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Empowering School Principals with Data Visualization to Enhance Students' Reading Skills: A case from Sweden

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Abstract

School principals play a vital role in guiding schools and shaping teaching practices. While students and teachers use various technologies for teaching and learning practices, the challenge remains in turning raw data into actionable insights for decision-making. Although teachers receive support for their close work with students, less attention is given to principals, who make higher-level decisions and allocate resources. This thesis explores how data visualization tools can help principals gain insights to improve students' reading skills, which have been considerably declining during the last decade, and especially during the last few years.

The research examines how data visualizations can support principals in identifying students needing reading assistance and tracking reading progress through a mixed-methods approach. Seven school principals with varying levels of computer experience participated in the study, which involved interacting with prototype visualizations across three rounds. Methods used include Think Aloud protocols, A/B testing, and follow-up interviews. The findings show that well-designed data visualization tools can help principals better identify students struggling with reading. The study highlights the importance of iterative design in improving these tools and emphasizes the need for clear, informative visualizations. Overall, effective data visualization enhances principals' decision-making, ultimately supporting students' reading development.

Keywords

Data Visualization, UX-TAM Model, Usability, School Principals, Decision-Making, Students' Reading, User Experience, K-12 education

Sammanfattning

Rektorer spelar en avgörande roll i att leda skolor och forma undervisningsmetoder. När elever och lärare använder olika tekniker för undervisning och lärande, kvarstår utmaningen att omvandla rådata till handlingsbara insikter för beslutsfattande. Även om lärare får stöd för sitt nära arbete med elever, ges mindre uppmärksamhet åt rektorer, som fattar beslut på högre nivå och fördelar resurser. Denna avhandling undersöker hur datavisualiseringsverktyg kan hjälpa rektorer att få insikter för att förbättra elevernas läsförmåga, som har minskat avsevärt under det senaste decenniet och särskilt under de senaste åren.

Rapporten undersöker hur datavisualiseringar kan stödja rektorer i att identifiera elever som behöver läshjälp och spåra deras läsutveckling genom en blandad metodansats. Sju rektorer med varierande nivåer av datorvana deltog i studien, där de interagerade med prototypsvisualiseringar i tre omgångar. Metoderna inkluderade "Think Aloud"-protokoll, A/B-testning och uppföljningsintervjuer. Resultaten visar att väl utformade datavisualiseringsverktyg kan hjälpa rektorer att bättre identifiera elever som har svårt med läsningen. Studien betonar vikten av iterativ design för att förbättra dessa verktyg och behovet av tydliga, informativa visualiseringar. Sammanfattningsvis förbättrar effektiv datavisualisering rektorernas beslutsfattande, vilket i slutändan stöder elevernas läsutveckling.

Nyckelord

Datavisualisering, UX-TAM-modell, Användbarhet, Skolledare, Beslutsfattande, Elevers läsning, Användarupplevelse, K-12 utbildning.

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INTRODUCTION

Reading skills are essential for students' academic success and active participation in society. However, recent research results from PISA[1] and PIRLS[2], has highlighted a significant decline in students' reading abilities, particularly in Swedish schools [39]. These evaluations reveal a troubling downward trend in students' reading performance. In line with educational principles that prioritize individualized support and personalized learning, efforts should be made to address the issue of declining reading abilities.

Reading is the primary academic skill for instructional learning that is directly linked to knowledge acquisition [32]. Several studies reveal that there is a positive correlation between learning to read at the initial grade level and later literacy and learning experiences (e.g., [3]). Educational policies like Sweden's "Education for children and young people" [38], stress the need for young people to receive the necessary education that will enable them to achieve the knowledge requirements that are needed to position to get opportunities in the world. The heads of the school, the principals, are required to facilitate the students and ensure they can perform to the best of their capability. One of the most important capabilities is the development of student reading skills. To this end, however, school principals still face difficulties in identifying students' weaknesses, particularly in reading skills. Even though institutions have stepped up efforts to gather data regarding student performance, the task of converting these into useful information remains challenging. Data visualization tools are normally absent from the hands of principals and thus, they find it difficult to understand the data and thereby fail in their ability to notice patterns, make changes where necessary, and put in place corrective measures [50]. This can be particularly a setback in a bid to enhance student reading accomplishment since the data cannot be interpreted optimally so, empowering school principals with better tools for data analysis is important to help school leaders to make correct decisions on allocating resources and deciding strategies for reading improvement of the students. The emphasis of this thesis is on how to enable school principals to use enhanced data representations for monitoring and understanding trends in students' reading accomplishments over time.

