterations.

Section 4.5 briefly explains parallel work being performed regarding adapting the screening tests on Magno to younger children. Lastly, Section 4.6 provides an overview of the findings and results from the preceding specialization project and summarizes the insights that have served as the foundation for this master's thesis.

4.1. Application for Early Detection of Dyslexia

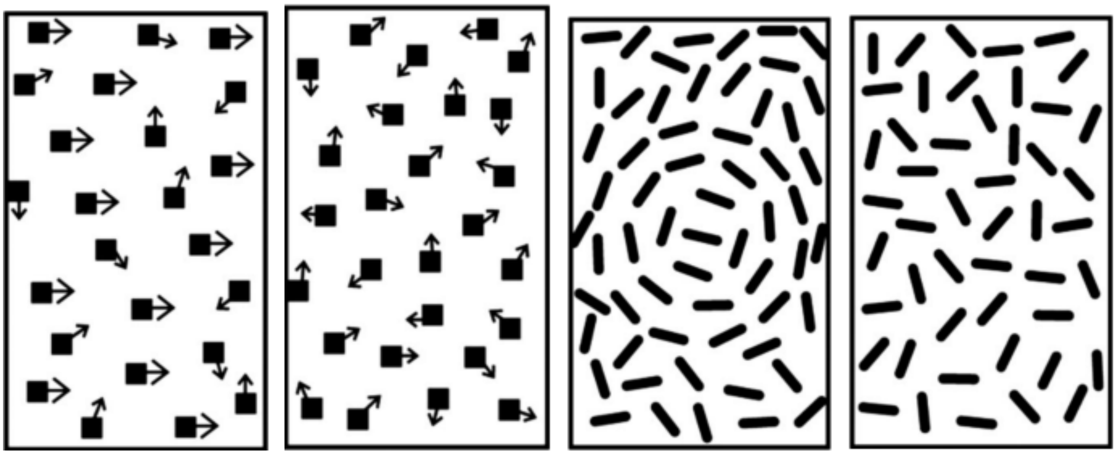
The initial work on Magno was undertaken by Wold [6] during the 2015-2016 academic year. Wold's Master's thesis focused on exploring the feasibility of creating an application that could serve as a screening tool for dyslexia. The application was based on the work of Hansen et al. from 2001 and aimed to replicate the functionality of an old MS-DOS program called *Form*. This program consisted of three test methods for detecting dyslexia:

- A random dot kinematogram[1] testing for motion discrepancy (Figure 4.1a, 4.1b)
- Static global pattern processing with a randomized target (Figure 4.1c, 4.1d)
- Static global pattern processing with a fixed target (Figure 4.1c, 4.1d)

The two static global pattern processing tests served as control tests, ensuring the validity of the results obtained from the random dot kinematogram test. Thus, individuals with dyslexia were expected to perform lower on the motion test and similarly on the pattern processing tests compared to a control group.

Wold developed a simple application for conducting the screening tests, implementing the functionality using Java and libGDX, a game development framework [6]. The application comprises a main menu, the screening tests, and a settings page. Screen

[1] A display of moving dots used to investigate aspects of vision



(a) Coherent Motion (b) Random Motion (c) Coherent Form (d) Random Form

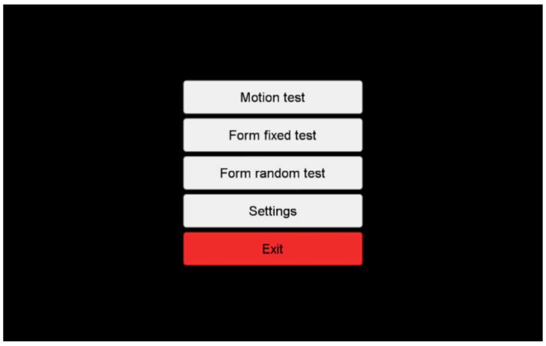
Figur 4.1.: Schematic Diagrams of the Coherent and Random Motion (a,b) and Coherent and Random Form (c,d) Stimuli [6]

captures showcasing different screens of the application can be seen in Figure 4.2. In order to assess the accuracy of the developed screening tests of the application, Wold conducted evaluations with a test group consisting of six individuals, three of whom had been previously diagnosed with dyslexia. The results indicated that Wold's motion test successfully detected dyslexia, as the dyslexic group exhibited significant differences compared to the control group in terms of test performance. The form test yielded more comparable results between the dyslexic and control groups. These findings align with the outcomes reported by Hansen et al. [42].

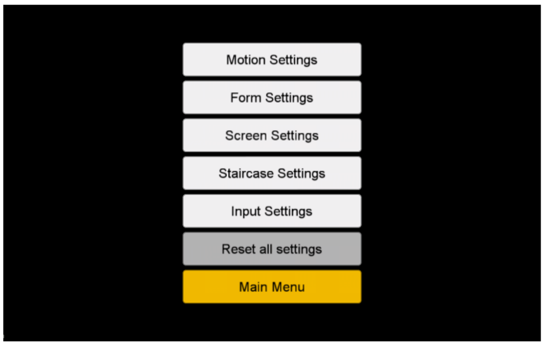
4.1.1. The Motion Test

The motion test consists of two squares containing 300 randomly placed dots. Each dot has a radius of 1 pixel and is separated by at least 1 pixel from surrounding dots. In one square, the dots move in a random fashion, while in the other square, the dots move coherently in a horizontal pattern from left to right with equal intervals. The direction of the coherent motion reverses every 0.527 seconds or when a dot collides with another dot. All dots have a velocity of 50 pixels per second. The selection of which square contains the coherently moving dots is randomized. A screen capture depicting the frames of the motion test of the application is presented in Figure 4.3a.

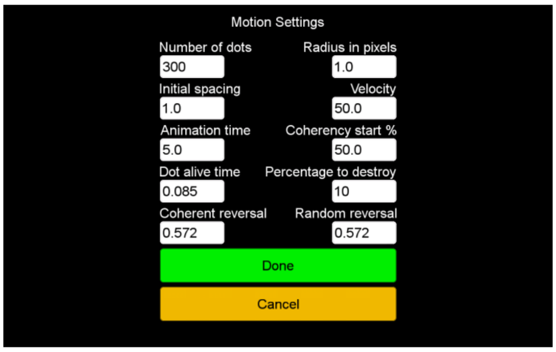
During the test, both squares containing the dots are visible to the user simultaneously. The user is instructed to click on the frame that they believe contains the dots moving coherently. They have a time limit of five seconds to observe the motion in the squares before the dots disappear. Depending on the user's selection, the level of coherence is adjusted, and new test samples are presented. If the user selects the correct frame, the coherency decreases, making it more challenging to identify the coherent motion.



(a) Main Menu Screen



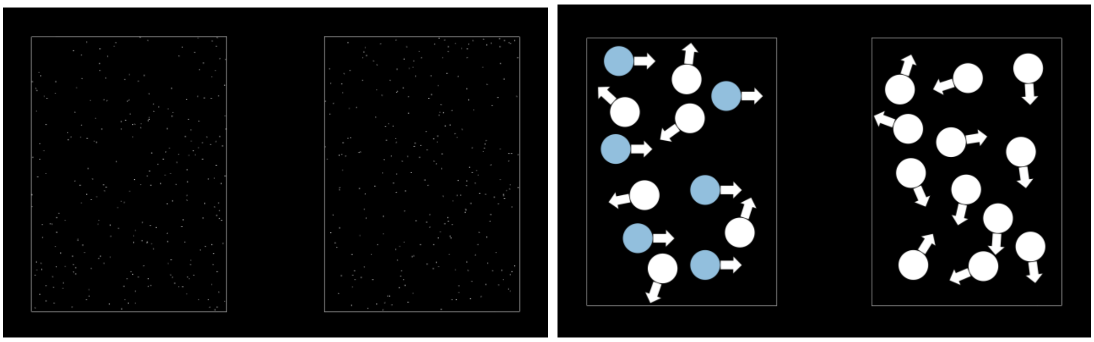
(b) Settings Screen



(c) Motion Settings Screen

Figur 4.2.: App for Early Detection of Dyslexia: Screens [6]

Conversely, if the user makes an incorrect selection, the coherency increases. This adaptive approach ensures that each subsequent set of frames, or level, becomes more difficult or easier based on the user's performance. The degree of coherency is quantified by the percentage of dots moving horizontally. For example, Figure 4.3b provides an illustration of a motion test with 50% coherency, indicating that 50% of the dots in one of the frames are moving horizontally, while the remaining 50% are moving randomly.

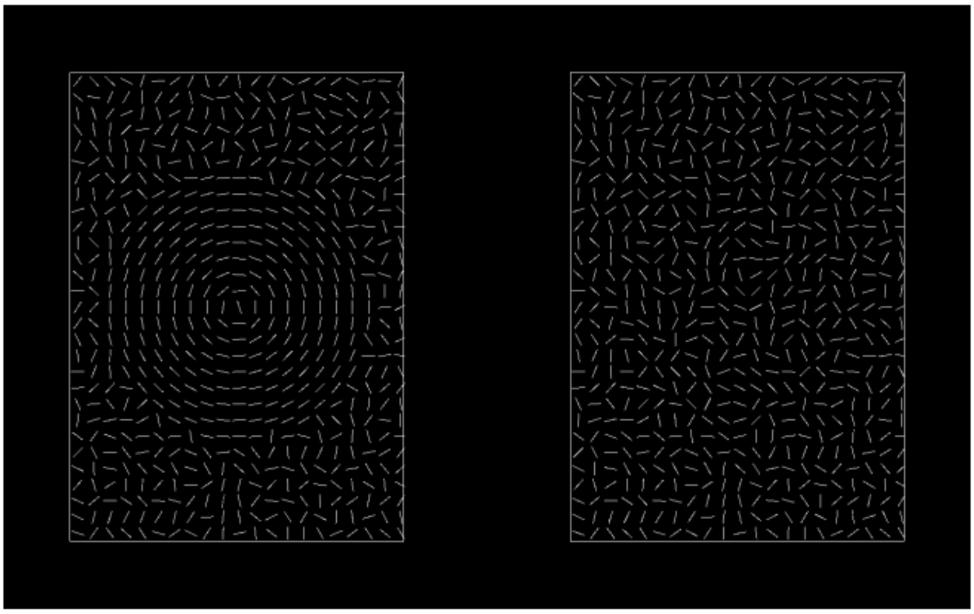


(a) Screen Capture of the Motion Test Frames (b) Illustration of 50% Coherency

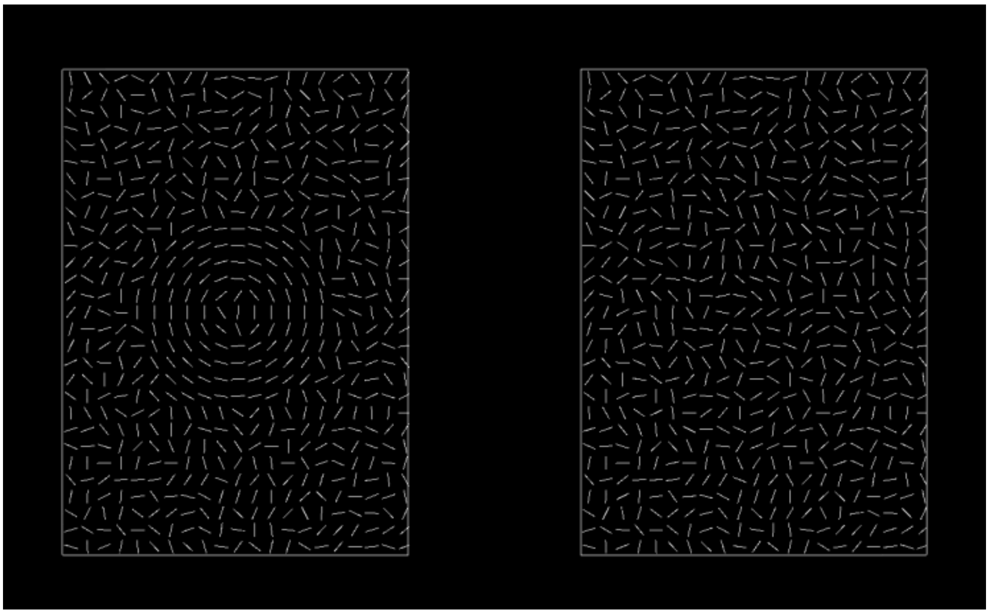
Figur 4.3.: The Motion Test [6]

4.1.2. The Form Tests

The two form tests, fixed and random, share a similar design. Each test consists of two square frames, each containing 60 evenly distributed short lines. Each line segment is 1 pixel thick and has a length of 0.4 degrees of the viewing angle. In one of the frames, the line segments are centered around a fixed point, while in the other frame, the distribution does not follow any pattern. Similar to the motion test, the frame containing the coherent pattern of lines is selected at random. The lines remain visible for four seconds before disappearing. In the frame with the coherent form, the lines form a circle around a specific point. In the form fixed test, this point is consistently located in the middle of the frame, while in the form random test, the point is randomly determined. The user's task is to identify the frame that displays the coherent form. As with the motion test, the level of difficulty adjusts based on the user's performance, increasing if the correct frame is selected and decreasing if an incorrect frame is selected. The difficulty level is determined by the number of line segments forming the circle around the target point. Figure 4.4 illustrates a screen capture of the form test with 100% coherency, while Figure 4.5 showcases a form test with 50% coherency.



Figur 4.4.: The Form Test at 100% Coherency [6]



Figur 4.5.: The Form Test at 50% Coherency [6]

4.2. Improving Usability and Design

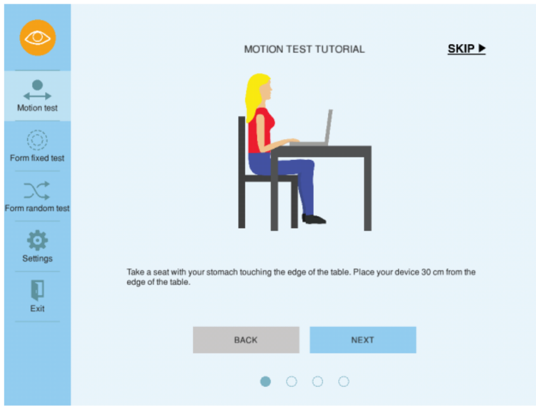
The following year, the Master's students Johansen and Kirkerød [7] continued developing the application. Their main focus was on improving the usability of the application and tailoring the design to accommodate users with dyslexia. Individuals with dyslexia commonly experience challenges related to text distortion, blurred vision and pulsating vision, and discomfort during reading [43]. Johansen and Kirkerød aimed to create a user interface that would mitigate these sensations and optimize the experience for dyslexic users.

Based on paper-based prototypes, Johansen and Kirkerød developed and tested a set of digital prototypes before they began the implementation of the new user interface. To ensure a dyslexia-friendly design, they incorporated various measures such as colored overlays, double spacing after paragraphs, avoiding black text on white backgrounds, and eliminating justified text. These measures were found to enhance the digital experiences of individuals with dyslexia [43][7]. In addition to improving the design, the application was extended with new features. Notable additions included a user tutorial, a sidebar facilitating navigation between different screens, and the integration of textual messages based on the user's test results. Figure 4.6 presents a collection of screens from the application following Johansen's and Kirkerød's contributions.

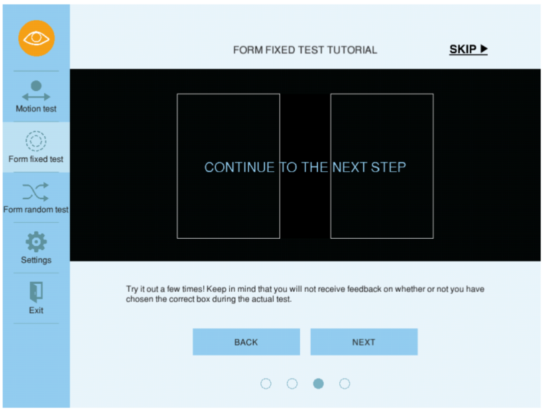
4.3. Adding a Database System

The consecutive work on Magno was related to implementing a database system for the application. The work was performed by Petersen [44] in 2018 through his Master's thesis. The thesis focuses on developing an Application Programming interface (API) and a database that collects and processes data. The ultimate goal was to make the application accessible to a wide range of users and to facilitate larger scientific studies. Petersen also created a dedicated website for Magno, which introduced additional functionalities such as user login, authentication, and a page where the stored data can be viewed by authenticated users. Node.js was used for building and running the application, and the website was hosted in Microsoft's Azure Cloud. Security related to authentication was provided by Microsoft's Asp.Net framework.

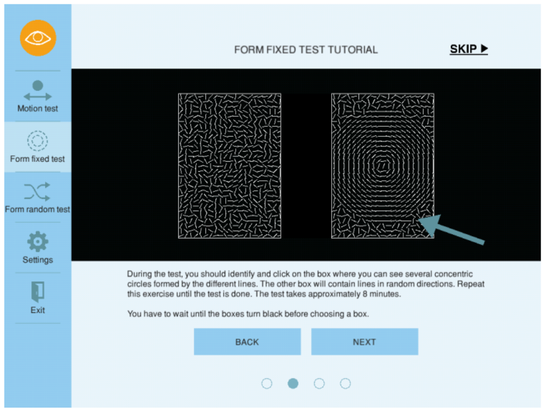
(a) Home Screen



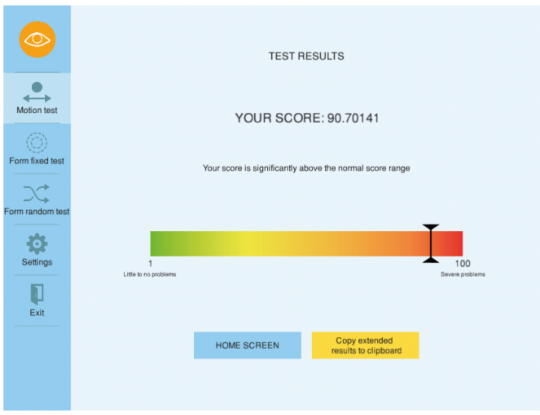
(b) Tutorial Screen (1)



(c) Tutorial Screen (2)



(d) Form Test Screen



(e) Score Screen

Figur 4.6.: Screens of the Improved Application (v.2017) [7]

4.4. Magno: A Platform for Dyslexia Screening

The last iteration of Magno was performed by Syvertsen [45][1] in the 2021-2022 academic year. The primary objective of his work was to create a digital dyslexia screening tool specifically designed for teachers and special educators in primary schools. His specialization project involved conducting a case study and identifying a set of requirements necessary for achieving this goal. In his master's thesis, he focused on implementing an administrative application that integrates the screening tests based on the identified requirements. Syvertsen's efforts have resulted in an application that, with some adjustments, can be effectively utilized in school settings. The subsequent sections provide a comprehensive description of Syvertsen's findings and the development work he undertook.

4.4.1. Results of Case Study

During the course of the specialization project, Syvertsen conducted interviews with teachers and special educators to ascertain the specific requirements they have for a dyslexia screening tool targeted toward young children. In addition, Syvertsen conducted interviews with developers to gather insights into the technical requirements and the developers' needs for the system.

Findings from the Interviews with Teachers and Special Educators

The interviews with teachers and special educators aimed to explore their current usage of digital tools and services in their professional settings and gain insights into their perspectives on key considerations in this context. Through these interviews, Syvertsen sought to identify the enhancements required for developing a digital tool specifically tailored for teachers and special educators in primary schools, as well as a test user interface suitable for young children.

The findings from these interviews indicated that the solution's design should have an intuitive and user-friendly interface. Syvertsen suggested that drawing inspiration from other tools that the teachers are familiar with, such as Google Docs, can greatly assist in achieving this goal. Consequently, the design should align with the guidelines established by Google, specifically following the principles of Material Design [45]. Additionally, Syvertsen emphasized the importance of ensuring that the application is easy to administer and that the test results provide immediate guidance or information regarding their interpretation. Furthermore, it should be possible for teachers to include additional comments, such as observations made during the test, to facilitate a more comprehensive evaluation of the scores and differentiate between reading difficulties and other factors, like lack of motivation, that may have influenced the results. Additionally, the test results should include a baseline that reflects the average performance of children within the same age group, enabling comparison. Moreover, there was an emphasis on the significance of tracking a child's progress over time. To facilitate this, the application should incorporate graphs or other visualizations that display this information effectively.

The interviews also revealed the needs of the test takers, who will be young children with limited reading comprehension skills. Consequently, it is essential that instructions are provided orally by the supervisors to ensure understanding.

Findinds from the Interviews with Developers

Through interviews with developers, Syvertsen sought to gain expert knowledge regarding the development of the solution, particularly to facilitate seamless integration of new screening tests in the future. He emphasized the significance of documentation and understandable unit tests and integration tests. Additionally, he uncovered requirements to enhance the maintainability and modifiability of the system, including minimizing code complexity, loosely coupled modules, and writing clean code. The specific needs expressed by the developers can be found in Appendix C in Table C.1 as non-functional requirements (NFRs).

4.4.2. Implementation

In his subsequent Master's thesis, Syvertsen implemented an administrative application based on the established requirements from the specialization project. The primary objective was to create a system that would be well-received by teachers in primary schools. The application encompasses a fully functional user interface, a server responsible for handling API calls, and a database storage system integrated with the existing screening tests. The list of requirements, which delineates the intended development work, can be found in Appendix C in Table C.2. The table also denotes whether each requirement was fulfilled in the implementation. The attained requirements summarize the accomplished development of Magno and the current state of the application. To evaluate the application, Syvertsen conducted usability testing with teachers and special educators, and with a SUS score of 92.2, the results indicated that it was well-accepted and could already be helpful for the teachers and special educators. Furthermore, Syvertsen emphasized the need to prioritize security enhancements in future iterations of the application.