Information visualization, the ability to represent information and data graphically, provides one of the most effective approaches to help in decision-making [5]. For school principals, data visualizations might help to shed light on certain trends or areas of difficulty as well as monitor performance.

These data visualizations have some core concepts that are essential to be understood: usability, design, and evaluation within a digital work environment related to educational facilities. Usability is defined as the ease with which the users of the tool or system can accomplish the set objectives. When it comes to the application of data visualization, good design plays a vital role in delivering information that is easy to understand and in the same manner useful. Evaluation refers to assessing the impact of these visual tools on decision-making and the resulting outcomes for students

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[1] Axelsson, M., Klingenstierna, C., Fredriksson, P., Sandqvist, J., Gustafsson, D., Wester, A., Auer, A., Sollerman, S., & Bach, F. (2023). *PISA 2022 15-åringars kunskaper i matematik, läsförståelse och naturvetenskap*.

[2] Fredriksson, P., Stenman, C., Skolverket, The International Association for the Evaluation of Educational Achievement (IEA), Wiksten Folkeryd, J., Af Geijer-stam, Å., Westman, M., Stenman, C., Wennerberg, U., Tegnér, C., Tallberg, C., Auer, A., & Wester, A. (2023). PIRLS 2021 Läsförmågan hos svenska elever i årskurs 4 i ett internationellt perspektiv

School leadership represented by principals constitutes a key component of education. They often have to analyze information and make conclusions with potential impact on all members of the school population. Leadership plays a crucial role in policy implementation and resource management and in shaping the learning culture [33]. The government's policy for education for young people [38] has put principals under immense pressure to monitor all students' reading abilities to ensure that their students can learn properly. The problem, however, is that principals have to analyze and contend with large volumes and a wide range of data types. Standardized outputs present data in tabular and graphical formats, which may be cumbersome to study, thereby increasing the time required before the necessary efforts such as intervention are instituted [34]. In addressing this concern, data visualizations can offer well-researched, simple, and highly attractive forms of summarizing the data gathered [35]. This thesis aims to enhance an existing dashboard by developing a data visualization prototype that empowers school principals to capture low-performing students in terms of reading, monitor the progress of students' reading, facilitate the implementation of interventions, and thus consequently allow them to provide proper decisions that will improve the students' reading performances. The prototype will be developed around the Lexplore platform, which is a modern web-based tool for improving students' reading ability based on the application of artificial intelligence and eye-tracking technologies [14]. The main tool for designing and improving the prototype will be Figma. To ensure its usability and effectiveness in an educational setting, the prototype's development will be evaluated through the UX Technology Acceptance Model (TAM). The Technology Acceptance Model (TAM) is a theoretical framework that evaluates how people interact and accept technology, especially in terms of perceived usefulness and ease of use. The study uses this model to examine how successfully principals will be using the prototype.

Research Questions

1. What challenges do school principals encounter when trying to identify students with poor reading ability?
2. How can existing technology be improved to better support principals in their decision-making process?
3. What is the perceived usability of data visualization tools by school principals, according to the UX-TAM evaluation model?

BACKGROUND

A child's ability to read at a proficient level is critical in school and crucial for their academic achievement [2]. Despite the significance of reading competence in the completion of primary school education, most education systems worldwide, including Sweden, experience difficulty in ensuring that all students read at adequate levels by the end of primary education [6]. Various instructional approaches such as standardized tests [9] and formative assessments of student's reading ability [11], used to monitor students' reading skills have not always produced desirable progress on student's needed reading levels [7]. These approaches will be discussed in detail below.