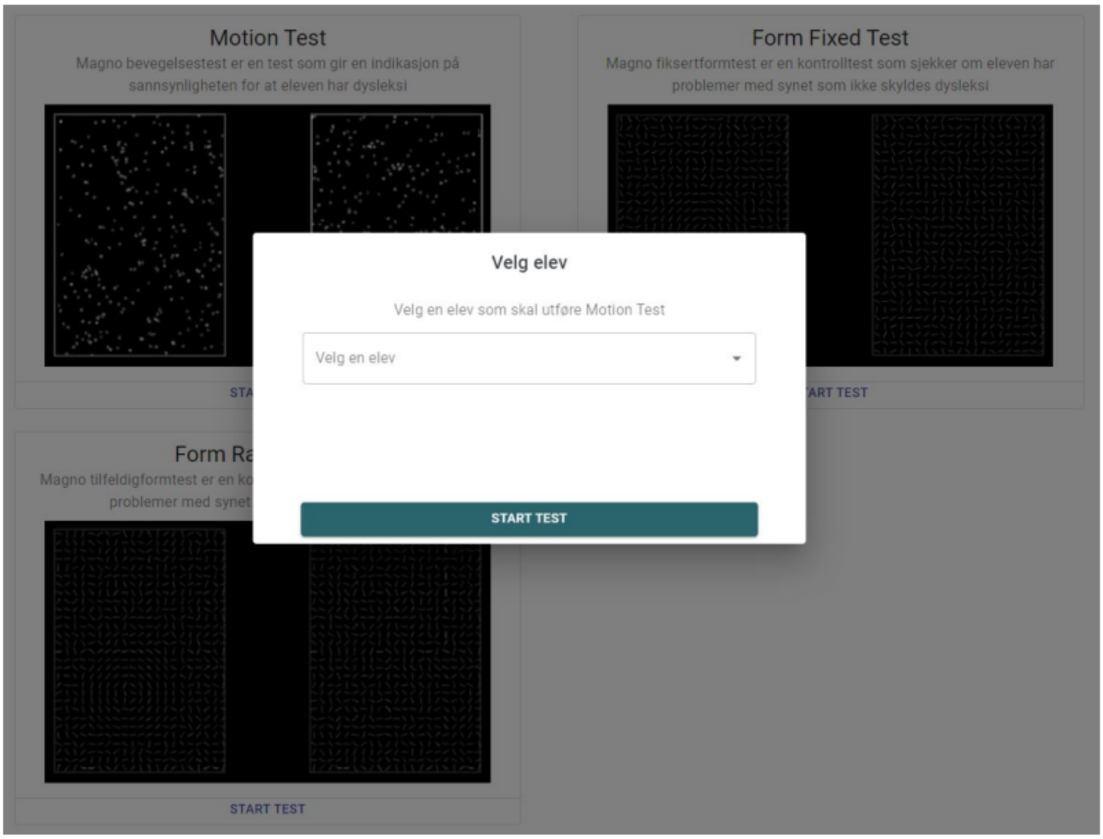
4.4.3. User Interface

The Figures 4.7, 4.8, 4.9, 4.10 and 4.11 show some of the screens of Syvertsen's Magno application. Figure 4.7 shows the new screen for logging in and registering a new user in the system. Figure 4.10, and 4.11 illustrate some of the added functionality regarding the pupil overview. In the application, the test results are stored for the different test takers, allowing for an overview of pupils and their respective results. Additionally, the language of the application was modified to Norwegian to cater to the target user base.

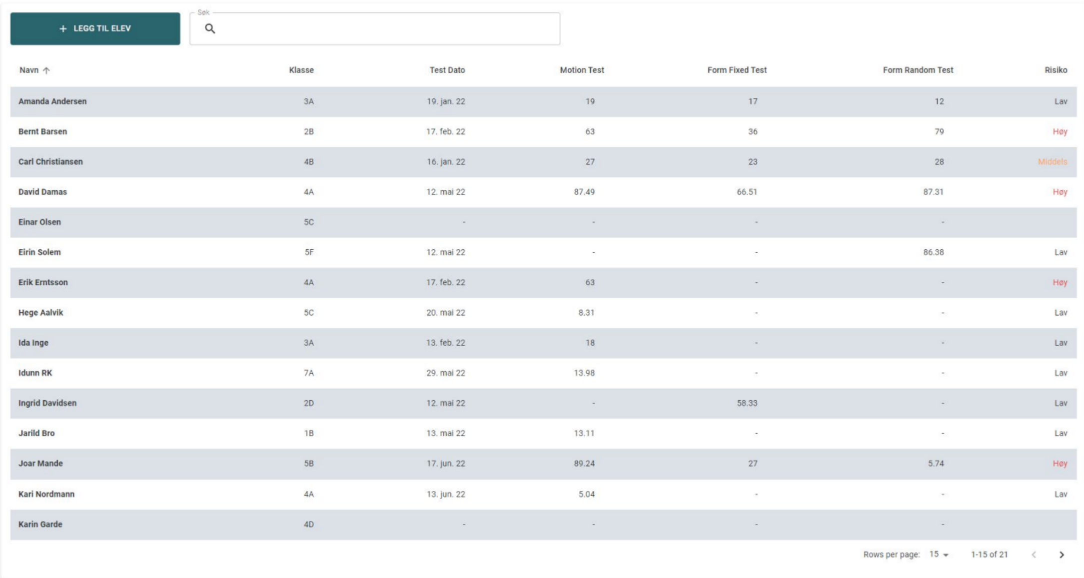
(a) Login Screen (b) Register Account Screen

Figur 4.7.: Login and Register Account Screens of the Platform (v.2022) [1]

Figur 4.8.: The Home Screen of the Platform (v.2022) [1]

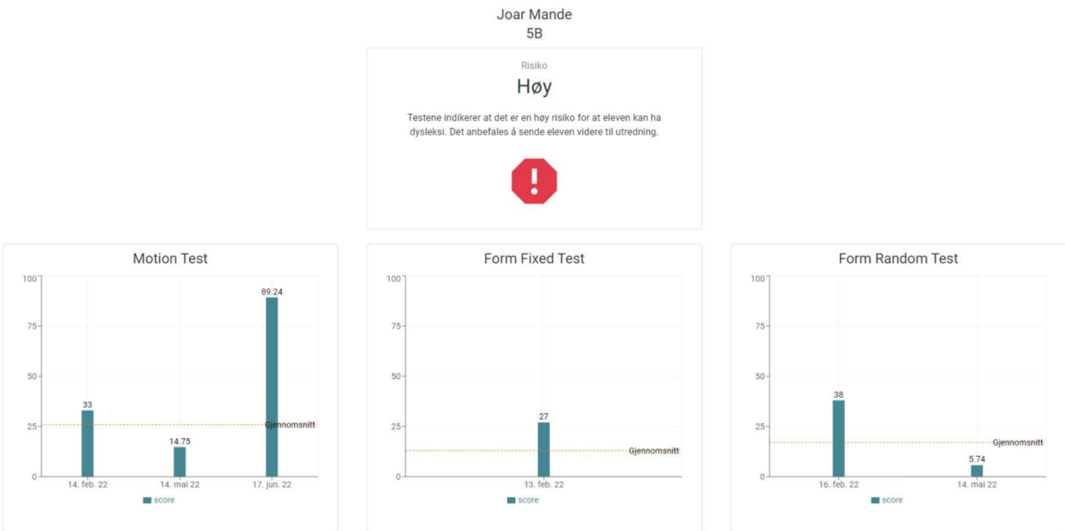


Figur 4.9.: Test Screen with Dialog Box (v.2022) [1]



Navn	Klasse	Test Dato	Motion Test	Form Fixed Test	Form Random Test	Risiko
Amanda Andersen	3A	19. jan. 22	19	17	12	Lav
Bernt Barsen	2B	17. feb. 22	63	36	79	Høy
Carl Christiansen	4B	16. jan. 22	27	23	28	Middels
David Damas	4A	12. mai 22	87.49	66.51	87.31	Høy
Einar Olsen	5C	-	-	-	-	
Eirin Solem	5F	12. mai 22	-	-	86.38	Lav
Erik Erntsson	4A	17. feb. 22	63	-	-	Høy
Hege Aalvik	5C	20. mai 22	8.31	-	-	Lav
Ida Inge	3A	13. feb. 22	18	-	-	Lav
Idunn RK	7A	29. mai 22	13.98	-	-	Lav
Ingrid Davidsen	2D	12. mai 22	-	58.33	-	Lav
Jarild Bro	1B	13. mai 22	13.11	-	-	Lav
Joar Mande	5B	17. jun. 22	89.24	27	5.74	Høy
Kari Nordmann	4A	13. jun. 22	5.04	-	-	Lav
Karin Garde	4D	-	-	-	-	

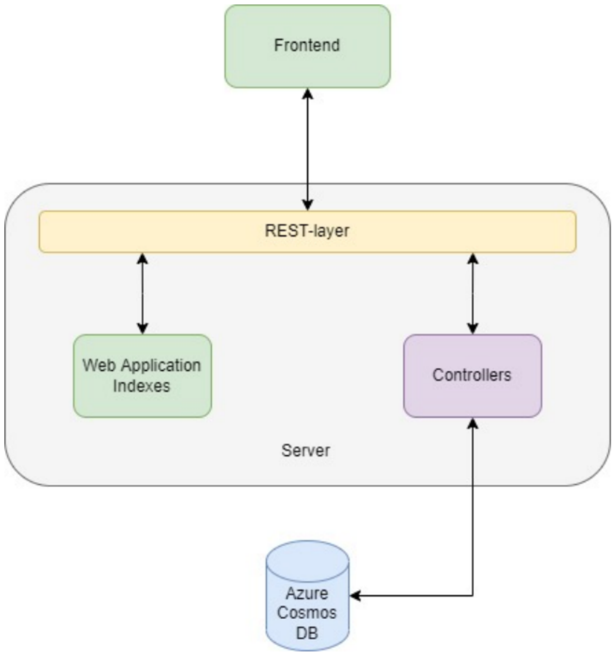
Figur 4.10.: Pupil Overview Screen (v.2022) [1]



Figur 4.11.: Selected Pupil Screen (v.2022) [1]

4.4.4. Software Architecture

The application follows a client-server architecture. Followingly, the code is separated into a client and a server, where the client logic contains code for the graphical user interface (GUI), and the server logic handles requests from the client and the connection with the database. Specifically, the server logic contains a representational state transfer application programming interface (REST API) to handle requests. The client follows the Model-View-Controller (MVC) architecture and the observer pattern. Figure 4.12 shows a simple illustration of the software architecture of the application, providing an extended view of the server structure.



Figur 4.12.: Software Architecture v.2022

4.4.5. Unattained Requirements

Several of the suggested improvements and developments from the case study are not included in the list of requirements that Syvertsen based his implementation on. For instance, the interviewed teachers emphasize the importance of including notes or comments on the test results, explaining any variables that could have affected the results. Furthermore, he found that instructions for the screening tests should be given orally, yet the developed test view intended for the pupil still contains textual information.

4.5. Adapting Magno for Screening on Young Children

During the fall semester of 2022, Larsen and Nedregård investigated adapting Magno for children who have not yet started formal reading education. The foundation of their research was built on previous work on Magno by Klevstuen [46] in 2021, which focused on developing a user-friendly interface for young children incorporating gamification elements. This investigation led to the decision to implement a game-based approach for children aged 5-7 years.

Continuing their research, Larsen and Nedregård are currently developing and testing this approach. The testing phase is centered around evaluating how children complete tasks based on given instructions, their navigation within the application, and the influence of incorporating gamification elements on their task motivation. Their work contributes a new solution for the screening tests of Magno.

4.6. Requirements Specification for Role-Based Access Control (RBAC) and Enhanced Pupil Follow-up

The specialization project, conducted in the fall semester of 2022, aimed to determine the relevant features and functionalities to be added to the platform, making it valuable for teachers and special educators in primary schools. To gain this information, qualitative interviews were conducted with special educators and special education advisors.

The research findings emphasized the importance of access control to ensure data security and restrict unauthorized access to sensitive information. In the previous iteration of Magno, all users who create an account for a specific school are granted access to data about the pupils registered under that school, along with their test results. Furthermore, all users can add new pupils, classes, and test results. However, in a real-life scenario, it is essential to have proper limitations on these actions to maintain data privacy and comply with confidentiality requirements.

Consequently, the specialization project identified the need for implementing an RBAC system as a key requirement. This system would enable the assignment of specific roles to users, granting them appropriate access privileges based on their responsibilities and the scope of their work. The implementation of RBAC would ensure that teachers have access solely to the relevant data they are meant to access, thus preventing unauthorized access to sensitive information about pupils for whom they are not responsible. This enhancement addresses security concerns and aligns the application with the requirements of a real-life educational setting.

Furthermore, the interviews conducted with end users revealed additional needs and suggestions. One such finding is that the presentation of information, particularly the test tutorial, contains a significant amount of text. To address this, the interviewees proposed having a separate user manual and reducing the amount of text and instructions in the general user interface.

The interviewees emphasized the importance of considering multiple factors beyond the results of screening tests to obtain a complete understanding of a pupil's reading and writing abilities. To facilitate accurate evaluation, the application should provide additional information about the pupil, enabling teachers to make more informed assessments.

Building upon the findings from the interviews, a set of functional and non-functional requirements were developed. The functional requirements, which outline the desired features and functionalities, are presented in Figure 4.1. The non-functional requirements, which address aspects such as usability and security, are listed in Figure 4.2. These requirements serve as guidelines for the further development of the application, ensuring that it meets the needs of its end users.

Id	Description	Priority
FR1	The test view should not contain any textual information - only the test	High
FR2	The teacher should be shown the test tutorial in a simple and point-by-point manner	High
FR3	The teacher should get a message to pass on the device to the pupil when the instructions are finished and the test is about to start	Medium
FR4	The teacher should have a user manual with guidelines on how to use Magno and how to perform the tests with pupils	Medium
FR5	The teacher should receive guidelines on further actions for the pupil based on the result of the tests	Meidum
FR6	The teacher should be able to find and read the theory behind the test in the application	Medium
FR7	The teacher should only be able to see pupils and their results from his/her own class	High
FR8	The special education advisor should be able to see all pupils in his/her school	High
FR9	The teacher should be able to add a list of pupils into the application	Low
FR10	The teacher should have an overview of previously taken mapping and screening tests, if there is dyslexia in the family, and other relevant information for each pupil	High
FR11	The teacher should have an overview of other potential diagnoses for each pupil	High
FR12	The teacher should have an overview of test results on other performed mapping, screening, or diagnostic tests for each pupil	High

Tabell 4.1.: Functional requirements from the specialization project

Id	Description	Priority
NFR1	The application should maintain a high quality of information security and privacy	High
NFR2	The application should be designed according to Material Design Guidelines	Medium
NFR3	The documentation of the application should be precise and easy to understand	High

Tabell 4.2.: Non-functional requirements from the specialization project

5. Methods, Frameworks, Tools, and Technologies

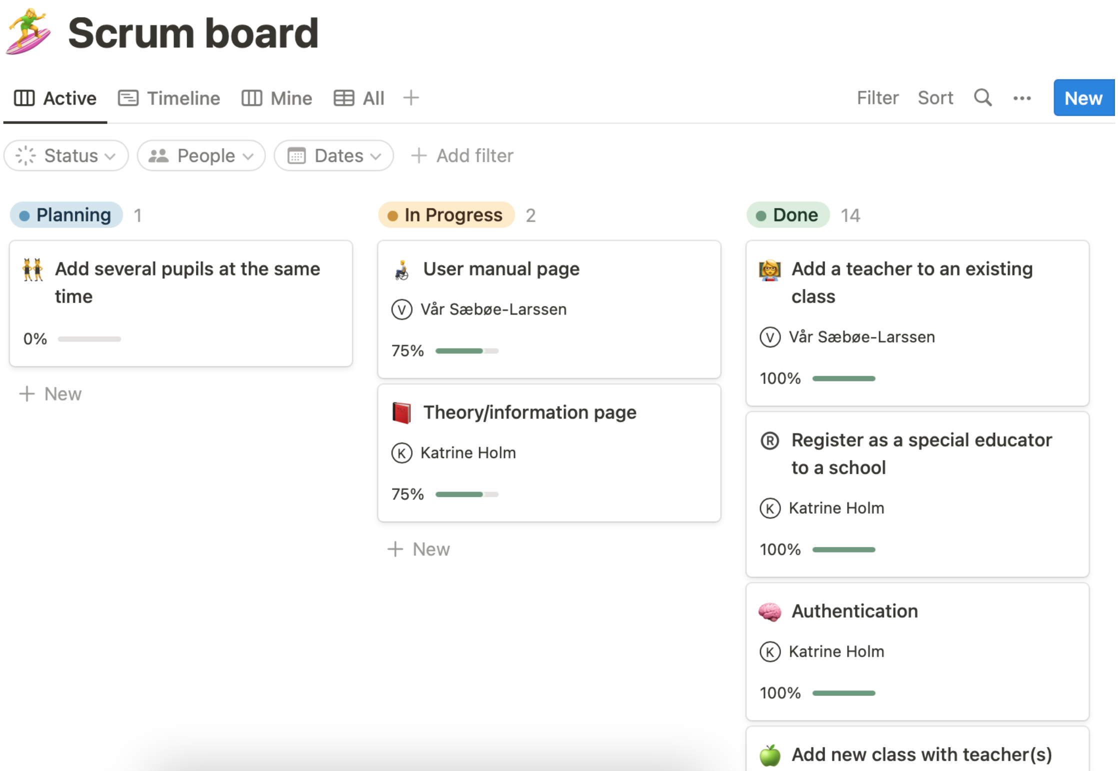
This chapter will describe the methods, frameworks, tools, and technologies that have been utilized in this project. First, Section 5.1 will describe how the framework Scrum has been used in the development process, adhering to the principles of agile software development. Section 5.2 will go into detail about the different usability testing methods that have been used in the evaluation of the development, including information about best-practices approaches as well as a description of how they are implemented to suit the performed research. Lastly, Section 5.3 will describe all frameworks, tools, and technologies utilized in the artifact's development work.

5.1. Scrum

Scrum is widely adopted as an effective framework for managing and executing agile development projects. It offers a structured approach that is particularly well-suited for addressing rapidly changing business requirements [47]. One of the key advantages of Scrum is its emphasis on iterative and incremental development. Development work is divided into short development periods called sprints, typically lasting two to four weeks [48]. Furthermore, expressing the development tasks as user stories is a common practice. A user story is a concise, user-centered description of a specific feature or functionality from the perspective of the end user [49]. It is a simple yet effective way to capture requirements in agile software development.

As a small development team consisting of two members, we adapted the approach to meet the needs of the project. The implementation phase of eight weeks was divided into two sprints, each lasting a period of four weeks. This arrangement was well-suited to our team's size and allowed for efficient adjustments and adaptations within each sprint.

At the beginning of each sprint, a sprint planning meeting was conducted with the aim of planning the development work for the sprint. The requirements were formulated as user stories, with each user story representing a specific functionality or feature that was planned for implementation. However, these user stories often encompassed a broad scope. To provide more detailed specifications, smaller development tasks associated with each user story were created. These user stories and development tasks made up the Scrum board and were categorized into "Planned", "In progress", and "Done" depending on their status. The scrum board offered a convenient overview of the remaining work, facilitating seamless planning and continuous re-planning of the development tasks. Figure 5.1 shows a screen capture of the Scrum board.



Figur 5.1.: Scrum Board

5.2. Usability Testing

The research's main form of evaluation was performing usability testing of the design sketches and implementations. Usability testing plays an essential role in the user-centered design process of software development projects. Its purpose is twofold: to ensure that interactive systems are tailored to the users and their tasks and to identify and prevent any potential negative outcomes that may arise from their use [50]. The usability testing aimed to prevent any considerable deterioration in usability when expanding the application. The following subsections will present the utilized test methodologies.

5.2.1. Remote Testing

Usability testing has traditionally been conducted in a controlled laboratory environment, where test-takers are invited to complete tasks while being observed and recorded.

However, remote testing has gained popularity as an alternative approach, enabling testers to participate from their own locations. Remote testing offers several notable advantages. Firstly, it provides cost-effectiveness in terms of time and financial resources. Secondly, remote testing enables participants from distant geographical areas to be included, resulting in a broader and more diverse participant pool. This expanded reach enhances the potential for gathering insights from a wider range of perspectives [50].

Remote Synchronous and Asynchronous Testing

Remote testing can be categorized into two approaches: Remote Asynchronous Usability Testing (RAUT) and Remote Synchronous Usability Testing (RSUT). In the RSUT approach, the facilitator conducts the test session and collects data in real-time. This can be performed using screen-sharing through live-video services such as Teams or Zoom. In contrast, when performing RAUT there is no real-time access to data. It does not involve a facilitator interacting with the participant during the data collection, leaving the participant to perform the test “on their own” [50].

Among the remote approaches, RSUT stands out as a favored option by several researchers [50]. In a comparative study conducted by Andreasen et al. [51] in 2007, both RAUT and RSUT methods were compared with a traditional laboratory-based approach. The findings revealed that the RSUT performed almost identically to physical laboratory testing. Furthermore, the study indicated that the RAUT methods were more time-consuming for participants and identified fewer usability problems. Another study by Alghamdi et al. [52] in 2013 also found that RSUT performed better than RAUT in terms of the number of usability problems discovered. However, the study found that the RAUT methods were less time-consuming for participants than the RSUT methods. In other words, both studies state that participants discover more usability problems with RAUT methods, but differ in their findings regarding the time required for the methods. Note that the time gap between the studies, variations in website quality and performance, and differences in website types and participant instructions may attribute to the discrepancies in results.

Despite the research indicating that RAUT may identify fewer usability problems compared to RSUT, it is often perceived as more effective for facilitators. This is primarily because the facilitator does not need to be present during the testing sessions. As a result, RAUT allows a larger number of test users to participate concurrently, with a minimal or no additional cost [50]. Given a sufficient number of test participants, it is highly probable that usability issues will be identified during the evaluation process.

Choice of Remote Testing

Building upon the research discussed, both RAUT and RSUT were selected as test approaches for different stages of the development project. More specifically, RSUT was conducted during the design phase. This involved conducting qualitative interviews digitally using Zoom, with the primary objective of collecting a substantial amount of qualitative data regarding the design sketches and identifying any usability issues that may arise. RAUT was later conducted in the implementation phase. This test approach involved administering a quantitative questionnaire to gather numerical data and insights.