For school principals to develop strategies that would effectively increase students' reading proficiency, it is crucial to pay attention to the sustainable development goals in the 2030 Agenda [36]. Sustainable Development Goal number 4 has emphasized on the need to solve several existing policy issues within an educational context to promote sustainability and human-centered development. Knowledge about the SDGs is vital for school leaders as they have to address the challenges of developing Education Quality assurance for imparting reading literacy and sufficient reading skills among learners [36].

Traditional methods of tracking students' reading ability

Standardized Testing

Standardized tests are academic exams that are aimed at evaluating the students in a standard way. These tests are given and marked identically across all potential test takers irrespective of their location or background. Standardized testing is intended to provide equitable and objective assessment and thus provides educators, policymakers, and institutions with a basis for the comparison of results. Standardized testing is common in education delivery systems and serves as a comprehensive measure of the efficiency of student reading abilities across different populations, and education settings. Nevertheless, these tests are also helpful in generating benchmark scores, which, suffer from a number of critical drawbacks that prevent them from being truly effective instruments for improving reading abilities [9].

First, due to the infrequent administration of tests, including standardized ones, which are often conducted once or twice a year, principals do not have continuous access to relevant information about the students' learning progress. This temporal gap, caused by the infrequent testing, raises a concern because it hinders principals from making continuous changes in the teaching activities of their schools, based on the current performance of the students [10]. Therefore, the principal could be overwhelmed with outdated information and may not be able to respond to these emerging problems in a timely manner.

Secondly, these assessments often focus on only a limited set of reading skills, such as vocabulary or comprehension, and overlook other critical areas like analytical and interpretive skills, thus failing to foster a well-rounded, engaging reading culture in students. This leads to a skewed and narrow method that stresses on specific areas of knowledge rather than different reading skills thereby preventing students from attaining real reading skills for tests and otherwise. Of course, the practice of prioritizing vocabulary memorization could breed sheer rote learning and cramming that often downplays competencies in analytic and interpretative reading that can lead to steady improvement in reading [9].

Formative Assessments of Students' Reading Skills

Common formative assessments are helpful in determining the current learning needs of students during learning activities but are insufficient in order to include a long-term vision of students' learning [11]. Some of these formative assessment techniques that can be used include quizzes, reading logs, or observations from the teacher. The main benefit of such techniques is that it is an ongoing assessment of students' performance. This makes it possible for instructors to apply changes influenced by current data, which in theory should improve students' learning performance [11].
Nonetheless, even though formative assessments ought to be effective, there are several factors that still hold it back. The following are some of those factors, delivering and undertaking these assessments can

differ significantly from one classroom to another, creating dissimilarities in data that do not evenly portray students' reading capacities [12]. This variability can diminish the usefulness of formative assessments. Furthermore, since these evaluations are performed based on the specific culture of various schools, there are possible biases that are inherent in the data collected [11]. These shortcomings suggest that a more standardized approach, reducing variability and biases, could better assess students' reading abilities.

Observational Techniques

Qualitative information about students' reading behaviors and progress may be acquired through observations from the teacher's checklists or students' recording of their reading in reading logs while standardized and formative assessments might not capture such information. These can offer more refined measurements of reading, including the level of the students' interest and the frequency with which they read, which allow for a better, more contextual view of students' reading [13]. Nonetheless, observational techniques also experience issues that hinder it from being a proper reading assessment method. The manner in which the principals will interpret the observation data may be significantly influenced by the state of the mind of the teacher who made the observations while collecting the data. This leads to inconsistency and unreliability [11]. Also, there is burden on teachers to carefully document and interpret the reading behaviors of their students, so as to ensure that the data they present to their principal is accurate. This burden, may reduce the learners instructional time because the teachers may start spending too much time in ensuring the quality of the data they collect.

Another issue that derails efforts in studying and monitoring the progress in the student's reading process is the inconsistency in the paperwork that is used in documenting and assessing observations. When there are no clear guidelines for observation and the ensuing data analysis, the resulting information may not have a logical flow and cannot be utilized for the design of the focused intervention strategies [11].

Other methods for monitoring students' reading ability

The prevailing approach in assessing reading abilities has traditionally relied on standardized methods. However, when it comes to monitoring reading practices, various specialized technologies have been increasingly utilized to gain deeper insights into students' reading skills. Examples of such technologies include the Dynamic Indicators of Basic Early Literacy Skills (DIBELS), which provides rapid assessments of essential literacy components, and the Wechsler Individual Achievement Test, Second Edition (WIAT-II), which offers a comprehensive evaluation of individual academic performance, including reading [40]. More recently, advancements in eye-tracking technology have demonstrated even greater accuracy in capturing detailed data on reading behaviors, offering educators and researchers a more precise tool for understanding and improving student reading outcomes.

Eye-tracking methods of monitoring students' reading ability

Eye-tracking technology

Eye-tracking technology has the potential to identify students with reading problems at a very early stage to enable intervention. For example, if the child is demonstrated to spend more time on certain words than he should, or if he is shown to read in a way that indicates that he rarely goes back to previous words, he may require special attention from an educator or clinician [14]. It also improves the ability of educators and clinicians to effectively address students' reading difficulties.

The use of eye-tracking devices is a way of assessing the reading capacity of the individual; it has been found to be more effective than conventional stylometric analysis. The stylometric analysis involves the identification of patterns in written works to help with proper reading [15]. Lexplore[3] is a company that has implemented eye-tracking technology in educational environments, particularly in collaboration with schools to collect data on students' reading abilities and other related metrics. It has incorporated the opportunities of eye-tracking into educational environment [46].

Analysis of students' eye movements, Lexplore can provide detailed data on the student's reading skills, allowing to identify problem areas. In particular, it records several eye movement characteristics like fixation duration, length of saccade, and regression frequency for comparisons of reading practices at different age and skills levels. Research by Standberg and his peers indicates that as children learn to read, they gradually spend less time fixating on individual words and more time moving from one word to the next [15]. This shift suggests that with increased exposure and practice, children develop greater fluency and efficiency in reading. For instance, eye-tracking technology can be utilized to differentiate reading habits across different age groups, providing valuable insights into reading development.

One of the major strengths that this technology may probably have is the ability to conduct experiments in classroom environments. This is because it is non-intrusive and does its monitoring in the background. In addition to this it also allows the diagnosing of common practical reading difficulties faced by students under real-life conditions, in controlled laboratory environment [15].

For school leaders, eye-tracking technology is most encouraging. It gives principals data for assessing students' reading processes and skills, and where the student is struggling specifically. This provides interventions that could cause a positive reading development [15]. A good example is [37], where eye tracking provided insight to the students who were mostly distracted while reading and who could not concentrate for long periods, thus enabling the implementation of targeted support for those students such as incorporation of visual aids.

Lexplore's Approach

The assessment method of Lexplore is based AI technology that interprets the eye-tracking data. In an assessment, students view a series of texts – brief passages on a computer screen and the students' eye movements are recorded. This data is then used to assess other features of their reading capability: reading speed, cumulative reading, and reading comprehension. Since AI can analyze data at a very fast rate, the tool is efficient in giving the educators real time feedback [47]. However, while AI offers valuable insights, it is essential that its conclusions are continuously validated against traditional assessment methods to ensure accuracy and reliability. Cross-referencing the AI's findings with teacher observations and other diagnostic tools helps confirm that the diagnoses made are correct.

The main selling point of Lexplore is that it is capable of diagnosing complications in reading before other methods can observe them [15]. This can help in assisting the students to adopt the right reading habits

[3] Lexplore - Läsutveckling med AI. Retrieved from https://lexplore.com/sv-se/

when they are still young [46]. Also, the use of data visualization could potentially make it easier for principals and school leaders who have little time to try and interpret the data and make doable actions.

Involvement in the Educational setting

Lexplore works with a broad network of schools, mainly in Sweden but also in other countries. And since the platform is especially useful for early intervention, schools with high stakes for learning difficulties are more likely to work with them [46].