5.2.2. The Technology Acceptance Model

The technology acceptance model (TAM) is the most widely used theory to explore user acceptance [53]. This model addresses criticism of solely focusing on usability without considering the system's usefulness when investigating the adoption of information systems [54]. Introducing new information systems in organizations is of little use if the people in the organization do not end up using them. All information systems, ranging from simple applications to more complicated systems, require user acceptance. Therefore, understanding and predicting the user acceptance of new technologies is essential, both in organizations and for the developers of these [53].

Davis et al. [55] developed TAM, which uses the two variables, perceived usefulness (PU) and perceived ease of use (PEOU), as determinants of user acceptance. The PU is based on the observation that people tend to use or not use the application to the extent they believe it will help them perform their job better. However, even if an application is perceived as useful, it will only be used if the system is also considered easy to use (PEOU).

TAM is well known for its applicability, and numerous studies have extended it to fit different technologies, contexts, and user groups [56]. The TAM questionnaire typically consists of eight to twelve statements about the PU and PEOU of a system. The participants should rate their agreement with these statements on a Likert scale[1], ranging from 1 (strongly disagrees) to 7 (strongly agrees). In this project, a modified TAM questionnaire was utilized. The goal of the modified TAM questionnaire was to gain insight into the PU and PEOU of the design sketches developed in the design phase. The participants were encouraged to elaborate on the reason for their rating. The results, including the ratings but more importantly the participants' explanations and justifications, were qualitatively analyzed. Since the participants were encouraged to give lengthy and detailed answers, a shorter questionnaire of six statements was deemed appropriate. The following six statements were formulated for the questionnaire, translated from Norwegian, where four are related to PU and two are related to PEOU.

1. Given that I have access to the system, I imagine that I would use it.
2. The system would be useful for me in my job.
3. The system would make it easier for teachers and special educators to follow up with children with reading and writing difficulties.
4. I would be able to save time by using the system.

[1] a scale sometimes referred to as a satisfaction scale, that ranges from one extreme attitude to another

5. I think I would have to spend a lot of time learning the system to use it on my own.
6. I would assume that most people can learn this system very quickly.

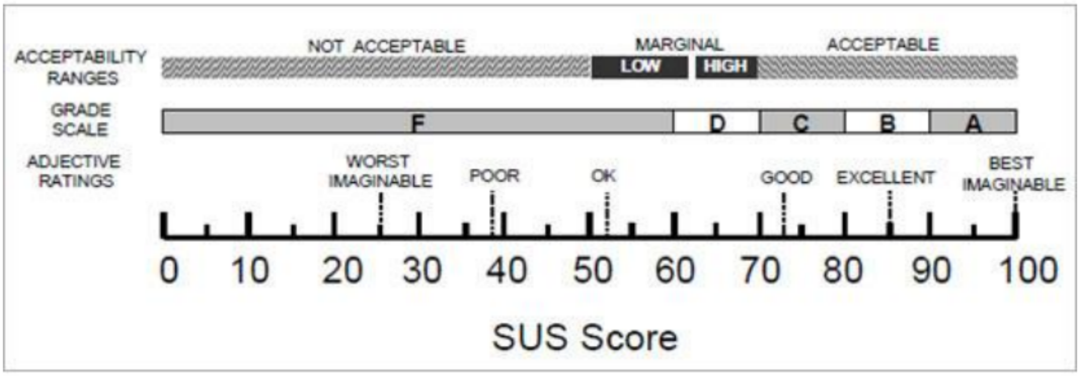
5.2.3. System Usability Scale

The System Usability Scale (SUS) is a simple scale giving a view of subjective assessments of usability. It is widely utilized as a usability testing tool that has proven robust and reliable and correlates well with other subjective usability measures [57]. The questionnaire covers various aspects of usability, such as ease of use, learnability, efficiency, and confidence in using the system. By administering the SUS questionnaire to a group of users, the system's overall usability can be evaluated and compared across different iterations. The SUS questionnaire follows a standardized format, consisting of ten statements designed to measure the perceived usability of a system. The test takers rate their level of agreement with each statement on a Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The statements in the provided usability form are the following:

1. I think that I would like to use this website frequently.
2. I found this website unnecessarily complex.
3. I thought this website was easy to use.
4. I think that I would need assistance to be able to use this website.
5. I found the various functions on this website were well integrated.
6. I thought there was too much inconsistency on this website.
7. I would imagine that most people would learn to use this website very quickly.
8. I found this website very cumbersome/awkward to use.
9. I felt very confident using this website.
10. I needed to learn a lot of things before I could get going with this website.

To analyze and evaluate the results from the SUS questionnaire, a total score is calculated. The total SUS score ranges on a scale from 0 to 100, where higher scores indicate better usability. A SUS score of 68 is considered average. Data from previous evaluations can be used to compare SUS scores and determine how a system performs relative to other systems or products [8].

Researchers have looked into the relationship between SUS scores and people's ratings of systems and products in terms of adjectives such as "good," "poor," or "excellent" and found that there is a close correlation. They state that it is possible to take the SUS score for a product and give it a grading score [8]. Figure 5.2 show this scale of grades based on the SUS score.



Figur 5.2.: Grade Rankings of SUS Scores [8]

SUS was utilized during the evaluation in the implementation phase, enabling quantitative measurements to test the effectiveness of the implemented functionality. By employing this method, we were able to calculate a total SUS score and compare the results with findings obtained from the previous year's research.

5.2.4. Participant Recruitment

In this study, several sampling techniques were employed to select suitable participants. The aim was to find participants with suiting backgrounds and levels of expertise and familiarity with similar systems within the field of education, while at the same time ensuring a diverse sample by including individuals with different geographical placements and age groups. This approach allowed for a broad range of relevant perspectives and feedback during the usability testing processes.

In the initial usability test conducted during the design phase, purposive sampling was utilized to select participants based on specific qualities and relevance to the research objectives. The selection criteria focused on individuals who possess experiences and knowledge within the field of special education and general education for young children. The purposive sampling method is commonly used in qualitative research to ensure the optimal utilization of available resources, leading to rich and meaningful insights that enhance the overall quality and depth of the research findings [58]. Recruitment was done through emails, which provided an explanation of the master thesis and its problem statement, and the purpose of reaching out. As a result, six participants took part in the usability tests, which involved qualitative interviews to evaluate design sketches. The participant group consisted of two special education advisors, two students in the education field, one current teacher, and one former teacher. It should be noted that the special education advisors were already familiar with the project due to their prior involvement in the specialization project. All participants signed a NSD contract, which can be found in Appendix D.

For the second usability test, performed in the implementation phase, a combination of purposive and snowball sampling was employed to expand the pool of participants. Snowball sampling involves recruiting additional individuals through referrals provided by existing participants [59]. To engage potential participants, we prepared emails containing details about the thesis and a link to the questionnaire. These emails were then shared by the 6 participants who had previously taken part in the usability tests in the design phase, forwarding them to their colleagues and other acquaintances within the field. Additionally, we sent these emails to individuals within our own network who possessed knowledge and experience in the field of education. Note that the participants who had contributed in the design phase were not asked to participate. The final participant group comprised 30 individuals, including teachers, special educators, pedagogy students, and individuals outside the field of education.

5.3. Frameworks, Tools, and Technologies

In the development, various frameworks, tools, and technologies were utilized. The following sections provide an introduction to these and their relevance to the project.

5.3.1. React

React is a front-end JavaScript library for building user interfaces (UI). It follows a component-based approach, which enables developers to create reusable UI components that manage their internal state as data changes [60]. Consequently, developers can efficiently update components, allowing for the construction of complex UIs. The decision to continue to use React was driven by its efficiency and widespread popularity among developers. According to the Stack Overflow Developer Survey from 2022, React emerges as the second most used web technology among developers, ensuring that future project developers of Magno are likely to be familiar with it [61].

5.3.2. Material UI

Material UI is an open-source library of React UI components. It offers a collection of pre-designed, customizable components following the Material Design guidelines established by Google [62]. The library was selected in the previous year's master project due to the teacher's and special educators' use of Google's tools for work [1]. By incorporating the design system utilized by Google, it leverages the users' familiarity with the interface. Moreover, Material-UI's extensive documentation, active community support, and regular updates make it a popular choice for development [62].

5.3.3. TypeScript

TypeScript is a programming language developed by Microsoft that serves as a superset of Javascript. More specifically, it offers all of JavaScript's features while introducing the concept of static typing. With static typing, developers can explicitly define and enforce types for variables, function parameters, and return values. This additional layer of type checking provides code quality that is easily comprehensible and enables early detection of errors, leading to more robust and reliable codebases [63]. TypeScript is implemented in the client code, as in the previous version of Magno.

5.3.4. Node.js

Node.js is a runtime environment that allows developers to develop servers for web applications using Javascript. It offers a collection of built-in modules and packages, which is managed by the Node Package Manager (NPM). With Node.js and NPM, developers have access to a vast ecosystem of open-source libraries and frameworks that simplify the development process. Furthermore, Node.js provides comprehensive documentation and benefits from an active community of developers [64]. This has contributed to its widespread popularity in building modern web applications. This is evident from the Stack Overflow Survey of 2022 [61], where Node.js emerged as the most commonly used web technology.

5.3.5. Express.js

Express.js is a web application framework designed for Node.js. It provides an efficient way to build web applications and APIs by simplifying the process of handling HTTP requests and routing. Furthermore, it offers middleware integration for tasks such as authentication and error handling [65].

5.3.6. Azure Cosmos DB

Azure is a cloud computing platform by Microsoft, offering a wide range of products and cloud-based services [66]. Among these, Azure Cosmos DB is utilized in this project, which serves as a fully managed NoSQL relational database for modern app development.

Azure Cosmos DB provides a highly scalable and flexible solution for storing and querying data. One of its key features is capacity management capabilities, which include cost-effective, serverless, and automatic scaling options. These features ensure that the database can dynamically adjust its capacity based on the application's needs, which helps to control costs while maintaining optimal performance and responsiveness. Moreover, as an integral part of the Azure platform, Azure Cosmos DB benefits from additional features that increase the service's availability and reliability [67].

5.3.7. Google Cloud Platform and App Engine

Google Cloud Platform is a cloud computing platform with numerous services and tools to support various cloud-based solutions. One of its offerings used in this project is Google App Engine, which is a platform-as-a-service that simplifies the process of hosting web applications.

As a fully managed environment, Google App Engine takes care of infrastructure on its own. It automatically handles tasks like resource provisioning, scaling, and load balancing, allowing developers to concentrate simply on application development [68].

5.3.8. Git and GitHub

Git is a distributed version control system widely used to collaborate and track changes in source code during software development. By using Git, developers can create shared repositories where they can store their codebase. Each developer can create branches from the repository to work on specific features. These branches are separate paths of development, allowing individuals to work independently without interfering with each other's work. Once the changes are completed, the branch can be merged into the main codebase, combining the collaborators' contributions. Git keeps a record of every addition, deletion, or modification through commits, enabling developers to keep track of changes and easily revert back to earlier versions if needed [69].

GitHub is a platform designed for software development that facilitates collaboration and version control through Git. With GitHub, developers can create, review and share source-code repositories while gaining access to various additional features. In this project, GitHub was used to host the Git repositories and perform code reviews for all changes made to the repository.

5.3.9. Visual Studio Code

Visual Studio Code is an open-source integrated development environment (IDE) by Microsoft. It has gained popularity among developers due to its ease of use, extensibility, and powerful features. In fact, according to the Stack Overflow Developer Survey for 2022, Visual Studio Code was ranked as the most preferred IDE by developers [61].

5.3.10. Figma

Figma is an online whiteboard tool used for design and prototyping, particularly in the field of user experience (UX) design. It provides a shared workspace for designers to brainstorm ideas, organize design elements and collaborate on the visual representation of user interfaces, all in real-time. Furthermore, Figma simplifies the process of gathering feedback on the design as stakeholders and clients can easily review and provide comments directly on the design [70]. Figma was primarily used for developing the design sketches in this project and showcasing them during the usability testing.

5.3.11. Notion

Notion is a collaborative workspace tool that aims to simplify the organization of work by offering a comprehensive set of features. These include note-taking, task management, project tracking, to-do lists, and more. In this project, Notion was used to effectively organize and track the overall progress of the master thesis. This involved incorporating elements such as setting deadlines, tracking tasks and progress, and assigning tasks in the scrum board to ensure effective project management.

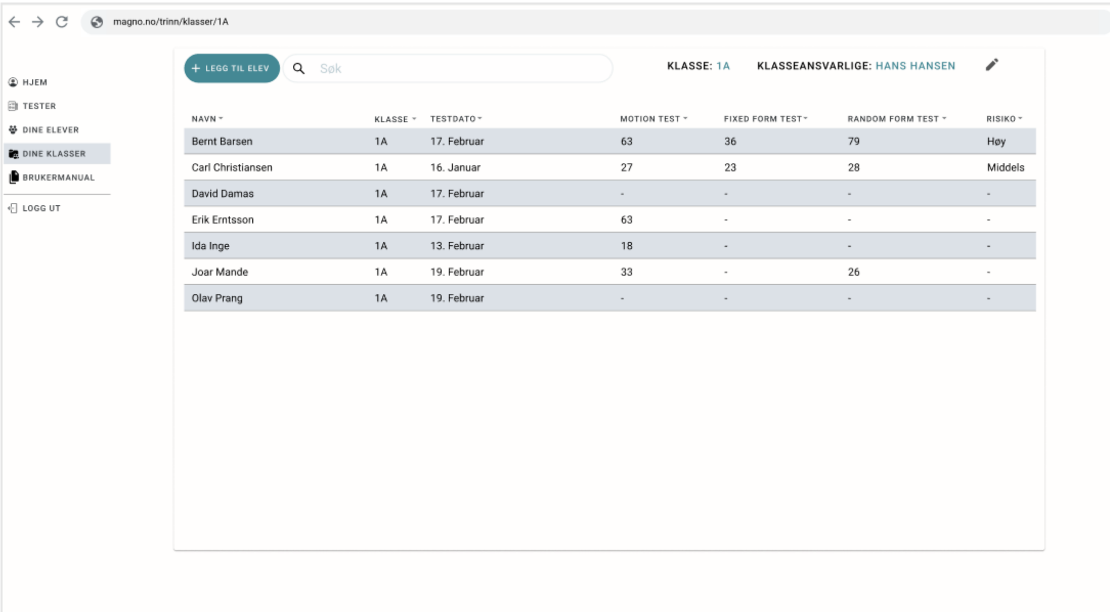
6. Design

This chapter will give a detailed description of the work conducted in the design phase of the development and the attained results. The design phase spanned a duration of four weeks, focusing on creating sketches illustrating the new functionalities for the upcoming implementation phase. Additionally, the objective was to obtain feedback on these sketches and the intended extensions to Magno. Section 6.1 will describe how the design was developed and showcase the developed design sketches. Thereafter, Section 6.2 will describe in more detail the usability testing performed in the qualitative interviews, along with the participant group of this usability testing session. Lastly, Section 6.4 will summarize the obtained results of the usability testing, and elaborate on the changes that were made based on the results.

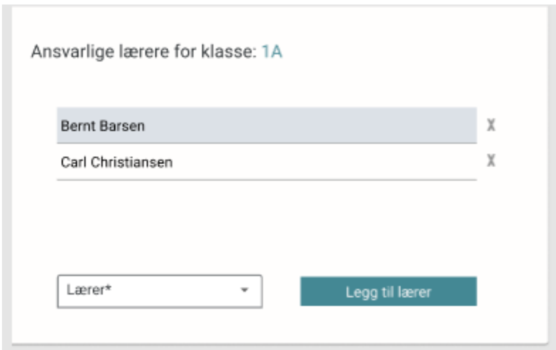
6.1. Developing Design Sketches

Using the functional requirements outlined in the specialization project (Table 4.1), sketches were created illustrating the intended functionality. First, tentative sketches were created as a suggestion, following the steps in the general design cycle. These preliminary sketches served as a starting point to establish a shared understanding of the features and new screen layouts. Building upon these initial ideas, the final design sketches were developed in Figma.

Many functional requirements are related to the implementation of roles (RBAC). The majority of the work related to this is implemented through changes in the back-end part of the code and can not be illustrated with design sketches. However, the implementation of roles includes having somewhat different screens and functionality for a basic user (a teacher) and an administrator (e.g., the special education advisor in the school). For instance, the administrator should have the possibility to add new classes (with or without pupils) to a school and to manage the teachers that are responsible for and should have access to a class. In Figure 6.1, the pupil overview for a given class is presented, including an area in the upper-right corner displaying responsible teachers. In addition, Figure 6.2 shows the window for managing responsible teachers for a class, which should only be accessible to an administrator.

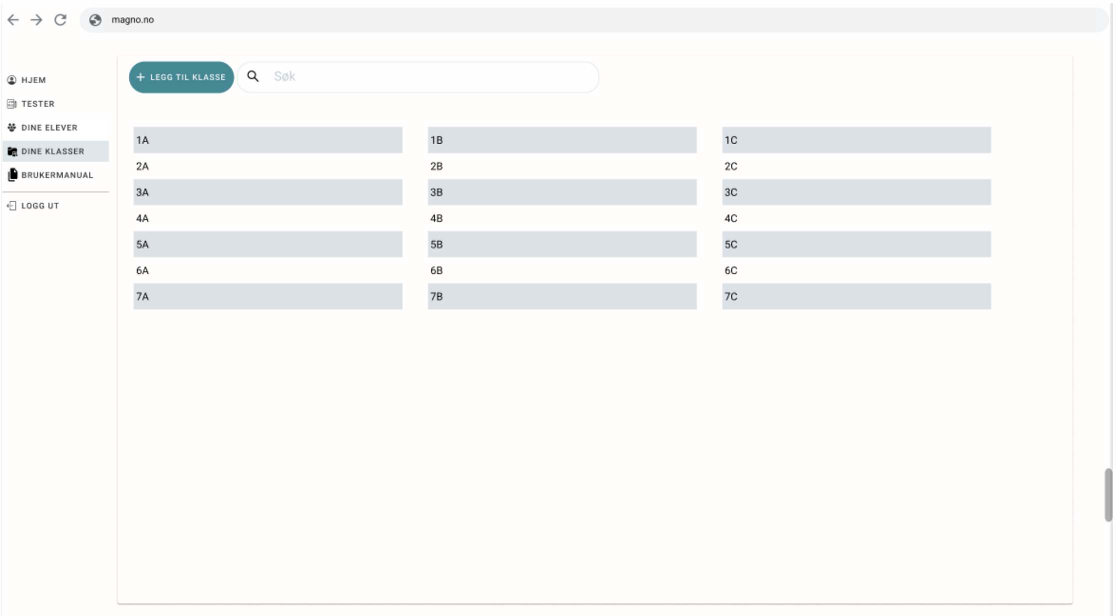


Figur 6.1.: Class Overview Showing Responsible Teacher

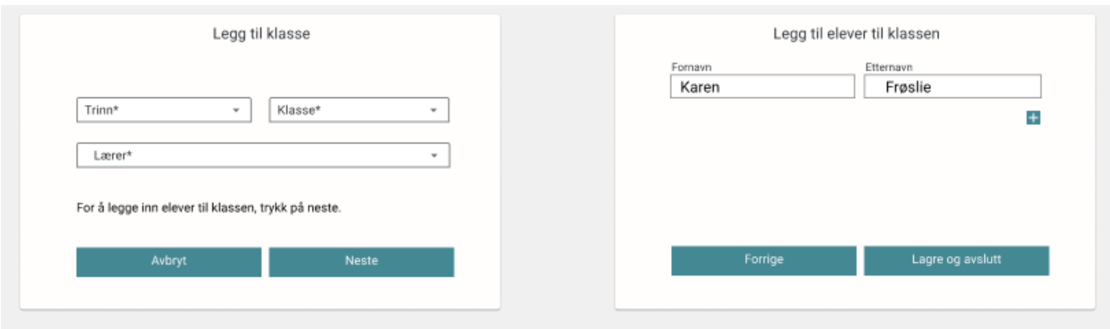


Figur 6.2.: The Possibility for an Administrator to Manage Responsible Teachers for a Class

Furthermore, the basic user should be able to see an overview of the classes the user is responsible for. The administrator, on the other hand, will have access to all classes assigned to the school. The class overview for an administrator is shown in Figure 6.3. Additionally, the administrator should have the possibility to add new classes. To facilitate this action, the class overview will include a button in the top left corner, as illustrated in Figure 6.3. The design sketches of the window for adding a new class, with the option to add pupils during class creation, are shown in Figure 6.4. It should be possible to click “Save and exit” without adding any pupils to the class, enabling the addition of pupils at a later time. The button for adding a class together with its functionality is only available to the administrator.