The network of schools that Lexplore operates with can share effective teaching methods and learn from each other collectively. These schools use the same assessment and data visualization tools and therefore, they can benchmark their results with other institutions in the network. This makes the involvement of the schools to be cooperative so that they can share lessons learnt and the most successful practices [48]. For example, a school that has demonstrated that Lexplore data can help with interventions in reading might describe how they have done that, in order to support improvement amongst the network. This improves collaboration within the network.

In addition, Lexplore works in partnership with schools and also provide training and help to teachers and principals. The schools in the network get trained to utilize the Lexplore platform most efficiently, ensuring they are positioned to help their learners. This includes guidance on interpreting data from the current dashboards, which present an overview of student performance (see Appendix 6, Figures 15, 16, and 17). These dashboards offer visualizations of students grouped into categories like low, average, and high performers, enabling schools to track and monitor progress.

Impact on School Leadership

For school principals, using Lexplore can be one of the most productive forms of work [46]. The visualization of progress feature in the platform enables the principals to monitor the reading levels of schools, classes, and students in general, and allows them to draw the attention of relevant stakeholders to the specific areas that require more allocation of resources and early intervention [48]. Furthermore, working within the Lexplore network allows the principals to respond to the challenges related to monitoring reading levels and providing necessary support to students as part of a larger community of schools that are tackling similar objectives thus benefitting from collaboration [46].

Learning Analytics and Dashboards

Learning dashboards intend to assist school staff in their practice and work in schools [16]. These dashboards enable principals to track different sorts of learning undertakings which include; online learning, K-12 teaching and learning environments, collaboration learning, and adaptive learning. Learning Analytics (LA) simply refers to the process of collecting, analyzing and interpreting data related to student’s learning. However, these dashboards frequently still face challenges: The dashboards may not be very reliable or easy to use, this may make it difficult for the teachers to make correct assessment of the student’s reading progress. Some dashboards are developed to focus on a specific area of functionality and may need a certain level of expertise to operate, and thus, the layout of the dashboards often neglects the principals’ instructional requirements [16].

LA research shows that even as LA dashboards seek to be effective, the application calls for enhancement of the principal's computer literacy and data literacy, as they need to understand the data to interpret it correctly. Lack of data literacy among principals may result in incorrect conclusions in the analysis with consequences for learners. Though the impact of computer literacy with regard to the use of dashboards has not been researched, it is clear that the visualization aptitude –a facet of data aptitude is necessary for the principals to properly engage with LA dashboards [16].

Literature has described instances when teachers have experienced difficulties to use LA dashboards to inform decisions [16]. The usability of these dashboards often depends on how versed the user is with all the intricacies of the dashboard. At the same time, it remains to be a common practice that teachers face challenges in the understanding and application of the collected data [17]. To address these issues, research suggests two main strategies: increasing teacher's data proficiency as well as optimizing the content of the dashboards to explicate them in better ways [16].

Data visualization

The field of data visualization has come a long way in the last few years primarily due to the refinement of computational tools and data availability. The following attributes have been fueled by open data movement, large collection of data by internet firms and social media. These have made data available and created new possibilities to bring life to the figures and statistics [18].
In fact, data visualization has always been instrumental in the presentation of facts and the analysis of events together with the facilitation of decision-making. Some of the early examples are as effective as the Florence Nightingale chart on shown mortality rate of British Army in Crimean War and John Snow map of cholera cases in London. Such early slashes successfully communicated information in a way that could be easily understood and similarly allowed for an effective extraction of conclusions from the retrieved data [18].

Data Visualization in Educational Settings

Within the modern processes of education, data visualization has appeared as a significant approach that allows not only to analyze but also to create new methods of data interpretation. In its essence, data visualization involves turning numbers into graphical representations like charts, graphs, and even an interactive dashboard and has the likelihood to impact favorably different areas of the educational practices [20].