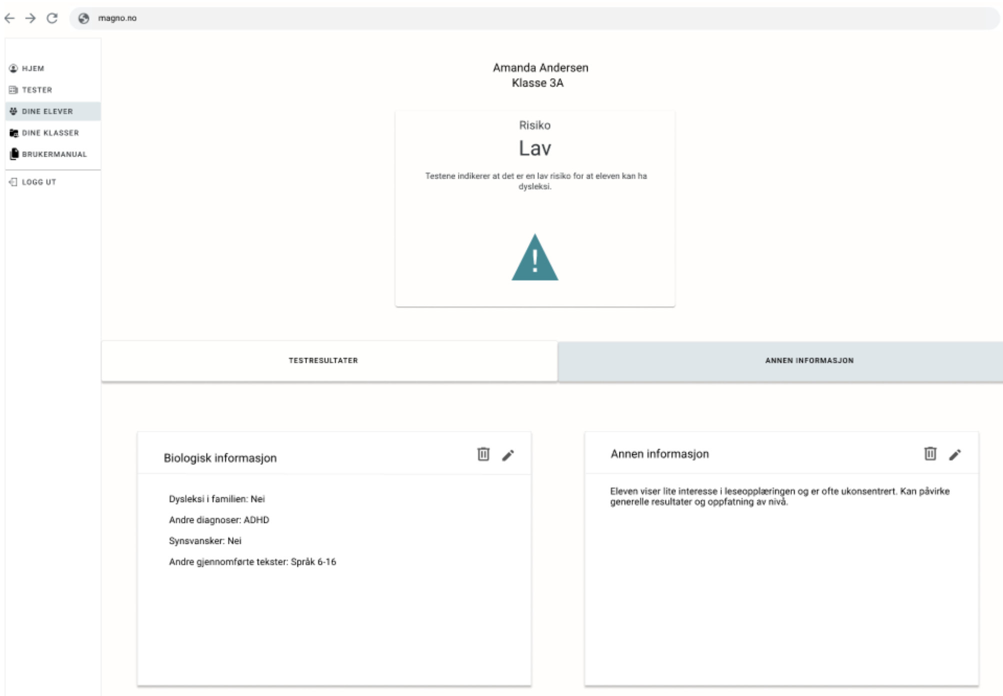


Figur 6.3.: Class Overview for an Administrator with the Button for Adding Class



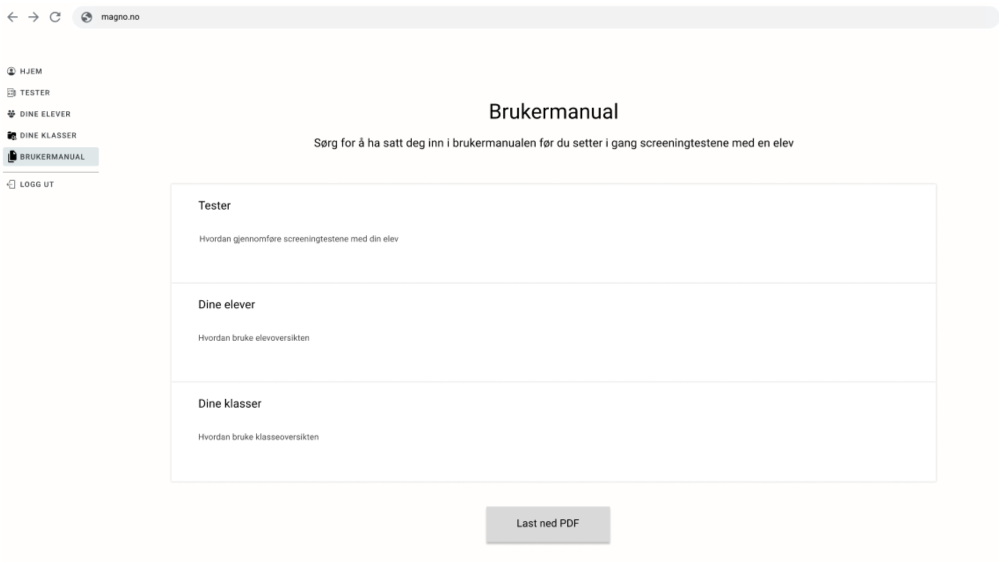
Figur 6.4.: Add a Class with Pupils

FR10-FR12 describe the possibility of finding additional information about a pupil in the application. Through the specialization project, it was made clear that a teacher needs more information about a pupil to assess the pupil's situation correctly. However, it is important to exercise caution regarding the information that can be entered about a pupil. This precaution is essential to prevent the inclusion of sensitive information in the system. The functionality of entering additional information about a pupil will therefore be implemented in a point-by-point manner, with predefined points, to encourage the teachers to adhere to these points. Furthermore, the use of predefined options with limited possibilities will also lead to a simpler UI with clearer instructions. In this way, using predefined options can also improve usability. However, a dedicated section for additional comments has been included to allow the teacher to provide unrestricted comments about a pupil, such as general observations about the concentration level during the tests or the reading and writing training in general. The sketches for these requirements can be found in Figure 6.5.

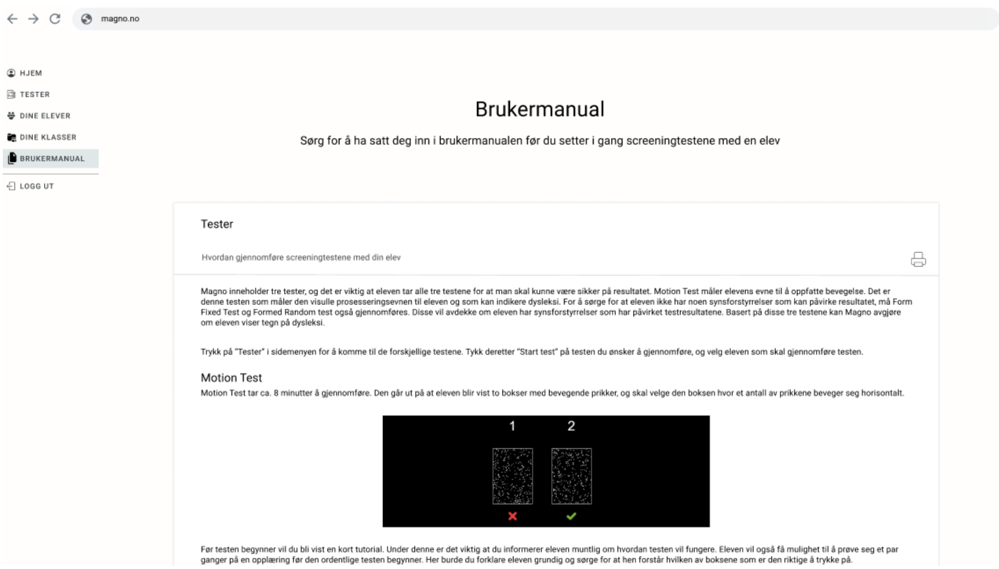


Figur 6.5.: Additional Pupil Information Page

FR1-FR4 are about simplifying the test view by removing text and keeping test instructions in a separate manual. To meet these requirements, a user manual page was designed containing guidance on test administration and general application usage. The user manual proved highly beneficial to the special educator advisors from the conducted specialization project, particularly when the user manual could be printed. The design sketches of the user manual can be seen in Figure 6.6 and Figure 6.7.



Figur 6.6.: User Manual



Figur 6.7.: User Manual: Information about The Tests

6.2. Evaluating the Design

An evaluation of the design sketches was conducted to ensure the intended functionality's usefulness. The evaluation was performed through remote semi-structured interviews with the objective of gaining qualitative feedback on the design sketches and the system's perceived usefulness and ease of use. Details of the usability testing are outlined in Section 5.2. The complete interview guide can be found in Appendix E.

The interview sessions were structured into two parts. The first part aimed to receive feedback on the sketches in terms of the general usability and usefulness of the designed features presented in the sketches. The second part included the TAM questionnaire. The goal was to gain qualitative insights into these matters. The participants were encouraged to explain and justify their answers, and during the analysis, emphasis was placed on these explanations and justifications rather than solely focusing on the numerical scores. The results from the interviews provided indications of the acceptance of the new features. Furthermore, the feedback was used to modify certain design sketches and the list of requirements.

6.3. Results from the Evaluation

This section will go into detail about the results retrieved from the evaluation of the design sketches and intended functionality. The first part will focus on the feedback on the design sketches, while the second part will look into the results of the TAM questionnaire. As the interviews were conducted in Norwegian, all quotes in the following sections have been translated.

6.3.1. Feedback on the Design Sketches

All in all, the participants gave positive feedback regarding the design and layout of the new screens and functionality, although with some suggestions for improvements. This section will present the feedback received.

User Manual

In general, the participants responded positively to the sketches of the user manual. The feedback was very similar to what was found in the specialization project, confirming the need for these implementations. They stated that the tutorial viewed by the pupil should not contain any text.

Yes, I agree with it being a lot of text, especially for testing on children in primary school who do not read well and even more so if they have dyslexia. I think it will be easier to be able to listen to a task and maybe have the possibility to listen to it several times so they will know for sure what to do.

The participants also found it very convenient that the user manual could be printed out. They stated that they would most likely use this feature and keep the user manual nearby while conducting tests with pupils.

And I think it is very nice that you can print it out. I have this experience from testing with Logos[1], where it is very difficult to go from the test (when testing with a pupil) to view what is on the page (Logos' website). This gets very cumbersome, especially in front of the children. So being able to have a piece of paper in front of me, especially the first few times, I think would be very nice.

I would definitely print out the user manual and have it beside me when performing the tests.

I think it is nice to have bullet points. And it is an appropriate amount of text. [...] I assume I would print out the user manual when using it. I think teachers generally like to use paper and have it in front of them. Then you can also take notes on the paper if something occurs during the test.

One participant highlighted the importance of clearly distinguishing information for the teacher and information intended for the pupil before the test. Additionally, the participant recommended including a reminder to ensure that the pupil has understood the task, such as "make sure to ask the student if he/she has understood the task". Furthermore, multiple participants provided feedback regarding the language used in the user manual. They suggested that the manual should exclusively include Norwegian words, as opposed to incorporating English terms.

The participants also found it useful for teachers and employees in schools that instructions on how to use the application, and not only the tests, are included in the user manual:

In my experience, teachers are not the most technical when it comes to new digital tools. So I think it will be very useful to have a user manual with information about how to use the application in the best way. And explaining that "By using 'Your classes', you will come to a list of your classes", and so on.

Different Roles and Access

Consistent with the findings from the specialization project, the participants expressed that a teacher should not have access to all pupils within their school. One of the teachers commented on the separation of access and responsibilities:

That sounds very good. I do not see any reason why a teacher such as me, who teach in second grade, should have access to the pupils in fourth grade. Unless they have responsibility for these students. I think this has to do with confidentiality. But of course, there will always be collaboration between teachers.

[1] a diagnostic tool widely adopted in Norwegian schools

It also became clear through the feedback that having an administrator role in the application is similar to what they are familiar with from other tools they use and that the assignment of the administrator role is school-dependent.

I think it is important to have an administrator. We have that in almost all systems we use. Then it is usually the department manager (trinnleder) who is the administrator. [...] It depends on how the school is structured. [...] We are not a classroom school, but some schools are.

The same teacher stated that in her school, a teacher should have access to all students in the grade he or she is teaching. This teacher works in a school where the teaching is structured on grade level (trinnskole).

A special education advisor responded with the following:

It sounds like a perfect solution, really. Not all teachers should know about everything. But at the same time, it is nice that I can give access to the teachers who should have access. [...] It is nice that I can determine the accesses.

One of the teachers also suggested that there could be a parent role - giving the parents of the pupils the possibility to log into the application and see their children's test results and other information. She stated that there is often a tight collaboration with the pupil's parents in the process of detecting and diagnosing dyslexia and that it could be beneficial for the parents to be able to access the data stored in the system.

Class Overview

When going through the sketches of the class overview page, all participants agreed that having a class overview would be beneficial for efficiently keeping track of pupils. The possibility of categorizing classes by grade was discussed, enabling users to select a grade, such as the first grade, and subsequently choose from the classes within that specific grade.

Some participants preferred the two-step process, where they could select the grade and then choose the class. However, it was noted by other participants that this approach might be redundant for teachers who are only responsible for one or two classes, which is a common scenario. In such situations, there would be only one or two grades available for selection, resulting in a limited number of classes to choose from. As a result, this option was deemed unnecessary as it did not significantly simplify the class view. One of the teachers stated the following about combining the class overview page shown in Figure 6.3 with the two-step approach:

I think I would prefer a combination of the two. Instead of having them side by side, you can have the classes listed below each other.

Regarding the screens for adding a new class, shown in Figure 6.4, it is essential to ensure clear communication through the user interface that adding pupils to the class is optional. The action of creating a class should only be available to the administrator, while it will probably be the teacher's responsibility to add the pupils to the class. Failing to communicate that a class can be created without adding pupils may result in the administrator, e.g., the department manager, taking on a heavy workload of adding all pupils to the classes.

If the administrators see that "you can add pupils", maybe they feel that they have to do it. [...] I think it would be easier for the teacher to get access to a class and then add the pupils.

Additional Information About a Pupil

The sketches of the new pupil page were also well received. The participants appreciated the inclusion of additional relevant information about a pupil in the system, allowing them to utilize the information when evaluating the test results. The participants highlighted the convenience of checkpoints, making it easier to know what information to fill out on the page.

I think having boxes you fill in is nice. It is probably also smart to have a box where you can write freely. [...] To write about how the pupil is in class. And a little about what the pupil struggles with, if you have heard him/her reading - does he/she read unevenly, does he/she struggle with words written in a specific way, etc.

One special educator raised the concern that certain information depicted in the sketch should be omitted unless the system is very secure.

It has to be a secure system if it is going to contain a lot of different information about a pupil. The type of information displayed here is information I keep in a secure system because it is sensitive information. I think I would make it more simple - only related to dyslexia."Is there dyslexia in the family?", "Is eyesight checked?", "Is the hearing checked?". These are typical checkpoints when we start to map for dyslexia. You can include other performed tests, but maybe not more than that. For instance, information about ADHD, autism, and other diagnoses can probably be stored in a different place. But hearing, eyesight, heredity, and other performed tests, can be stored here.

Another participant also stated the importance of knowing about the pupil's hearing and eyesight and whether there is dyslexia in the family:

It is often asked early on whether there is dyslexia in the family. And eyesight and hearing are very important and must be tested first (before further diagnosis).

One of the participants pointed to situations where this information could be difficult to retrieve and suggested the inclusion of an answer option such as "not sure" for these questions. The option to clarify in some way in the UI that this information is not possible or difficult to retrieve would be helpful in the assessment of the pupil's situation.

Should it also be possible to answer "do not know"? There may be situations where it is *difficult to communicate with the parents or where there is a language barrier between the school and the family. In these cases, getting concrete information about these things may be challenging.*

6.3.2. TAM

Regarding the TAM questionnaire, the participants generally gave high scores indicating a high level of perceived usefulness ease-of-use of the new features and screens. The following sections will present the feedback received on the TAM part of the interviews.

Statement 1: Given that I have access to the system, I imagine that I would use it

The participants answered that they thought they would use the system if they had access to it. The respondents highlighted the simplicity of the application and the ease of use as the main reason for this. One of the participants said the following about using the application:

I think it was very easy to use. I imagine I could use it on the whole class as a mapping tool, as we do with other mapping tests. [...] So I think I would use it.

Absolutely, if the screening tests are based on research, and I trusted they would give me the right results, I would absolutely use it. Especially because it seems so simple.

Statement 2: The system would be useful for me in my job

In general, the participants thought the system could be useful. Among other things, this is due to the simplicity of the application. One of the participants stated the following:

Yes, I think so. Everything that makes things easier, is easy and user-friendly, that you can receive a link to and learn to use quickly, and do not need to spend much time on, I think is very nice.

Another participant stated that the simple and quick screening tests would be useful for her in her job:

Yes, absolutely. It seems like a very easy measure. [...] The tests are short and simple, and then you get an indication of whether there might be dyslexia or not, and then you have already started the process, making it easier to speed up the process.

Statement 3: The system would make it easier for teachers and special educators to follow up with children with reading and writing difficulties

The participants all agree that Magno would support teachers in the work of following up with pupils that show signs of dyslexia.

I think it is a nice way of detecting it, instead of going through a long process. So I think it is a nice start before beginning to diagnose. I think I would use it as a start.

Another participant justified his score by the simpleness of the class overview and ways of inputting information into the system:

I'll give this a five based on how the system is structured. It is very easy to find the class, and then the pupils in the class. It was a systematic way of entering information about the pupil and seeing the test results.

Statement 4: I would be able to save time by using the system

According to the participants, using Magno would allow them to save time. More specifically, it was emphasized that teachers would find Magno beneficial to streamline tasks related to the detection and diagnosis of dyslexia. However, it was also noted that the workload for the person having the administrative role in the application may increase.

Once you have gotten familiar with the system, added in the pupils, and done that job, then there's time to save. But it will probably also take some time to implement the system in the school. For teachers, it will be easier. For the administrator, the workload will maybe be larger if he/she has to do the manual work of entering the classes and teachers.

Another participant points to how she thinks it would save time for both the teachers and the special education teachers:

Yes. I think you could filter out those who do not need further detection and/or diagnoses more quickly. So long term, I think you could save time. [...] Having a test like this, that anyone can take without the special education teacher taking the pupil out of the class - I think that will save a lot of time for both the teacher and the special education teacher.

Another participant also explains how being able to take the tests on the whole class, because the tests are less time-consuming, will have positive effects on the pupils:

Yes, I absolutely think I would save time. [...] When a single pupil is taken out of the classroom, it is not fun for that pupil. But if the teacher says, "This week I will take out all of you one by one, and you will all try some things [...]". That makes it all very harmless, and it feels safer for the pupil.

Statement 5: I think I would have to spend a lot of time learning the system to use it on my own

All participants agreed that the system appeared easy to learn, though some highlighted the importance of teamwork and school-wide implementation for maximum benefit.

I think it is something that teachers will have to work with in teams in order to be able to implement it in the school. It is very important that all teachers are in on using it. If *not, the whole school will not benefit from it.*

There are a lot of tools we would like to use, but we end up not using them because we don't have the time to get to know the system, or we don't want to spend the time we have on it. So I think it needs to be something user-friendly. That will increase the chances that it is actually used.

Statement 6: I would assume that most people can learn this system very quickly

The participants believed that most people could quickly learn and navigate the system due to its user-friendly interface.

It is a very easy system to get familiar with. There are boxes for information, it's easy to find the test results, etc. I think it is something most people can learn very easily.

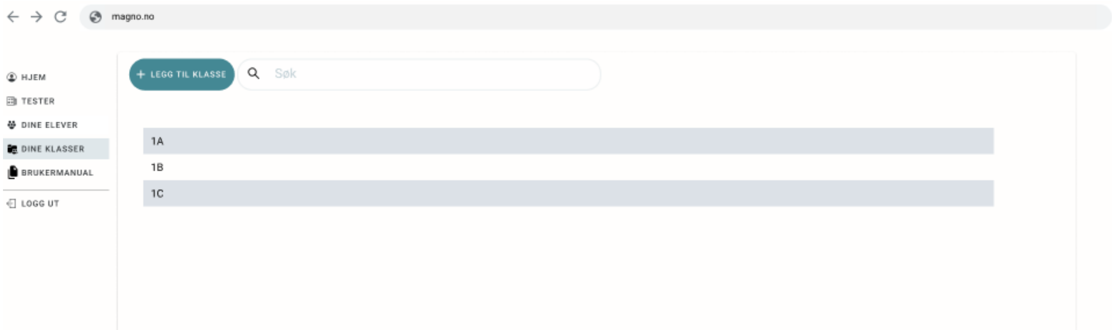
6.4. Conclusion

To summarize the results from the evaluation of the design, the participants gave positive feedback regarding the usability and usefulness of the design of the new features. The TAM part of the interview revealed that teachers found Magno easy to use and believed it would streamline their work, saving them valuable time. Some challenges were mentioned, for instance, concerning the implementation of new tools in schools. However, the majority of the feedback indicated that Magno has the potential to save time for teachers and special education teachers and that it would be easy for them to learn how to use the system.

Certain feedback suggested making smaller changes to some screens and functionality. For instance, it became clear that the administrator should have the possibility to grant access to teachers across grades to accommodate the various structures across schools. This will allow for different schools to personalize the access control, and for instance, grade-based schools can accommodate this structure easily.

Furthermore, a decision was made to change the class overview, as suggested by one of the participants. The new design sketch for the class overview can be found in Figure 6.8. This decision was made despite receiving positive feedback on the two-step approach. However, in the cases where teachers have access to only a few classes, which probably will be the majority of cases, the option to select the grade was deemed unnecessary.

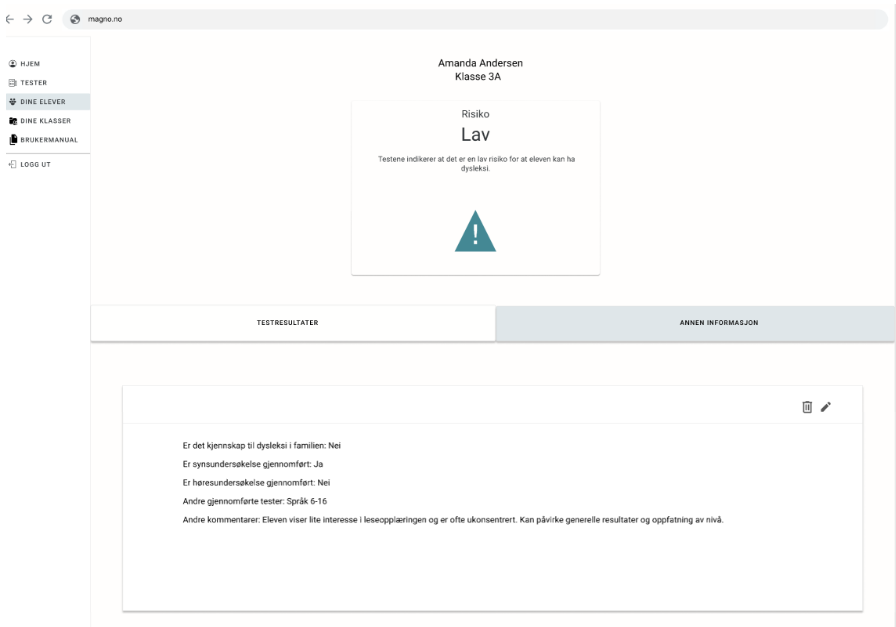
In addition, certain information, such as "other diagnoses", has been excluded from the pupil page due to safety measures. As advised by one of the special educators, we chose to keep the list of checkpoints a bit simpler and not include information that may be considered too sensitive. Furthermore, as advised, a "Not sure" ("Vet ikke") option will be included for checkpoints. The modified sketches for the additional information on the pupil page can be found in Figure 6.9 and Figure 6.10.



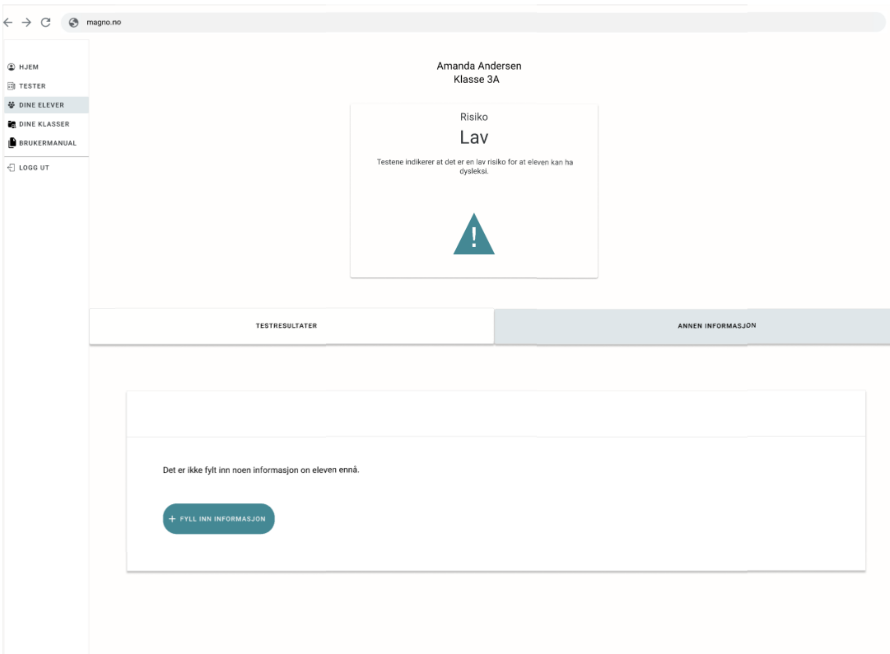
Figur 6.8.: Modified class overview

Lastly, the option to add pupils when creating a class will not be available to prevent any sense of obligation on the administrator's part. The administrator will still have the possibility to add pupils at a later stage. This change is illustrated through the change in phrasing in FR13.

The listed changes have led to the removal of information about other diagnoses and other performed mapping tests from the pupil page (FR11 and FR12). Furthermore, FR10 has been changed to only contain information about whether there is dyslexia in the family and if hearing and eyesight examinations have been performed. The updated list of requirements, with additional explanations, can be found in Section 7.



Figur 6.9.: Modified Student Page



Figur 6.10.: Modified Pupil Page with no Information

7. Implementation

This section will give a detailed description of the work performed in the implementation phase, consisting of implementing the features illustrated by the design sketches and other functionality related to improving usability and security. As mentioned, the implementation phase was divided into two sprints. In the first sprint, the goal was to complete the back-end functionality of the RBAC. The second sprint aimed to complete the remaining user stories from the backlog related to implementing front-end functionality regarding the class overview and easier pupil follow-up. The efforts resulted in the realization of a new version of the application containing a role-based access system with different screens and functionality for the different roles. Additionally, an improved system for managing pupil information and results was developed to enhance the pupil follow-up process.

Section 7.1 presents an overview of the updated requirements that emerged from the design phase and served as the foundational basis for the implementation phase. Furthermore, Section 7.2 provides an overview of the system's software architecture, highlighting the modifications made to its components. Section 7.3 will give a detailed explanation of the security measures implemented through authentication and facilitating the RBAC. Section 7.4 showcases the screens and functionalities that constitute the new version of Magno. Thereafter, Section 7.5 describes the usability testing performed as the evaluation method of the implementation phase. Lastly, Section 7.6 will present the results from this evaluation, presenting a quantitative and qualitative analysis of the results.

7.1. Updated Requirements

Throughout the design and implementation phase, the list of requirements from the specialization project underwent revisions. The updated versions of the functional and non-functional requirements are presented in Table 7.1 and Table 7.2. These modifications were driven by the feedback received during the evaluation of the design phase, as summarized in Section 6.4. Additionally, some updates were made based on personal ideas and suggestions during the design phase and sprint planning.

The list of requirements has been expanded with the inclusion of FR13-FR15 and NFR4-NRF5. FR13 and FR14 were created at the beginning of the design phase when design sketches were made. It became evident that adding a class and assigning a teacher to it were necessary requirements to address other functional requirements related to role separation within the application. Additionally, the class overview page was included as a practical means to exclusively view students belonging to a particular class. FR15, which allows for registering with a name, was also included to facilitate administrators in identifying teachers by name rather than solely by email when assigning them to classes. Furthermore, NFR4 was added to ensure the code is comprehensible and maintainable. During the implementation phase, it was observed that certain parts of the code could be separated into different files, enhancing readability. Thus, the non-functional requirement was incorporated. Lastly, the inclusion of NFR5 was intended to maintain a high level of usability within the application. The score is derived from the SUS score of the previous year's version of Magno [1]. The objective was to maintain or improve the score obtained to ensure there was no degradation in usability.

Another change that was implemented involved the modification of FR6, which concerns the ability to see the information page that contains the theory behind Magno. Initially, the requirement specified that a registered user should be able to access and read the test theory within the application. However, this requirement was revised to allow for the possibility of viewing the page and reading the theory even before a user logs in. As a result, anyone, regardless of whether they have registered as a user or not, can access and explore the theory.

Id	**Description**	**Priority**
NFR1	The platform should maintain a high quality of information security and privacy	High
NFR2	The platform should be designed according to Material Design Guidelines	Medium
NFR3	The documentation of the platform should be precise and easy to understand	High
NFR4	The code should adhere to the principle of single responsibility and code modularity	High
NFR5	The application should have a minimum SUS score of 92.2	High

Tabell 7.1.: Modified Non-Functional Requirements

Id	Description	Priority
FR1	The test view should not contain any textual information but only contain the test	High
FR2	The teacher should be shown the test tutorial in a simple and point-by-point manner	High
FR3	The teacher should get a message to pass on the device to the pupil when the instructions are finished, and the test is about to start	Medium
FR4	The teacher should be able to find a separate user manual with guidelines on how to use Magno and how to perform the tests with pupils	Medium
FR5	The teacher should receive guidelines on further actions for the pupil based on the result of the tests	Medium
FR6	A general user should be able to view the theory and information page without logging in to the app	Medium
FR7	The teacher should only be able to access information and test results of pupils from his/her own class	High
FR8	The special education advisor should be able to access information about all pupils in his/her school	High
FR9	The teacher should be able to add a list of pupils into the platform	Low
FR10	The teacher should be able to see and edit information about the pupil, including if there is dyslexia in the family, and if hearing and eyesight examinations have been performed	High
FR13	The special education advisor should be able to create classes and assign teachers to the class	High
FR14	The teacher should be able to see an overview of the classes he/she is responsible for	High
FR15	The teacher and special education advisor should be able to register with a name	Medium

Tabell 7.2.: Modified Functional Requirements

7.2. Software Architecture

While the overall architecture of Magno remains unchanged, modifications were introduced to specific components within the system. The following sections will provide a more detailed overview of the software architecture employed in both the client (front-end) and server (back-end).

7.2.1. Client-Server Architecture

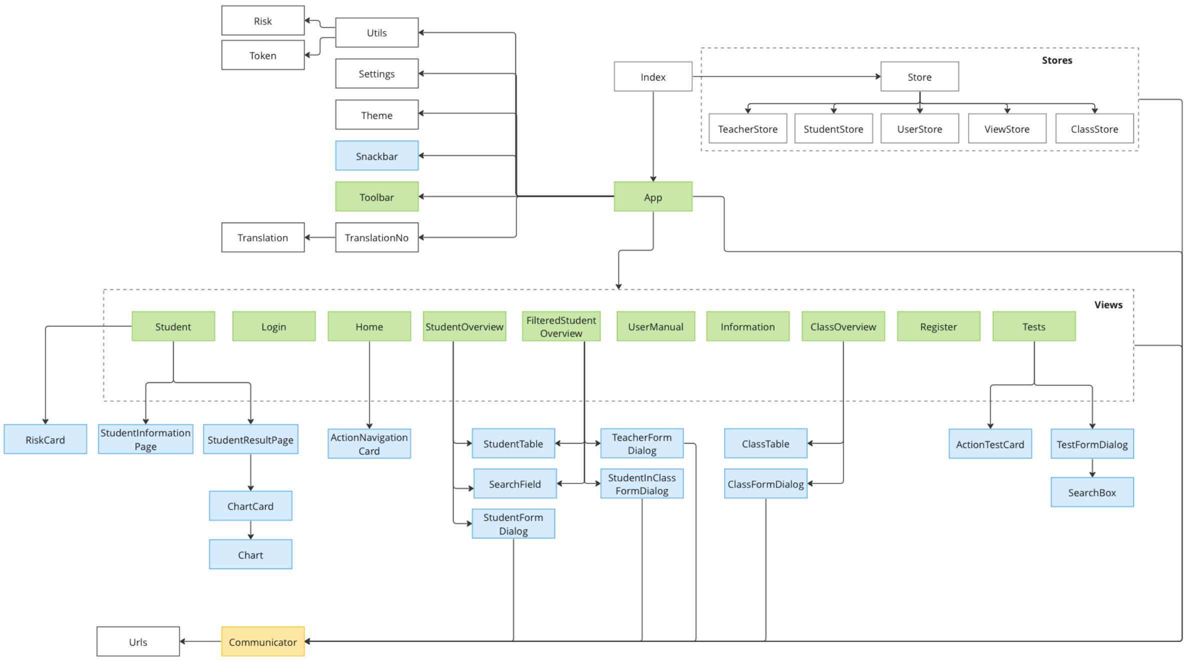
As in the previous year's version [1], the application adheres to a web-based client-server architecture. This architecture establishes a clear separation between the client-side and server-side. The client-side encompasses the user interface and functions that operate on the user's device. On the other hand, the server-side facilitates the back-end infrastructure responsible for processing requests, executing business logic, and managing data [71]. The communication between the client and the server is handled through HTTP requests. In this process, the client initiates requests to the server, which further manages necessary logic and interacts with the database. These requests encompass a range of operations, including requests to web pages and performing various operations.

In the book *System Assurances* from 2022 [72], Rana and Saleh present several advantages of the architecture. Firstly, it offers ease of maintenance and updates, as modifications can be made to one of the sides without impacting the other. This promotes flexibility and scalability for further development. Moreover, the architecture enables the centralization of data and business logic on the server-side, which ensures that critical information is stored and processed in a controlled and secure environment. Centralization of data on the server-side also simplifies integration with other systems, if required in future development efforts.

7.2.2. Front-End Architecture

In the front-end, the overall architecture remains unchanged. As mentioned in Section 4, it follows the MVC architecture. The model is divided into separate data-model stores with clear responsibilities, managing all shared data between components or data that needs to persist. Components handle the remaining data internally; specifically data not required by other components. To track changes to the data-models, components adopt an Observer pattern, enabling them to easily detect and update the view if needed. By following these patterns, the system effectively minimizes the number of callback functions and properties passed between components, resulting in reduced overall complexity.

The application was extended with new views and components related to the class overview page and student overview page for a class. Additionally, a new "utils"-folder was implemented, which includes functions for handling tokens and calculating risks. The purpose of this folder is to centralize reusable functions that multiple components can utilize as the application's functionality grows. This approach helps to reduce code duplication and aligns with the non-functional requirement NFR4, which emphasizes adhering to the principle of single responsibility and code modularity. The updated class diagram of the front-end architecture is shown in Figure 7.1 and in Appendix F, Figure F.1 in an enlarged version.



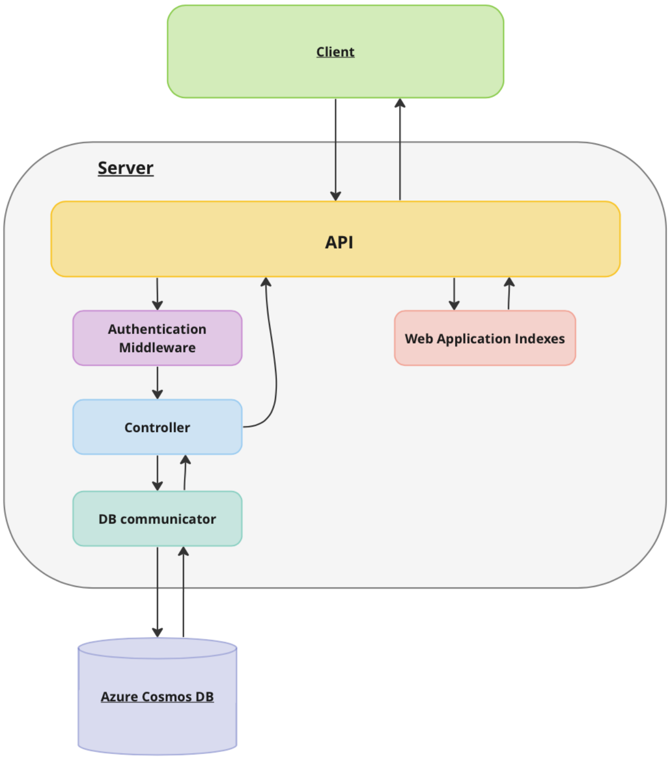
Figur 7.1.: Front-End Architecture

7.2.3. Back-End Architecture

Several changes have been made to the file structure in the back-end from the previous version. Figure 7.2 illustrates the integration of different modules within the back-end system.

Consistent with the previous architecture, the back-end system is designed with an API as an intermediary between the front-end and back-end. The API encompasses two main responsibilities. Firstly, it manages initial requests by determining the appropriate web application to serve. This entails the display of either the application platform or one of the three tests accessible within the system based on the specific requirements of the incoming request. Secondly, the API handles the remaining requests, such as retrieving data from the database and facilitating the submission of forms. In this context, the API ensures that the requests are routed to the corresponding controllers, responsible for handling the logic and generating responses.

The structure of the modules for handling the remaining requests changed due to several



Figur 7.2.: Integration between the Different Modules in the Back-End

reasons. To begin, an authentication middleware was implemented in the back-end to validate the authenticity of incoming requests and to ensure that only authorized users are granted access to the relevant functions, thereby supporting NFR1. Section 7.3.3 will provide a more detailed explanation of the authentication middleware.

Building upon NFR4, the next modification involved dividing the existing controller module into two separate modules: "controller" and "db-communicator". This division serves two purposes: to minimize the amount of code in a single file and to achieve a clearer division of responsibilities in the request process. With this modification, the controller module is responsible for executing all logic and communication with the API, while the db-communicator handles all interactions with the database. The division provides a better code structure and improves maintainability by ensuring a clear separation of concerns within the system.

7.3. Security and Authentication

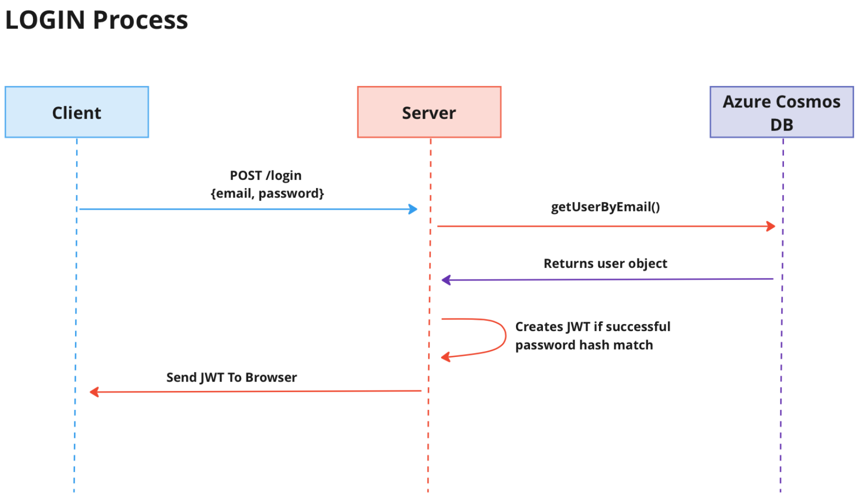
As mentioned, the focus for the first iteration of the implementation phase was to prioritize RBAC and implement security measures to ensure a high level of information security when storing sensitive pupil data. The following sections will explain the implementation details pertaining to the authentication and authorization mechanisms implemented within Magno. Furthermore, these sections will highlight the differences between the new implementation and the previous system.

7.3.1. JSON Web Tokens (JWT)

The new version of Magno leverages JSON Web Tokens (JWT) to facilitate secure user authorization. JWT is an open standard that establishes a compact and self-contained method for securely exchanging information in the form of a JSON object between parties [73]. This token consists of three parts:

- *Header:* Carries information about the type of token and algorithm used for signing
- *Payload:* Includes the identity of a user and the permissions they are allowed
- *Signature:* Verifies the integrity of the token, and is generated using a secret key

Figure 7.3 illustrates the login process in Magno. The login endpoint facilitates user authentication by requesting a username and password. Once a user is successfully authenticated through the login endpoint, the server generates a JWT and sends it to the client. This JWT will then be used as an authentication key when the client sends a request to other protected endpoints.



Figur 7.3.: Login Process: Creation of JWT

7.3.2. Secure Password Storage: Using Salt Hashing Function

Secure storage of passwords is crucial for protecting user accounts. Thus, a salt hashing function is implemented for storing passwords in the Magno database. The utilization of the salt hashing aspect is retained from the previous version. However, the code and file structure has been modified to enhance the overall structure and provide a clearer overview.

When a user creates an account, the password is first added with a randomly generated *salt*. A salt is a unique value that contributes an additional layer of security to the hashing process [74]. The combined password and salt are then passed through a hashing function. The hashing password converts the password and salt into a string of characters and letters, known as the hash. The hash is then stored in the database, while the original password and salt remain private. During the login process, the same steps are repeated and subsequently compared to the stored hash in the database.

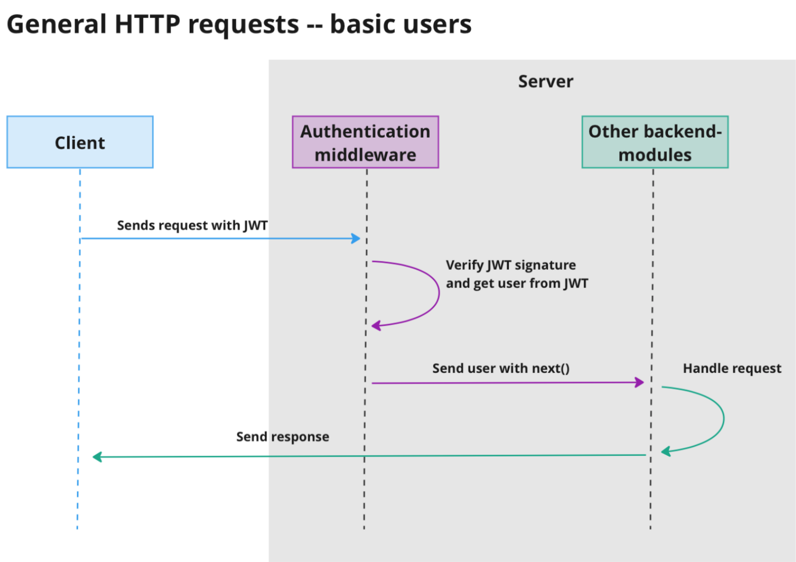
The advantage of using a salt is that it introduces uniqueness to each password's hash. As the hashing function hashes in a consistent way, two identical inputs will get equal outputs. However, due to the unique salt applied, two users with the same password will have different hashes. This prevents attackers from employing pre-computed attack methods to easily crack user passwords [74].

7.3.3. Authentication Middleware

In Section 7.3.1, it is explained that the client receives a JWT from the server when the login is successful. This JWT serves as an authentication key when the client sends a request to other protected endpoints. In the new version of Magno, nearly all endpoints accessible from the user interface are protected by the middleware in the back-end system. The login endpoint is an exception and does not require the middleware, as explained in the previous section.

The authentication middleware acts as an initial defense layer by authenticating users' identities, ensuring that only those with valid credentials can access the associated functions and resources. Once the middleware successfully authenticates the request, it is passed to the controller, which handles the remaining processing and sends a response back to the client.

There are two middleware functions in the system: "authenticated" and "isadmin". The authenticated function is a middleware for all endpoints available for the users, ensuring that the user is verified. Additionally, since the administrator has access to several features, certain endpoints have an extra middleware that first verifies the user's authentication and then checks if they are assigned the admin role. To illustrate the authentication process for basic users and administrators, a sequence diagram is shown in Figure 7.4.



Figur 7.4.: Sequence Diagram for HTTP Requests

7.4. Screens and Functionality

Drawing upon the accumulated knowledge from studying previous iterations of Magno, the conducted research in the specialization project, and the feedback received during the design phase, the modified design sketches and updated functional requirements were implemented in the application. The following sections will describe the implemented changes and enhancements by showcasing the new screens and components, accompanied by a description of the implemented functionality.

Different Roles and Access

FR7, FR8, and FR13 are related to the separation of responsibilities and permissions between an administrator role and a basic user role. This includes that the basic user should only be able to access information and test results of pupils from a class they are responsible for, while the administrator will have access to all pupils in the school. Moreover, the administrator will have access to additional features, such as adding classes and editing access for teachers to the classes.

In the previous version of Magno, anyone could create a user for a school, granting immediate access to pupil data within the school upon login. In the new version, users retain the ability to create an account associated with a school; however, their access privileges remain restricted until they are formally assigned to a class by an administrator. As a result, these users are unable to access pupil data or utilize features such as pupil inputting or test administration until the assignment process is completed.