The major beneficiaries of the concept of using data visualization in the education sector are the teachers, learners, parents and the school leaders. The core group of consumers of these instruments is teachers and professors who use them to monitor results of their students and modify their approaches consequently. To the benefit of each student, visuals provide self-evaluation and personal progress check, control of one's learning. Parents benefit from the enhanced ways through which they can communicate with schools, and hence they get to know how their child is performing academically. School administrators employ data visualizations to learn about the general performance of the school, plan tactical and budgetary procedures [20].

Of all the applied communication tasks in education, data visualization can be considered most effective in making the data digestible. Thus, visual tools are perhaps the most helpful to educators, as they give the overview of the students' performance immediately and allow to make deductions that otherwise may go unnoticed [21]. For example, the graphical representation of activities related to reading contributes to the understanding of how students' skills evolve throughout the year and thus, reveals potential learning difficulties. This immediacy in being able to understand this results in more timely and accurate instructional intervention [22].

In addition, learning with data visualization can be benefiting to the student due to the individual learning since it lays out a detailed explanation of how the particular student is performing. For instance, dynamic data read rate, comprehension, and interest level dials to assist teachers in identifying learners' needs in the course. Such an approach of study makes learning more effective and improves students' performance since particular learning needs are met [20].

Visual aids also facilitate interaction with the teachers, students, and other stakeholders in the kid's life. Lecturers also get to make better and far more comprehensible discussions about a student's performance by virtue of the interactive reports and visual summaries. For instance, parents can quickly understand their child's performance and work hand in hand with the teachers of the youngster. It also opens a way to enhance the efficiency of the relationships between the schools and families which results in the further development of the students [22].

However, the implementation of data visualization in education is not without its issues, as this thesis aims to illustrate. Among them, there is one concern which is related to the quality and the comparability of the used data in the context of the visualizations. Hence, qualitative data have the potential of yielding poor visual image representations that can be followed by wrong decisions, strategies and measures. Furthermore, the syntheses of the data resulting from diverse sources including standardized tests, formative assessments, and observation data poses a great challenge because of the need to have sound procedures and reliable systems that can support such integration. Another conflict is the training and expertise that will be required to make these systems work from the store's side. One of the purposes of data visualization tools is to enable the teacher or administrator to interpret the data visually thus the importance of acquiring skills that enable one to decode the graphic data. Therefore, the utilization of these tools will not translate into the desired outcomes if the trainers are not well-trained [23]. Another implication is the need to undertake professional development programs that will enable stakeholders to use data visualizations to enhance their practices [23].

The student's information should be protected to avoid unfavorable events such as theft, and for that reason, certain privacy and security measures should be taken [22]. Schools are required to use proper measures to address the security of student's information while applying visualization.

Moreover, despite the role of simplification of data interpretation, there is somewhat an issue of over-simplification with visualizations. This means that, complex data can be easily misrepresented if the overlying visualizations are not well planned, which leads to various misjudgments. The data needs to be accurate, meaningful and as such the risk of misinterpretation has to be managed via clear labeling, contextual information, and explanatory notes [23].

THEORETICAL LENS

Theoretical Framework: UX-TAM

The User-Experience-Technology-Acceptance-Model (UX-TAM) is an integrative theoretical framework where TAM was combined with the practice of UX design [24]. This combination is particularly important in the learning environment where technology instruments shall be both efficient and easy to use. With the help of UX-TAM, we can look at school principals and how they engage with chosen data visualization technologies aimed at increasing students' reading fluency comprehensively, emphasizing both their technology acceptance and user experience. Below is an illustration of the model. For the purpose of this study we will focus on Perceived usefulness, Perceived Ease of use, Usability, Design quality and User Satisfaction.

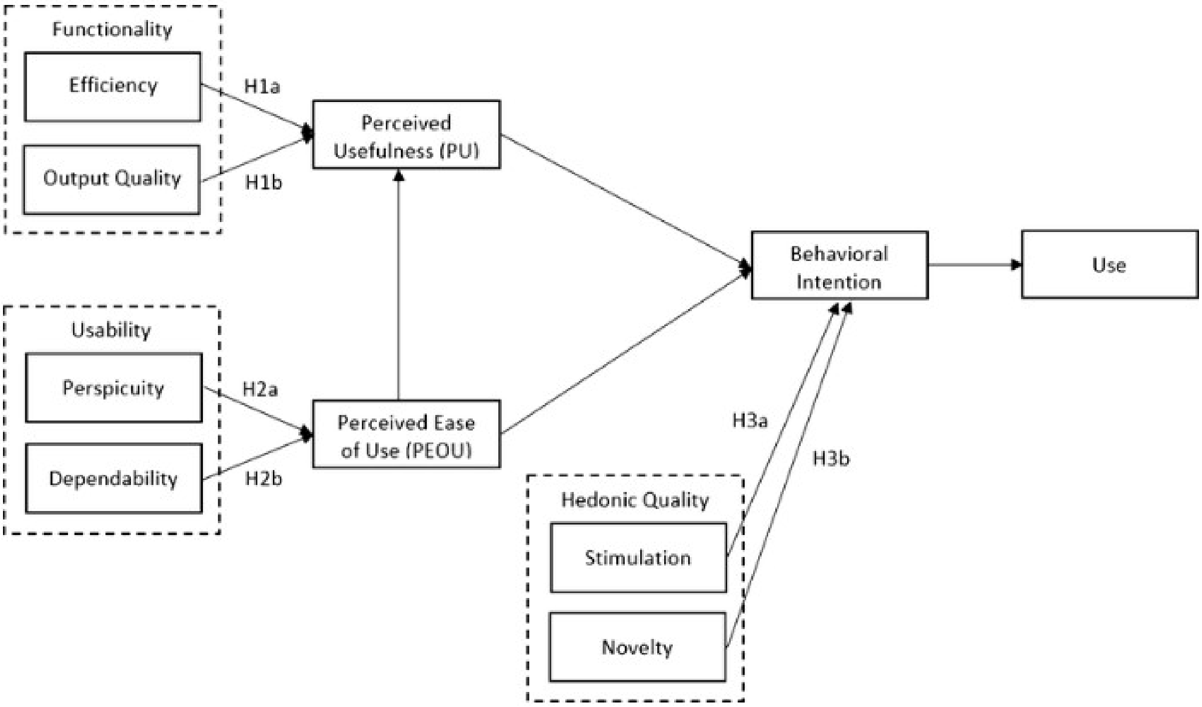

Figure 1: UX-TAM model [4]

Technology Acceptance Model (TAM)

Technology Acceptance Model (TAM) is one of the most widely recognized models that describe the process through which a user accepts a technology. Developed by Davis in 1989 [25], TAM posits that two primary factors influence technology adoption: The technology adoption model consists of two factors: perceived usefulness (U) and perceived ease of use (EU).

- **Perceived Usefulness (U)**

  This is defined as the extent to which a person feels that applying a certain system would help him or her to perform a certain job better. In the case of school principals, Perceived Usefulness would correspond to how much they think this array of data visualization tools can assist them in properly supervising how students mitigate their weaknesses in reading [26].

[4] Mlekus, L., Bentler, D., Paruzel, A., Kato-Beiderwieden, A., & Maier, G. W. (2020). How to raise technology acceptance: user experience characteristics as technology-inherent determinants. *Gruppe Interaktion Organisation Zeitschrift Für Angewandte Organisationspsychologie (GIO)*, *51*(3), 273–283. https://doi.org/10.1007/s11612-020-00529-7

- **Perceived Ease of Use (EU)**

Known as perceived ease of use, this is the extent to which a person considers the use of a system to be trouble-free. Concerning EU from school principals' perspective, it encompasses the simplicity through which they can understand and apply the data visualization tools without facing a lot of difficulty and or time consumption [26].

User Experience (UX) Design Principles

User Experience (UX) design is defined as the process of understanding user needs and then increasing the user's level of satisfaction with the product and the experience of usage [27]. The UX component introduces several additional dimensions to TAM:

- **Usability**

This comprises the extent, speed, and level of satisfaction with which users accomplish their tasks. High usability implies that the school principals are able to attain the objectives with the data visualization tools without much difficulty. It also contains features like easily learnable, how often errors are made, and subjective satisfaction [28].