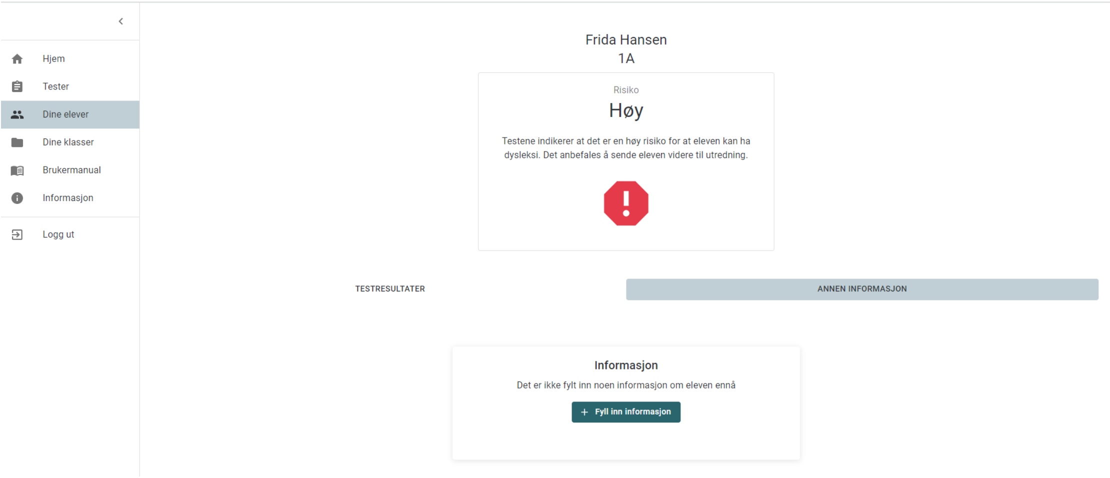
Much of the work related to the functional requirements was done in the back-end, as explained in Section 7.3. However, implementations in the front-end system include the visibility of some components. All pages share the same layout for administrators and basic users, with the exception that administrators have additional buttons allowing the editing of data and accesses. This will be described in more detail in the following sections.

Pupil Information Page

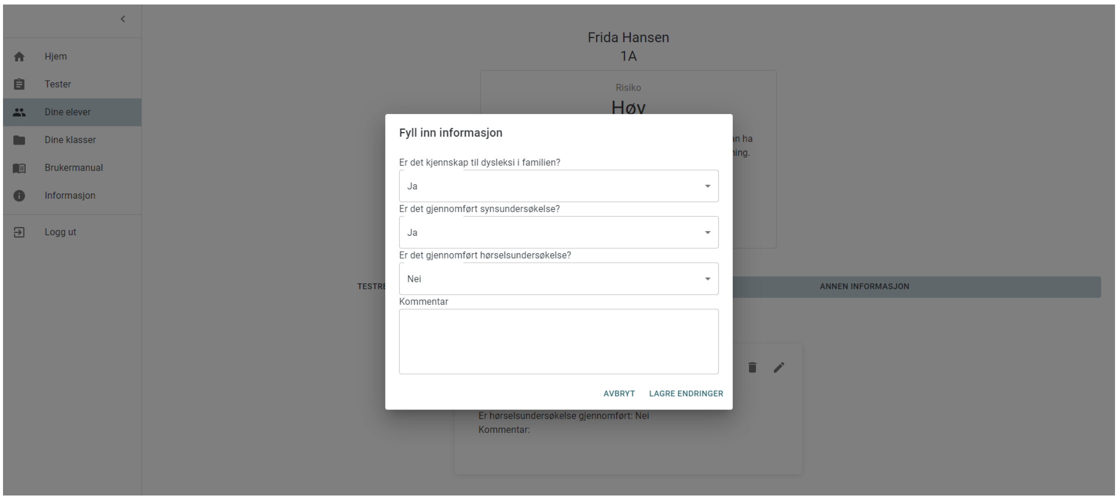
FR10 states that the teacher should be able to find additional information about a pupil. As already explained, this functionality has been implemented with pickers, rather than freely typing in the information, to avoid the inclusion of sensitive information. The implemented page for additional information about a pupil is shown in the screen captures in Figure 7.5.

Class Overview

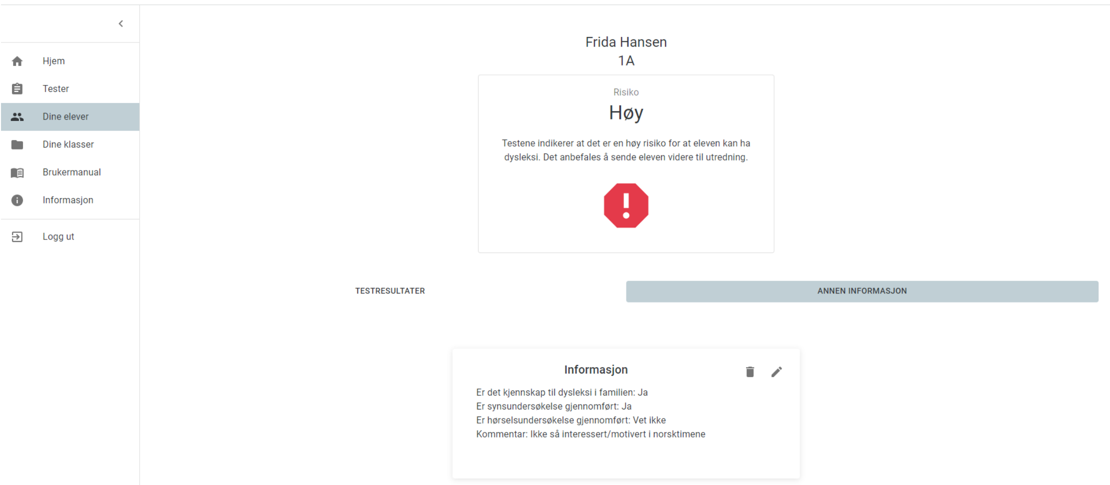
FR13 and FR14 are related to the class overview page. Teachers should be able to see an overview of the classes they are responsible for, along with a list of the students in each class. Similarly, administrators should have the same capabilities and should also be able to manage classes across the school. This includes the possibility to add new classes and administrate the teachers that have access to the classes. Figure 7.6 shows screen captures of the class overview page and the functionality (for an administrator) to add a class to the school. When adding a class, the administrator has the option to assign a teacher to the class, choosing from all registered teachers belonging to the same school



(a) No Additional Information



(b) Adding Additional Information



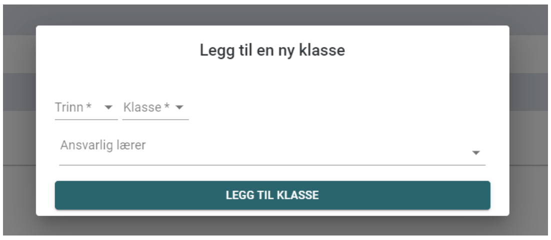
(c) Additional Information

Figur 7.5.: Pupil Page

as the administrator. This action is optional, and the administrator can choose not to assign a teacher and do this at a later time.

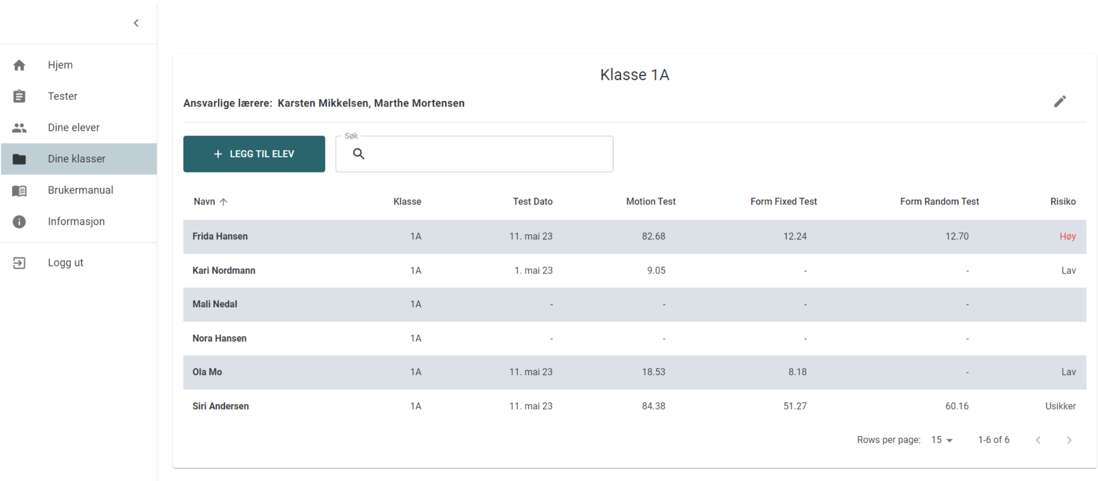
From the class overview page, a user can access the students in a class by clicking on the respective class. This will take the user to the screen shown in Figure 7.7. In this updated version of the pupil overview, it is also possible to see the teachers that are responsible for the class. Additionally, administrators will have access to an edit button that enables them to manage the teachers' access to the class. The windows for administrating this are shown in Figure 7.8.

(a) Class Overview Page

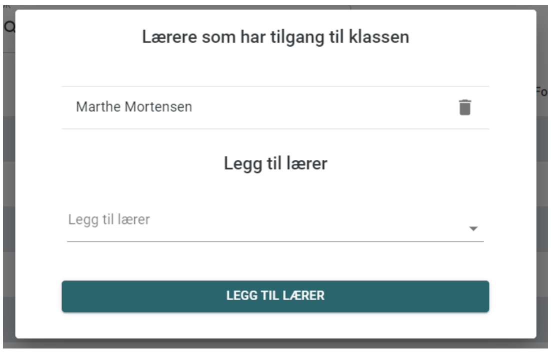


(b) Add Class

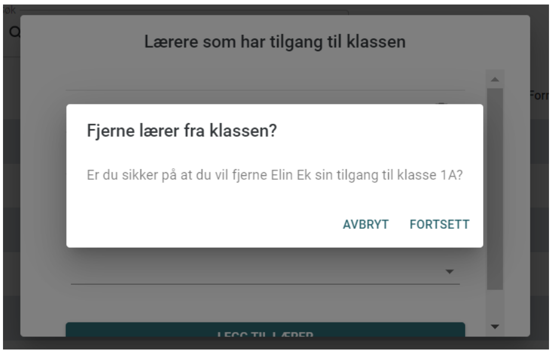
Figur 7.6.: Class Overview



Figur 7.7.: Pupil Overview for Class 1A



(a) Administrate Teachers Window



(b) Remove a Teacher Message Pop-up

Figur 7.8.: Administrate Teachers

User Manual

FR4, related to having a separate page for the user manual, has been realized by developing a separate user manual containing a detailed explanation of how to perform the screening tests with a pupil and how to use the application. The work focused on making the instructions simple. Through the usability testing of the sketches, it was made clear that there was a lot of text in the user manual and that it would be beneficial to reduce the amount of text shown to the user at first sight. As a result, the use of tabs was implemented in the user manual to limit the amount of text shown to the user at once. Screen captures of the user manual are shown in Figure 7.9.

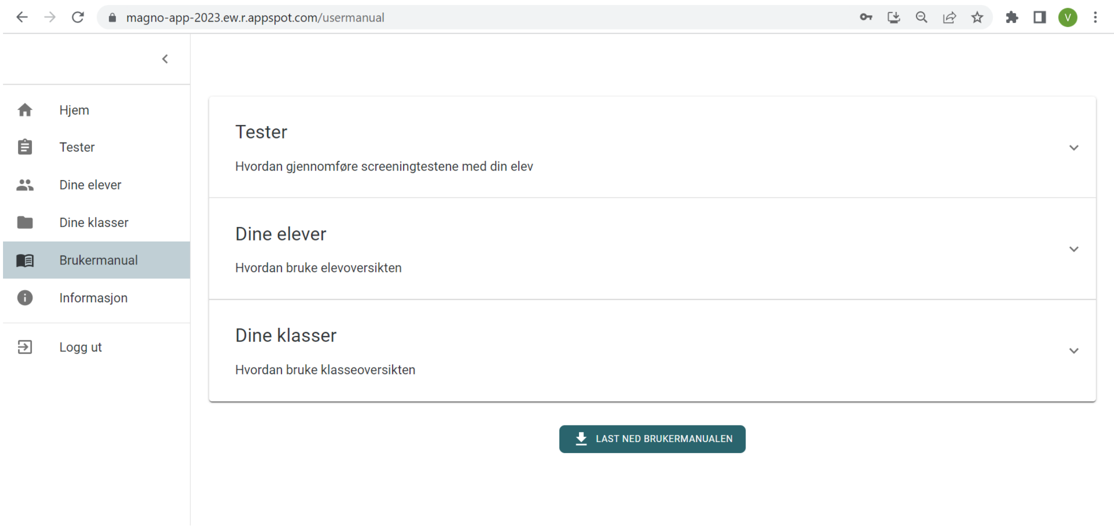
Regarding the parts in the user manual explaining how to use the application, the text is different depending on the role of the user, as an administrator and a basic user will have different options and possibilities in the application.

Information Page

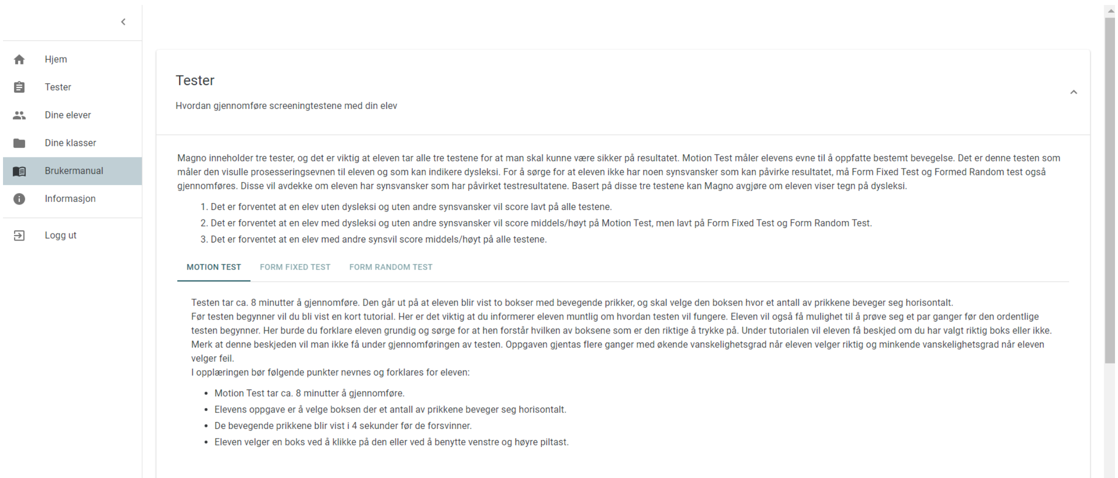
FR6 regards the information page. Through the interviews, it became clear that the information, especially about the magnocellular theory of dyslexia and the screening tests, should be accessible to all who may want to study it. This may increase interest in the application. It is, therefore, possible to access the information page without being logged in to the application. The information page also has an updated layout, as we wanted to include more information on this page. Furthermore, efforts have been made to limit the amount of text shown to the user on the initial rendering of the page and have therefore included drop-downs. A screen capture of the information page is shown in Figure 7.10

7.5. Evaluating the Implementations

The usability testing performed in this phase was performed remotely and asynchronously. The test activities consisted of tasks representing real scenarios that the participants were asked to perform in the user interface, followed by rating the perceived difficulty level of the task on a scale of one to five. The tasks focused on testing the new functionality of the system. Tasks related to login and registration functionality, which had already been tested in Syvertsen's thesis [1], were therefore not included. The tasks primarily focused on the class overview, user manual, theory page, and the new features specific to the administrator role, such as creating classes and assigning teachers to classes. The first six tasks were related to the tasks of a basic user of the system, while the next three tasks were specific to the administrator role. The translated version of the complete usability test form can be found in Appendix G, along with the link to the actual form.

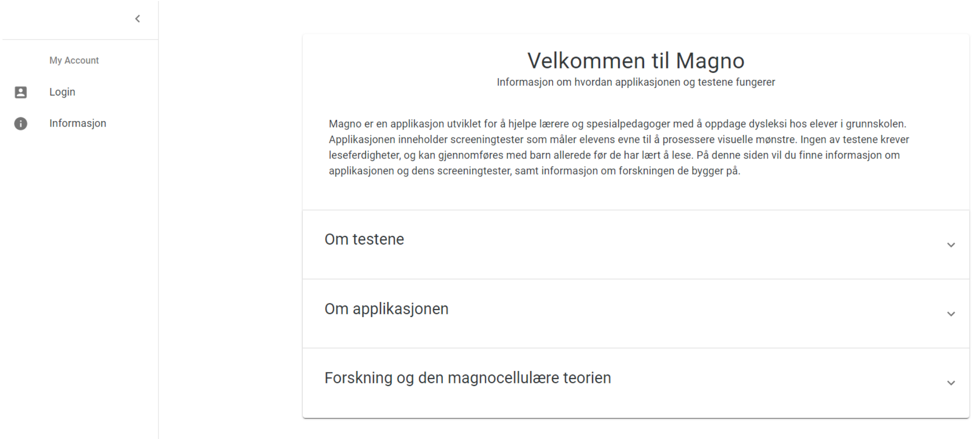


(a) Initial Page



(b) Clicked on Tests

Figur 7.9.: User Manual



Figur 7.10.: Information Page

7.5.1. Participants

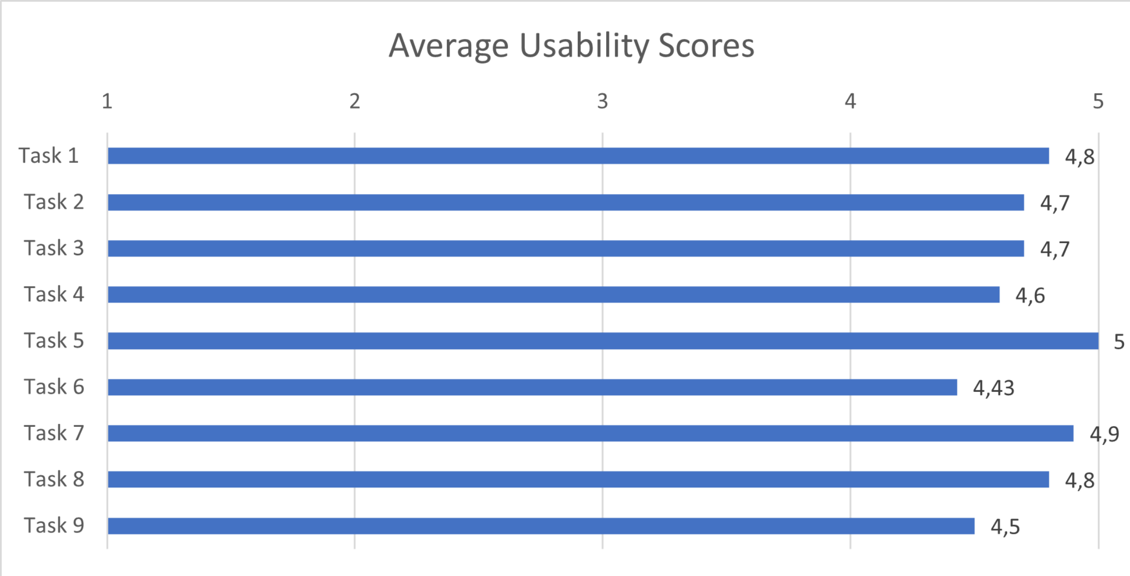
The usability testing form was distributed to and completed by a group of 30 participants in different age groups and with different backgrounds. The focus was to ensure that the majority of respondents had relevant backgrounds, such as teachers, special education advisors, or individuals pursuing studies within pedagogy with practical experience in schools. However, it was not considered a requirement that all participants possessed this specific background, as the objective of the usability test was to identify any errors or weaknesses in the user interface and evaluate the overall usability and design of the new features. Of the participants, 20 were working as a teacher or special education advisors or were pursuing studies in those fields. The remaining ten participants were not in the field of education. 45% of the participants were in the 18-25 age range, 29% were in the 26-40 age range, and 26% were in the 41-60 age range.

7.6. Results from the Evaluation

Figure 7.11 shows the average score on each task of the user test. For each task, participants were provided with a text field to explain the assigned score and offer general feedback on the tasks performed and the user interface. The following sections will provide a summary of the feedback received for each task.

Task 1: Finding and Reading the User Manual

This task was generally considered easy to understand. The participants stated that the user manual was visible and easy to find on the website. Clear headings and few options contributed to a good overview. They also said that the layout was tidy and easy to navigate. Some participants mentioned that certain areas, such as the "Your pupils"



Figur 7.11.: Avarage Scores on the Tasks of the Usability Test

section, contained an excessive amount of text. However, it was noted that the text, in general, was legible and well-structured. Buttons and text fields were clearly placed, and the use of symbols and UX standards was appreciated.

Task 2: Downloading the User Manual

Furthermore, the participants stated that the download button was easily visible and accessible. Participants found it straightforward to locate and click on the button. The button's placement and use of recognizable icons contributed to its visibility. Some participants suggested keeping the button visible at all times, also when multiple tabs are open. The button's placement at the bottom of the page was generally intuitive, although a few participants questioned its position as it was not visible when a section in the user manual was expanded. The button's size, color, and clear labeling made it stand out and easy to click.

Task 3: Navigating to the Class Overview, Selecting Class, and Adding Pupil

The participants found the interface of the class overview intuitive, straightforward, and well-explained. They stated that the left-side menu provided clear navigation. One participant initially had minor difficulties understanding that the classes could be clicked. A suggestion was to use a school icon for the class section. However, aside from these points, participants generally found the class overview to be easy to navigate, with clear instructions and a user-friendly interface that minimized errors.

Furthermore, one participant suggested adding more information to the class overview, as it felt somewhat empty when it contained few classes. Participants appreciated receiving a confirmation when a pupil was successfully added. One consideration raised was the clarity of entering middle names, as the fields labeled “first name” and “last name” might cause confusion. Another suggestion was to alphabetize the list of pupils by last name, resembling a standard class list.

Task 4: Navigating to the Pupil Page and Adding Information

Some participants found it somewhat challenging to locate the additional information and suggested improving the visibility of the buttons on the pupil page. Several participants did initially not realize that “Additional Information” was a clickable tab and did, in general, not like the look of these buttons. Some participants made the point that they would assume “Other information” to be information such as an address, phone number, etc., and it was suggested to change the label to “Information about the pupil”. However, most participants considered the task intuitive and easy once participants identified the correct buttons or tabs. In general, the process was praised as straightforward, intuitive, and efficient, requiring minimal effort to complete the task.

One participant also recommended requesting information on language development in preschool age, the performed assessments of the pupil, and any implemented interventions.

Task 5: Editing the Pupil Information

As the participants had already become familiar with the pupil page through the previous task, this task was considered very easy to perform.

Task 6: Navigating to and Reading the Test Results

Participants found it easy to read the test results as both tables and accompanying text were visible. The use of colored symbols at the top allowed for quick identification of relevant information. However, participants expressed uncertainty about the interpretation of scores. For instance, some participants did not understand if a high score was “good or bad”. Some participants suggested providing brief explanations of the tests’ meaning or goal to avoid the need to refer back to the user manual. Overall, the results and summary information on the pupil page was considered clear and easily accessible.

One of the participants pointed out an inconsistency in a pupil’s score, an error that we were not aware of. On the pupil overview page, the score of a pupil is based on the last test taken, while on the pupil page, the score is based on the average of all tests taken. This should be consistent in the user interface.

Task 7: Adding a Class with Responsible Teacher

This task required the participants to log out and in again with a new user account that had administrative privileges and access. Furthermore, a part of this task involved navigating to the class overview, which the participants were already familiar with. As a result, the participants generally found this task very easy to complete.

Participants found it easy and intuitive to understand how to add a class and teacher. They highlighted the use of clear buttons, icons, and fonts, along with an organized layout. The process of adding a class was straightforward, and participants appreciated that duplicate entries were not allowed. Overall, the task was considered simple and easy to accomplish, with minimal difficulties encountered.

Task 8: Managing Responsible Teachers for a Class

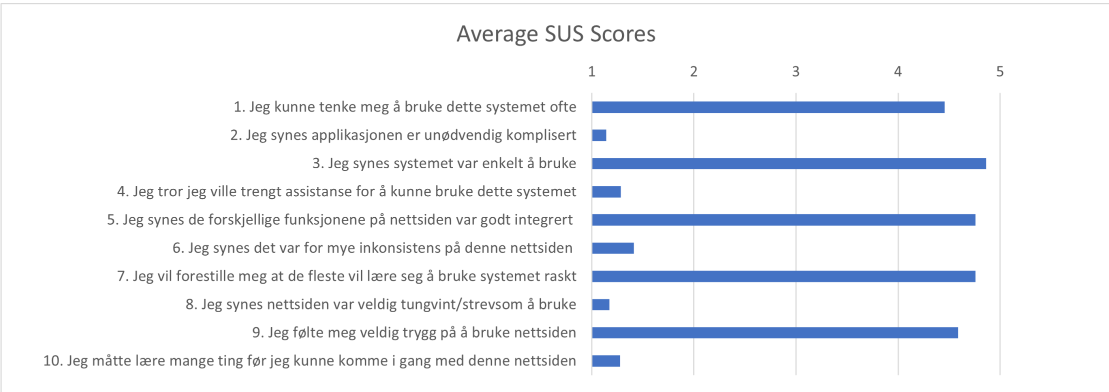
The participants found several aspects that made it easy to perform the task of managing responsible teachers. These included familiarity with icons and design consistency, clear indications of where to edit the responsible teachers, straightforward instructions, confirmation messages, and the ability to remove teachers easily. However, some participants mentioned that the absence of a “Cancel” or “Ok” button for adding new teachers might not be intuitive for everyone. Overall, the use of familiar icons and clear feedback contributed to the ease of performing the task.

Task 9: Finding and Reading the Theory about Magno

The participants generally found it easy to locate and access the information section. The limited number of choices on the page made it straightforward to find the desired information. Some participants initially had difficulty understanding that the section on dyslexia theory was located within the information tab. However, overall, the simplicity of the interface and the absence of unnecessary information or distractions contributed to an easy and efficient user experience. Participants suggested separating dyslexia theory and application information into distinct sections for clarity.

7.6.1. SUS

The SUS form was provided after the participants had finished the usability testing tasks. This gave them the necessary insights and familiarity with Magno to answer the items in the SUS form. To analyze the SUS results, the total SUS score was calculated, revealing a score of 92.8 from the conducted usability testing. The average SUS scores for each item can be shown in Figure 7.12. Using the scale of grades presented in Section 5, the new version of Magno would receive the grade A, equivalent to the adjective “excellent”.



Figur 7.12.: Average SUS Scores

8. Discussion

This section will evaluate and discuss the results obtained in this research. Firstly, Section 8.1 will evaluate and discuss the obtained usability test results from the design and implementation phases, with a focus on how the employed methods may have affected the outcomes. Section 8.2 will look into the changes that have been made to improve the security of the application and discuss the results of these implementations. Lastly, Section 8.3 will summarize the outcomes of the development by determining the fulfillment of all functional and non-functional requirements.

8.1. Evaluating the Usability Test Results

As emphasized throughout this paper, the evaluation of artifacts plays a critical role in design research. Earlier chapters have provided an explanation of the evaluation methods employed for the produced artifact and the results of these. The following sections discuss whether the chosen evaluation methods have provided valid results. Furthermore, they will consider aspects of the evaluation process or methods that may have affected the results in any way.

8.1.1. Design Phase

During the design phase, usability testing was conducted using qualitative interviews with six participants. Using RSUT, participants were encouraged to employ a “think-aloud method” where they verbalized their actions, thoughts, and motivations during the interview. This approach provided valuable insights into participants’ behaviors, goals, and cognitive processes, aiding in understanding user experiences, which is a well-known advantage of RSUT [75]. However, the qualitative interviews were time-consuming, which imposed a limitation on the number of participants. Several studies have investigated the optimal number of participants for usability tests. Earlier studies state that four or five participants can identify 80-85% of the usability problems in an interface, while more recent studies argue that this number of participants might not be sufficient [50]. Notably, the recommended number of participants for usability tests depends on various factors such as the complexity of the system, available resources, and the goals of the study. Moreover, in this project, an iterative form of usability testing was utilized to help uncover additional insights and refine the design further. Given that the evaluation conducted during the design phase was constrained by the time-consuming nature of interviews and that the evaluation in the following implementation phase was planned to involve 30 other participants, a number of six participants was considered suitable for receiving sufficient results while at the same time ensuring time efficiency.

In the participant group, two participants were already familiar with the application as they had contributed to the specialization project. Thus, several design sketches were based on feedback they had previously given. As a result, they were naturally positive to these changes as they had advised them. Therefore, the feedback on these design sketches regarding their usefulness is quite biased. However, the participants had not specifically advised the design or layout for the new features. In this way, they contributed more novel feedback on the general look of the sketches. We believe it did not significantly compromise the overall results, as the feedback primarily focused on the perceived usefulness of features and design decisions.

Another crucial aspect that should be considered is the potential risk of influencing participant behavior. The semi-structured format of the interviews allowed for a degree of flexibility, enabling both parties to share thoughts and insights during the discussion. While this approach facilitates exchanging ideas and gaining valuable insights, it is important to acknowledge that our contributions may have influenced the participants' perspectives to some extent. Therefore, the findings should be interpreted in light of the collaborative nature of the interviews.

8.1.2. Implementation Phase

This section will first discuss the results from the usability testing tasks, before looking into the SUS results.

Usability Tasks

As explained, the usability testing in the implementation phase was conducted remotely and asynchronously using a questionnaire format. This approach required participants to independently navigate and complete the tasks without the ability to seek guidance or clarification from the facilitators. Given this context, the wording of tasks becomes significantly important and requires careful consideration to prevent misunderstandings or unintentional influence on participants' behavior [75]. For instance, one of the tasks in the questionnaire contained the formulation "click on a student" instead of a more vague description such as "choose a student". In another task, the user was asked to log out before trying to access the theory. One participant commented that this left fewer options in the sidebar of the user interface, simplifying the task. Seen in retrospect, these formulations may have made the tasks easier to perform, potentially compromising the validity of the results.

Additionally, due to the remote nature of the testing, participants did not receive detailed explanations or instructions regarding the rating system of the tasks. Because of this, it cannot be guaranteed that all participants fully understood how to evaluate the tasks they performed, which may have influenced the obtained results. We observed some numerical responses that appeared inconsistent with the textual feedback provided. For example, there were some instances where participants gave positive feedback while assigning a score indicating low usability. Thus, we suspect these participants may have misunderstood the scale on certain tasks.

Furthermore, conducting RAUT may have limited the ability to gain valuable insight into participants' interactions with the applications and thoughts. In RSUT and in-person testing, direct observation of users' behaviors, gestures, and verbalizations provides a deeper understanding of their experiences compared to asynchronous testing. However, to compensate for this limitation, the inclusion of an input field where participants could provide comments on every task allowed participants to share their thoughts and provide general feedback on the functionalities.

As advised by Moran [75], it is crucial that the group of participants involved in user testing represents the actual user group of the application. In this particular case, two-thirds of the participants were teachers or studying pedagogy, making them part of the target user group. The remaining one-third did not fall into this category, which may have influenced the results to some extent. However, it is worth noting that the previous usability test conducted during the design phase exclusively involved participants with expertise and experiences within the education field, who provided valuable insights through qualitative interviews. The modifications made based on their feedback were aimed at enhancing the perceived usefulness and ease of use from a teacher's perspective. Consequently, there is a high chance that these implementations align with other teachers' expectations regarding perceived usefulness. Thus, for the usability testing in this phase, the primary focus was to assess the ease of use of performing tasks from a general user perspective. The general ease of use of the new functionality and features, such as locating buttons and understanding where to find certain information, can arguably be efficiently evaluated by people outside the user group. For this reason, additional participant groups outside the field of education were included.

Lastly, it should be noted that 45% of the participants were in the 18-25 age range, indicating a relatively young demographic. This demographic may be more proficient in adopting new technologies compared to the average teacher, who, on average, is older. As a consequence, the majority of participants may have found the tasks easier to perform compared to the typical end-user.

SUS

SUS is especially relevant when comparing two versions of an application [8]. When looking at the results from the performed usability testing of the last version of Magno, it is evident that the application was well accepted [1]. Syvertsen received a SUS score of 92.2. This proves that the implementation of the new features did not affect the usability to a large extent. As Magno had already received a high score, and our primary focus was on introducing new features rather than improving existing ones, this result is highly encouraging. It serves as strong evidence that the extensions successfully enhanced the application without compromising its overall quality. Since the usability testing tasks were performed primarily with the aim to test the new implementations, a direct comparison of the results may not be completely suitable. However, the received SUS score indicates that the application was well-accepted.

According to Brooke [57], the respondents are advised to check off all items in the SUS questionnaire, and in case of uncertainty, they should select the middle option. Despite this, the participants were informed that the items were optional and they were not obligated to answer every item. This decision was made because the questionnaire was administered to participants outside the application's intended user groups. For this reason, we did not want uncertainty among the participants about the application's performance in a real-life scenario to affect the results. As a result, several participants without a background in pedagogy did not answer all items in the SUS questionnaire, specifically those related to the application's perceived usefulness in schools. This may have led to inconsistent results, as some items received more responses than others.

8.2. Security Improvements

Section 7.3 presented the recent implementations aimed at enhancing the security of the application. The next sections will discuss these improvements compared to the previous version of Magno, offering a critical perspective on their efficacy.

8.2.1. Registration of Users

In the previous version of Magno, unrestricted user creation allowed immediate access to pupil data upon login. However, the new version now requires basic users to be assigned to a class by an administrator, ensuring they undergo an approval process before accessing pupil data and related features. This improves the confidentiality of the system, ensuring that access to data is only granted to authorized individuals [33]. While the new approach effectively limits access until authorization, there is still a possibility for individuals to create redundant user accounts for a school, thereby occupying space in the database. Therefore, additional solutions should be explored to mitigate this issue.

One potential solution is to implement invitation-based registration in the application. Rather than allowing general registration, the creation of user accounts could be limited to invitations sent by administrators. This ensures that only users with specific privileges have the authority to invite and onboard new users. Another solution is to require verification from the school during the registration process. In this case, users would need to provide information confirming their status as teachers, such as verifying their school email address and school or contacting the administrator to confirm their employment. This would improve the authenticity of users by verifying and validating the users' identities [33]. Integrating the application with schools' existing systems is also a viable solution. This would leverage the school's established approval processes, ensuring that only authenticated users from the school can access the application, and in this way further enhance the authenticity of the system [33]. By considering these alternative solutions, the application can further enhance its security and prevent the creation of unnecessary user accounts tied to a school.

8.2.2. Authentication through Login

In the previous version of Magno, the authentication mechanism relied on a login procedure. However, we had concerns about certain aspects of this implementation, such as storing the token in the database and performing authentication checks within the client. Additionally, working with this authentication became challenging due to the absence of proper documentation and a lengthy code file.

Therefore, the code was restructured for both the login function in the client's communicator and the login endpoint. The new implementation includes JWT and is divided into multiple files, providing a clearer overview of the process and separating different functions within the login functionality. For instance, authentication is now handled separately, which involves comparing hashed passwords. Furthermore, the token-generating functionality is also separated into its own file, both of which are stored in a designated "utils"-folder. Additionally, as mentioned in Section 7.2.3 concerning the back-end architecture, other parts of the code have also been separated into distinct modules. This modular approach improves code structure and makes working with the authentication system easier.

Nevertheless, the authentication process can be further strengthened and stabilized by incorporating additional measures such as two-factor authentication or utilizing Feide login. These enhancements offer an extra layer of authentication for users when accessing the application. However, based on the literature discussed in Section 3.2.3, it is important to emphasize that while these security improvements are valuable, they should be tested alongside usability considerations to ensure a balanced user experience.

8.2.3. Authorization to Endpoints

Syvertsens' [1] recommendations for further work emphasized the importance of endpoint authorization, which was not implemented in the previous version of Magno. For the new version, an authentication middleware was implemented to address this. By incorporating this authentication middleware, the system provides enhanced security and ensures that users can only access the endpoints relevant to their roles.

8.2.4. Testing Security Implementations

All security testing for the implementations in Magno was conducted manually, including verifying the functionality of access control mechanisms. The security should be tested more extensively to remove all potential errors or weaknesses. Unfortunately, it was not prioritized in this study due to time constraints.

Several additional approaches could be considered to enhance Magno. One approach is incorporating automated security testing tools or frameworks into the testing process. These tools can simulate various types of attacks, such as SQL injections and other common vulnerabilities. By subjecting the application to automated security tests, potential weaknesses and vulnerabilities can be identified more efficiently. Another approach could be conducting penetration tests. These tests involve ethical hacking attempts, where the goal is to identify potential weaknesses that real attackers could exploit [37].

8.3. Fulfillment of Requirements

Several changes were made to the list of requirements throughout the development process. The ones derived from the received feedback and gained knowledge through the design phase have been presented in Section 7. Furthermore, some of the planned functionality was not implemented throughout the implementation phase due to a lack of knowledge, time, and prioritizing.

8.3.1. Functional Requirements

Most of the functional requirements were successfully implemented during the implementation phase. The attained requirements have been demonstrated through screen captures and explanations of the implemented screens and functionality in Section 7. However, some of the requirements, namely FR2, FR3, FR5, and FR9, were not fulfilled for various reasons. The complete list of the functional requirements and their fulfillment is shown in Table 8.1.

FR2 and FR3 specifically pertain to modifications in the test view of the application, which is located in a separate repository. Since the primary focus of this master's thesis was to enhance administrative tasks for teachers and special educators, these modifications were not prioritized despite FR2 initially being assigned high priority. Furthermore, the screening tests are being changed by the ongoing work of Larsen and Nedregård, making these requirements redundant. However, the user manual includes a step-by-step guide for conducting the test. Thus, this requirement can possibly be considered partially fulfilled.

FR5 is regarding receiving guidelines on further actions based on the test result of a pupil in the user interface. These further actions can be future tests that should be run and other follow-up protocols that are applied in the specific school. After looking into this requirement, we found that this would require a more thorough investigation into what these guidelines would be specifically. This is something that may vary between schools, and it proved difficult to develop a set of guidelines appropriate to the different schools and situations in which the application will be used.

The last unattained requirement, FR9, was regarding making it possible to add several pupils to the application at the same time. This feature was intended to facilitate the initial setup, allowing teachers to organize their classes before initiating the detection process for a pupil. This requirement was not prioritized in the development work due to its low priority and little remaining time toward the end of the implementation phase.

8.3.2. Non-Functional Requirements

The non-functional requirements are less tangible and measurable compared to the functional requirements. Evaluating the fulfillment of these requirements requires a holistic assessment that takes into account various factors and perspectives. The non-functional requirements and their fulfillment status is shown in Table 8.2.

NFR1 states that the application should maintain a high level of security. As discussed in the previous section, we argue that we have made several changes that enhance the level of security. These changes have been designed with a special focus on improving the confidentiality and authenticity. Given that teachers can only edit the data of their own pupils, in classes they are authorized access to, the integrity of data to is also improved to some degree. However, guaranteeing that data remains accurate throughout its life cycle through data validation could be implemented, improving the overall integrity of the system. Availability of data and services was not a priority in the development work. Many improvements can still be made and are probably necessary before Magno is secure enough to be implemented in schools. However, given the implemented security measures the level of security and privacy is considered high, and this requirement is fulfilled.

In the process of taking over an ongoing project and an existing application, it was crucial to ensure consistency with the development methodologies and frameworks set by Syvertsen [1]. Emphasis was placed on aligning the work with the previous version, such as the continued utilization of Material UI and adherence to established implementation practices. This approach enabled us to meet the requirements specified in NFR2.

With a detailed ReadME, NFR3 is considered fulfilled.

One of the focuses during the development was to improve the structure and responsibilities of the codebase. For this reason, NFR4 was included to ensure this. Significant efforts were made to reorganize the codebase, dividing it into smaller files with clear and distinct responsibilities. By these efforts, adhering to the principles of single responsibility and code modularity, the objectives of NFR4 are considered fulfilled.

Id	Description	Priority	Fulfillment
FR1	The test view should not contain any textual information but only contain the test	High	Attained
FR2	The teacher should be shown the test tutorial in a simple and point-by-point manner	High	Partly attained
FR3	The teacher should get a message to pass on the device to the pupil when the instructions are finished and the test is about to start	Medium	Unattained
FR4	The teacher should be able to find a separate user manual with guidelines on how to use Magno and how to perform the tests with pupils in the application	Medium	Attained
FR5	The teacher should receive guidelines on further actions for the pupil based on the result of the tests	Medium	Unattained
FR6	A general user should be able to view the theory and information page without logging in to the app	Medium	Attained
FR7	The teacher should only be able to access information and test results of pupils from his/her own class	High	Attained
FR8	The special education advisor should be able to access information about all pupils in his/her school	High	Attained
FR9	The teacher should be able to add a list of pupils into the platform	Low	Unattained
FR10	The teacher should be able to see and edit information about the pupil, including if there is dyslexia in the family, and if hearing and eyesight examinations have been performed	High	Attained
FR13	The special education advisor should be able to create classes and assign teachers to the class	High	Attained
FR14	The teacher should be able to see an overview of the classes he/she is responsible for	High	Attained
FR15	The teacher and special education advisor should be able to register with a name	Medium	Attained

Tabell 8.1.: Functional Requirements and Their Fulfillment Status

The last non-functional requirement was related to receiving a SUS score equal to or larger than the one obtained by Syvertsen in the previous iteration. With a total SUS score of 92.8, NFR5 is attained.

Id	**Description**	**Priority**	**Fulfillment**
NFR1	The application should maintain a high quality of information security and privacy	High	Attained
NFR2	The application should be designed according to Material Design Guidelines	Medium	Attained
NFR3	The documentation of the platform should be precise and easy to understand	High	Attained
NFR4	The code should adhere to the principle of single responsibility and code modularity	High	Attained
NFR5	The application should have a minimum SUS score of 92.2	High	Attained

Tabell 8.2.: Non-Functional Requirements and Their Fulfillment Status

9. Conclusion and Future Work

This research has aimed to enhance Magno to become a more practical tool for primary school teachers involved in dyslexia detection and intervention by implementing a number of features and functionality while gaining knowledge about them through evaluation. Several research questions were formulated to guide the research and development process. In the first part of this chapter, the research questions will be reviewed to assess whether they have been effectively addressed and answered. Lastly, Section 9.1 will give some recommendations for work that should be prioritized in future research.

RQ1: How should additional features be implemented to achieve role-based access control, limiting unwanted access to pupil data and facilitating role-based task management

To achieve RBAC and limit access to pupil data, distinct user roles within the application were defined in the early stage of the development process. During the design phase, functionalities and permissions for each user role were proposed and carefully evaluated through qualitative interviews with experienced participants in the education field. This thorough process aimed to ensure that the designed solution aligned effectively with the administrative and structural aspects of Norwegian school systems. As a result of this evaluation, two primary user groups were identified and integrated into the system: basic users and administrators. Basic users primarily represent teachers who require access to essential functionalities for facilitating tests and managing relevant information during the dyslexia detection process. Administrators represent special educators, educational administrators, and leaders, who should be able to perform additional actions related to managing access permissions for basic users across different classes. This hierarchical division of user roles, access, and functionalities contributes to an efficient process for dyslexia detection while protecting pupil data.

The new solution includes a JWT-based authentication middleware system, which ensures that only authorized users with given permissions can access the intended data and functions within the application. Additionally, passwords are securely stored in the database using a salt hashing method, which adds an extra layer of security to protect passwords in the event of a database breach. While the application's security has been improved compared to the previous version, additional security measures can be implemented to strengthen the overall security of the application. One such measure is the adoption of two-factor authentication or Feide login, which provides additional authentication for users accessing the application. Another approach is to restrict user registration exclusively to school users, thereby enhancing the control and security of the system. Additionally, conducting various tests, including automatic integration tests of the back-end system, can help identify and address potential security vulnerabilities within the system, further enhancing its overall security.

RQ2: How should additional features be implemented to achieve a system that facilitates tasks related to detecting dyslexia and following up pupils in primary school?

Magno has been enhanced with several functionalities to facilitate the detection of dyslexia and enable efficient follow-up of pupils. These additions aim to support users in their tasks and provide them with the necessary tools. Firstly, a user manual is included to guide users in performing various screening tests and provide general instructions on how to use the application effectively. This resource ensures that users can easily navigate the assessment process and make the most of Magno's features.

Additionally, a class overview page is implemented, allowing users to conveniently manage and monitor their classes and have a structured overview of their pupils. Users can access this page to view the aggregated results of pupils within their classes, providing a comprehensive overview of the dyslexia detection process. Magno offers a dedicated pupil overview page. Within this page, teachers can access all the pupils they are responsible for, making it convenient to access and manage individual pupil profiles. Furthermore, administrators have the possibility to manage and administer access privileges for teachers, determining which teachers have access to different classes.

Within the profile of each pupil, teachers have the ability to add and edit relevant information. This includes information such as the presence of dyslexia in the family and the completion of hearing and sight examinations. By capturing this information, Magno ensures that teachers have a comprehensive understanding of each pupil's background, which can be helpful in the evaluation of whether a pupil may be at risk of dyslexia or other related difficulties.

These added functionalities in Magno allow users to easily navigate the dyslexia detection process, efficiently manage their classes and pupils, and access relevant pupil information.

RQ3: How do the additional features affect Magno's usability?

The extended version of Magno, encompassing new features, has been met with positive feedback from participants, including teachers and special educators. First, the inclusion of TAM in the qualitative interviews conducted during the design phase yielded valuable feedback regarding Magno's perceived usefulness. This feedback helped assess the level of acceptance among teachers and special education teachers. Furthermore, SUS was conducted with a new participant group, consisting of teachers, special educators, pedagogy students, and individuals outside the field of education. The overall SUS score increased from an average of 92.2 to 92.8 compared to the previous version of Magno [1]. This accomplishment successfully meets the non-functional requirement of maintaining or exceeding the same score as the previous versions' results (NFR5) and is regarded as an exceptional rating. This indicates that there is a high chance that teachers will find the new version of Magno easy to learn and use, thereby positioning it as a practical and user-friendly tool that can be effectively implemented in schools.

RQ4: What are the potential challenges of implementing Magno in schools?

Despite the positive results obtained from usability tests, the implementation of Magno in schools may encounter several potential challenges. Firstly, the introduction of any new information system (IS) can face resistance, particularly from individuals who are resistant to adopting new systems or work methodologies. Teachers accustomed to existing methods and systems may hesitate to adopt new technology, as it requires them to invest effort in learning the system and may raise concerns about potential errors. As mentioned earlier, it is worth noting that 45% of the participants who answered the SUS form were in the 18-25 age group, which tends to be more familiar with new technology and adaptable to it. Older age groups may find the extended functionality of Magno less intuitive, as they may be less familiar with new technology. Secondly, adequate training must be provided to ensure effective utilization of Magno. This training process may require time and resources to ensure all users feel comfortable using the application and its features. The results from the design phase revealed the presence of various tools that teachers would like to utilize but often end up not using due to the lack of time to familiarize themselves with the system. Therefore, prioritizing adequate training will address this concern and encourage full utilization of Magno's capabilities.

Furthermore, during the specialization project, it was observed that teachers already deal with multiple software systems for managing pupil data, curriculum, and administrative tasks. Integrating Magno with these existing systems can be a complex process, requiring coordination and collaboration with IT departments to achieve seamless integration and data synchronization. As a potential solution, Magno can be considered an additional application alongside the existing systems within the school. However, adding a new IS to the current systems may feel overwhelming and contribute to the resistance mentioned earlier. Therefore, efforts have been made to keep the application as simple as possible, with a minimal number of features still valuable and practical in the dyslexia detection process.

However, by proactively addressing these potential challenges, schools can mitigate risks and maximize the benefits of implementing Magno in the dyslexia detection process. The participants emphasized the user-friendly nature of Magno as a valuable attribute and generally expressed confidence in quickly becoming acquainted with the system. This positive feedback further reinforces the potential for a smooth integration and adoption of Magno within the school environment.

9.1. Future Work

This section will provide recommendations for future work, proposing specific steps that should be taken to achieve the goal of implementing Magno in schools as a digital tool for early detection of dyslexia.

As mentioned when answering RQ1, the application requires additional security measures to protect sensitive pupil information. One recommendation is to investigate further the implementation of limited registration access exclusively to teachers and special educators who are going to use the application, and implement a two-factor authentication system or integrate it with the Feide login system. Furthermore, the integrity of data and maintainability of the system should be a focus in future security improvement efforts. Subsequently, evaluating the usability of these measures through usability tests will be necessary. Additionally, conducting various security tests can help identify and address potential security vulnerabilities within the system, thereby enhancing its overall security.

Furthermore, the other master's thesis conducted by Larsen and Nedregård (described in Section 4.5) focuses on improving the test interface of Magno to fit young children aged 5-7 years by introducing a gamification approach to the screening tests. To advance Magno, it is recommended to integrate the findings from their work with the results of this project. Integrating their work with this new version of Magno will make Magno an even more valuable tool for teachers while providing motivating and engaging tests suitable for younger children. Ultimately, this will support the early identification of dyslexia in a more engaging and productive manner.

Finally, we recommend the implementation of the unattained functional requirements presented in Table 8.1. Achieving FR5, which involves providing guidelines for further actions based on the test results, requires additional research to determine specific recommended actions for the intervention of the identified difficulties. This research should involve expertise in the fields of education and psychology. A potential approach to further developing Magno is collaborating with experts in these respective fields. Their valuable input and insights can help incorporate clear guidance to teachers on providing support and follow-up to pupils with given difficulties. By fulfilling this requirement, Magno will become an even more valuable tool for teachers, enabling targeted interventions and enhancing the perceived usefulness.

The remaining unfulfilled requirements are not essential for the application's performance in real-life situations. Instead, they focus on enhancing the user experience and making Magno a more practical tool for streamlining administrative tasks. These functionalities include adding multiple pupils into the system simultaneously and modifying the test tutorial to be clearer. Other recommended functionalities are providing administrators with an overview of the school's teachers, allowing the deletion or editing of pupil names, and enabling users to modify their personal information, including passwords and usernames. These additions would contribute to a more efficient and convenient user experience, further enhancing Magno's value as an administrative tool.

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Appendices

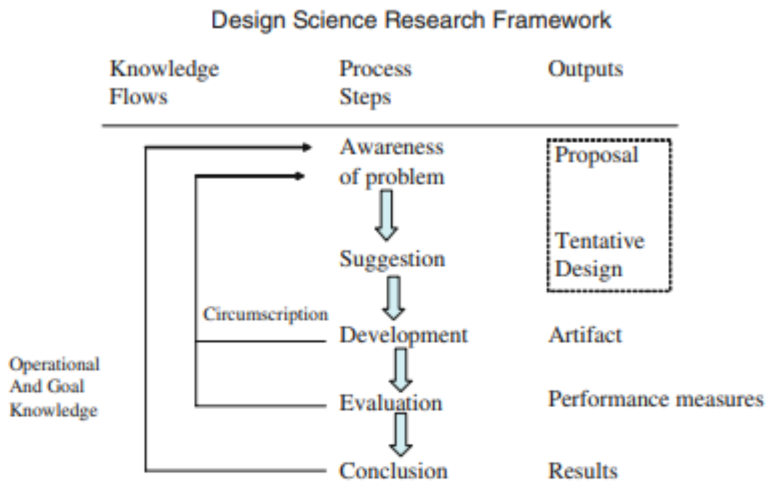
A. Design Research Guidelines by Hevner et al.

Guideline	Description
Guideline 1: Design as an Artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
Guideline 2: Problem Relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
Guideline 3: Design Evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
Guideline 4: Research Contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
Guideline 5: Research Rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
Guideline 6: Design as a Search Process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
Guideline 7: Communication of Research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

Tabell A.1.: Design Research Guidelines [9]

B. Reasoning in the General Design Cycle

Adapted by Hevner and Chatterjee [3].



Figur B.1.: Reasoning in the general design cycle [3][4]

C. Magno 2021: Non-Functional and Functional Requirements

Id	Description	Fulfillment
NFR1	The platform should have a minimum SUS[1] score of 80	Attained
NFR2	The server and platform should be loosely coupled to the tests	Attained
NFR3	Developers should have access to documentation which is thorough and precise	Attained

Tabell C.1.: Non-Functional Requirements with fulfillment status [1]

Id	**Description**	**Fulfillment**
FR1	It should be possible to register an account with an email address and a password	Attained
FR2	It should be possible to log in to a registered account by providing the correct email/password combination	Attained
FR3	The platform should allow users to register which school they work at	Attained
FR4	The platform should be responsive, and elements should adapt to fit the current screen size and resolution	Partly attained
FR5	The platform should be able to start motion and form tests and receive test results from these	Attained
FR 6	It should be possible to add students to the platform	Attained
FR8	Users should be able to view all the students that have been added to the platform, and attend the user's school	Attained
FR9	Student test results should be viewable in a table or list	Attained
FR12	The platform should be able to display detailed results for each student	Attained
FR14	The database should store data necessary for the users	Attained
FR15	The platform should be able to communicate with the server API	Attained
FR17	The back-end API should be able to store user information in the database	Attained
FR18	The back-end API should be able to store student information in the database	Attained
FR21	The server should be able to serve both the platform and the motion and form tests	Attained
FR7	It should be possible to remove students from the platform	Unattained
FR10	The table or list showing test results should be sortable	Attained
FR11	The table or list showing test results should be searchable	Attained
FR13	The platform should be able to give text-based information regarding a student's test results	Attained
FR14	It should be possible to both use and navigate the platform without any prior instructions	Attained
FR19	The platform should have Feide integration for authentication and authorization	Unattained
FR20	The platform should fetch user and student information from Feide	Unattained

Tabell C.2.: Functional Requirements with fulfillment status [1]

D. NSD Contract (Norwegian)

Vil du delta i forskningsprosjektet

Magno: En app for tidlig deteksjon av dysleksi

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å kartlegge hvordan Magno kan brukes til å detektere dysleksi hos unge elever og å følge de opp. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Målet med prosjektet er å videreutvikle Magno slik at den enklere kan brukes i skolen av lærere og spesialpedagoger i forbindelse med deteksjon av dysleksi i barneskolen. Magno er en applikasjon som lar deg gjennomføre screening-tester som måler dine visuelle prosesseringsevner. Forskning viser at svekkede evner til å prosessere visuell informasjon er knyttet til dysleksi.

Så langt inneholder applikasjonen funksjonalitet til å gjennomføre screening-testene. Videre vil mye av arbeidet gå ut på å implementere funksjonalitet som bidrar til at lærere enkelt kan bruke Magno for kartlegging og elevoppfølging. Dette ønskes å bli identifisert og testet i samarbeid med fagfolk med sterke domenekunnskaper innenfor emnet.

Prosjektet er en del av vår masteroppgave for studiet Datateknologi ved NTNU.

Hvem er ansvarlig for forskningsprosjektet?

John Krogstie er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?

Du er strategisk utvalgt basert på ditt yrke og din faglige kompetanse med å gjennomføre screening- og diagnostiseringsstester for dysleksi og lesevansker med barn. Dine kontaktopplysninger har blitt innhentet gjennom korrespondanse med personer knyttet opp til samme fagmiljø eller fra din intitusjons hjemmeside.

Hva innebærer det for deg å delta?

Hvis du velger å delta i prosjektet, innebærer det at du sier ja til å bli intervjuet og å teste applikasjonen under observasjon. Det vil bli tatt lydopptak og notater under intervjuet og testingen. Med unntak av personsensitive opplysninger, vil det du sier kunne bli brukt og nevnt i masteroppgaven eller forprosjektet.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

Vi og vår veileder vil være de eneste med tilgang til rådataen. Dataen vil være lagret på våre personlige PCer.

Deltakere skal ikke kunne gjenkjennes i publikasjon. Personsensitive opplysninger som navn vil ikke publiseres. Bransje/yrke eller selskap kan nevnes dersom det ikke anses som identifiserende (f.eks., optiker, spesialpedagog, Statped etc.).

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

All rådata vil slettes ved prosjektslutt ca. 11. juni 2023. Personsensitive opplysningene vil ikke brukes i prosjektet slik at deltakerne kan gjenkjennes.

Opplysningene slettes når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er ca. 11. juni 2022. Personsensitive opplysninger vil ikke brukes i prosjektet på en slik måte at deltakerne kan gjenkjennes.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- Innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,

- Å få rettet personopplysninger om deg,

- Å få slettet personopplysninger om deg, og

- Å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra NTNU har Personverntjenester vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med regelverket.

Hvor kan jeg finne ut mer?

Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

• NTNU ved John Krogstie, Vår Sørensen Sæbøe-Larssen eller Katrine Norheim Holm

• Vårt personvernombud: Thomas Helgesen, thomas.helgesen@ntnu.no, 930 790 38

Hvis du har spørsmål knyttet til Personverntjenester sin vurdering av prosjektet, kan du ta kontakt med:

- Personverntjenester på epost (personverntjenester@sikt.no) eller på telefon: 73 98 40 40

Med vennlig hilsen

John Krogstie (Forskere/veileder) Vår Sørensen Sæbøe-Larssen Katrine Norheim Holm

___

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet Magno: En app for tidlig deteksjon av dysleksi,

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)

E. Evaluation and Interview Guide

Step 1: Introduction

Magno is an application for early detection of dyslexia, containing screening tests and the possibility of keeping track of test results. Through our Master's thesis, we will develop additional functionality and features to this application, to make it more suitable for being used in schools. This includes developing a more detailed overview for teachers of their students, and a more comprehensive overview for special education advisors to keep track of all students and classes in their school. An essential part of this work is determining and developing the different possibilities a normal teacher and an administrator (typically an advisor or facilitator in the school) should have in the application.

Based on this, we have developed sketches of the changes and extensions we plan to apply to Magno. We will go through the sketches and ask you to give feedback on the look, usability, and usefulness of the feature that we are showing you. After this, we will ask you to answer some questions regarding the usability and perceived usefulness of Magno.

Step 2: Evaluating the Design Sketches

We will go through the sketches respective to the user stories listed below.

FR1-4 The teacher should be able to find the test tutorial and explanation in a simple and point-by-point manner in a separate user manual.

FR6 The teacher should be able to find the theory behind the screening tests in the application.

FR7 The teacher should only be able to see pupils and their results from his/her own class.

FR8 The special education advisor should be able to see all students in his/her school.

FR9 The teacher should be able to add a list of pupils to a class in the application.

FR10 The teacher should have an overview of if sight and hearing tests have been taken, and if there is dyslexia in the family.

FR5 The teacher should receive advice and guidelines for further actions based on the results of the tests.

FR12 The teacher should be able to add and read a comment to each execution of a test.

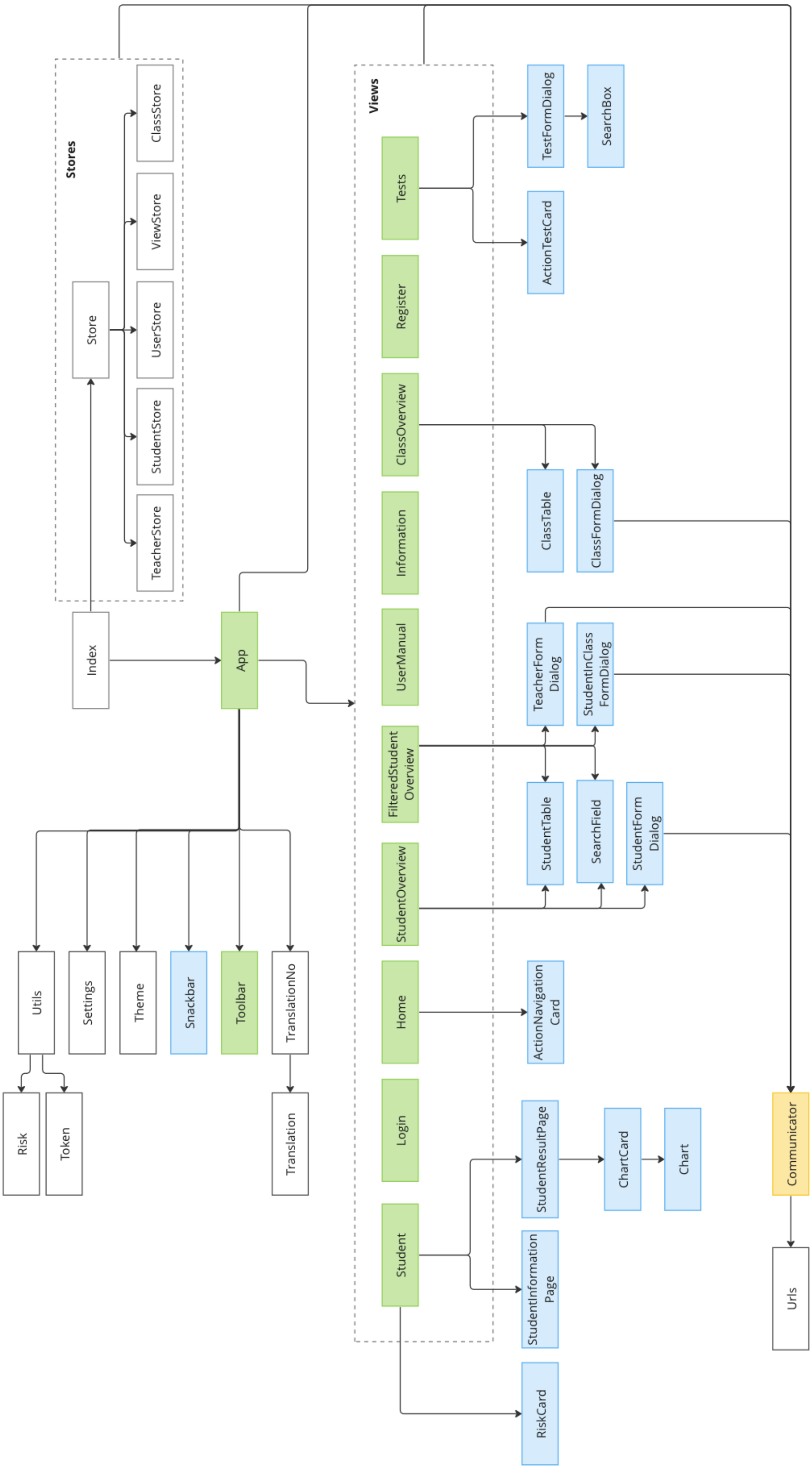
Step 3: Interview Questions Regarding Perceived Usefulness and Perceived Ease-of-Use

Please answer the following statements with a number on a scale from 1 to 7, where 1 is "I strongly disagree"and 7 is "I strongly agree", and explain the reason for your answer.

1. Given that I have access to the system, I imagine that I would use it.
2. The system would be useful for me in my job.
3. The system would make it easier for teachers and special educators to follow up with children with reading and writing difficulties.
4. I would be able to save time by using the system.
5. I think I would have to spend a lot of time learning the system to use it on my own.
6. I would assume that most people can learn this system very quickly.

Additional questions
What do you think are the main barriers to taking this system into use in Norwegian schools?

F. Front-end Architecture



Figur F.1.: Front-end Architecture

G. Translated Usability Test Form

Link to the test form: https://forms.gle/usabilitytest

Information about the test

Hi, and thanks for wanting to test Magno!

This usability test aims to assess the user experience of the Magno application. This will help us better tailor the application to teachers and special educators, increasing the likelihood of successfully detecting dyslexia in pupils at an early stage in primary school. Your answers will be treated confidentially and used solely for internal purposes.

To conduct the usability test, you will need a computer with internet access. The application will not function as intended on a tablet (such as an iPad) or mobile device.

You can read more about the master's thesis here.

Information about you

In this section, we will collect information about you to gain a better understanding of the respondents participating in our survey.

1. How old are you?

2. Which job title suits you best?

Usability Test

In this section, we will ask you to complete a series of tasks in the application that are relevant to its intended use. These tasks include entering students into the system, interpreting test results and other information, and more.

You can access the application here: https://magno-app-2023.ew.r.appspot.com/login

Open the link in a new tab and then proceed with the tasks in this questionnaire.

We appreciate it if you also answer the non-mandatory questions.

Task 1
Log in to Magno using the following login information:

Username: laerer@mail.no Password: jegerenlaerer

Go to the user manual. You do not need to read the text in the user manual carefully.

On a scale from 1 to 5, how easy do you find it to locate the information about the tests in the user manual?

Task 2
Download the user manual.

On a scale from 1 to 5, how easy did you find it to complete this task?

Task 3
Go to the class overview and click on class 1A. Add a student to the class.

On a scale from 1 to 5, how easy did you find it to complete this task?

Task 4
Click on the student you just added.

You know that several of the student's family members have dyslexia, and no vision or hearing assessments have been conducted for the student. Enter this information about the student.

On a scale from 1 to 5, how easy did you find it to complete this task?

Task 5
You find out that a vision assessment has indeed been conducted for the student. Update the information about the student accordingly.

On a scale from 1 to 5, how easy did you find it to complete this task?

Task 6
Click on Frida Hansen"and review her test results.

On a scale from 1 to 5, how easy is it to understand the test results?

Task 7
Log out of the application, and then log back in using the following login information:

Username: admin@mail.no Password: jegerenadmin

Go to the class overview and add a class to the list. Set Marthe Mortensen as the responsible teacher for the class.

On a scale from 1 to 5, how easy did you find it to complete this task?

Task 8
Click on class 1A and manage which teachers should have access to the class. Only Karsten Mikkelsen should have access to the class.

On a scale from 1 to 5, how easy did you find it to complete this task?

Task 9
Log out again.

Now, you want to read about the Magnocellular theory of dyslexia, which the application's screening tests are based on. Navigate to this information.

On a scale from 1 to 5, how easy did you find it to complete this task?

System Usability Scale (SUS)

In this section, you will be presented with ten statements, and you are to indicate the extent to which you agree with each statement. You will answer on a scale from 1 to 5, where 1 means strongly disagree and 5 means strongly agree. Your responses will provide us with quantitative data about the usability of the application.

If you feel that you do not have the necessary basis to answer one or more questions, you may choose not to respond to those particular questions.

1. I think that I would like to use this website frequently.
2. I found this website unnecessarily complex.
3. I thought this website was easy to use.
4. I think that I would need assistance to be able to use this website.
5. I found the various functions in this website were well integrated.
6. I thought there was too much inconsistency in this website.
7. I would imagine that most people would learn to use this website very quickly.
8. I found this website very cumbersome/awkward to use.
9. I felt very confident using this website.
10. I needed to learn a lot of things before I could get going with this website.

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