- **Design/Output Quality**

Design quality can be defined as the ergonomics and appearance of the tools both outside as well as inside. It encompasses how the visual looks like, its design, choice of color and even the logical manner used in presenting information. Consequently, judges and criterion definitions pointed out the importance of a high design quality of both data visualization tools and created visuals which provides two guarantees: the visuals are pleasing to the eyes and the content they portray is comprehensible and actionable [29].

- **User Satisfaction**

Overall, U and EU are elements of user satisfaction but in addition the user satisfaction measure encompasses the emotional aspect as well as the overall level of contentment with the tool. It constitutes the user's overall judgment of the interaction with the given technology [28].

METHOD

Study Design

Lexplore is a web-based tool for improving students' literacy based on the application of artificial intelligence and eye-tracking technologies. Using objective values, Lexplore assists in evaluating reading skills and defining learning difficulties of learners. It provides results of the reading speed, accuracy, and study the levels of comprehension that is facilitated by use of graphical displays in order to ensure that it is comprehensible to teachers, the school administrators and the parents.

Participants

The participants in this study were school principals who actively used the Lexplore platform. Seven principals were selected based on their computer proficiency, the frequency of Lexplore platform usage and their participation in data-driven decision-making in educational environments. During the initial interviews, participants provided information about their computer proficiency and how frequently they used the Lexplore platform. This information was used to assess whether the participants selected for the study were familiar with the Lexplore platform and comfortable using technology. The selection process was conducted by me, using a list of potential participants provided by Lexplore.

The study began with online interviews involving all seven principals. Of these, five returned to participate in the subsequent user testing phase, while two additional principals, who had not participated in the initial interviews, joined the testing phase.

Data Collection

This research makes use of both quantitative and qualitative research methodologies to ensure that the study collects and analyses both numerical and non-numerical data that can help capture the different ways in which data visualization tools can support school principals in the monitoring and the improvement of students' reading ability. The study is based on the user experience technology acceptance model adapted for the present research to the context of an educational setting.

Phase 1: Interviews

The first phase involved conducting online interviews using Microsoft Teams, lasting between 30 and 40 minutes. The goal of these interviews was to gather insights into the principals' experiences using the current Lexplore platform and their perspectives on how it supported data-driven decision-making. The interviews were conducted using a predetermined set of closed-ended and open-ended questions, the answers were transcribed manually and analyzed using website called miro-board to find important themes. A list of the questions that were asked has been translated to English and can be found in Appendix 1. The insights gained from these interviews influenced the development of the prototype.

Phase 2: Prototype Development

Following the interviews, a prototype of the data visualization dashboard was developed. Based on the feedback received during the interview phase, a prototype was created using Figma, with the aim of improving the current user interface and making the data more accessible to school principals.

Phase 3: User Testing

Once the prototype was developed, user testing was conducted with seven participants (five of whom had participated in the interviews and two new participants). The prototype's usability was evaluated through three testing sessions, each lasting between 40 and 45 minutes.

Data Analysis

Qualitative Descriptors

The labels employed included *clear, uncertain*, and *not clear* to group participants' knowledge and competency on how and when to accomplish the given tasks using the visualizations while particularly paying attention to the quality of data acquired from the techniques. These descriptors were defined as follows:

- **Clear -** Participants could accurately and confidently interpret the data visualizations.
- **Uncertain -** Participants expressed some hesitation or required additional clarification to understand the visualizations.

- **Not Clear -** Participants could not interpret the visualizations and exhibited significant confusion.

The responses from the participants were documented and grouped according to the above descriptors over three rounds of the study. Reviewing the results, a growing pattern of improved distinctiveness and reduced ambiguity and misunderstanding was noted. The observational data gathered from the testing sessions was then evaluated based on the given qualitive criteria as shown below.

Perceived Usefulness (PU)

Perceived Usefulness was defined as the extent to which users felt that using the data visualization tool improved their efficiency in their job by providing insight into students' reading capability. The measure of PU was based on participants' rates of recognizing students who required extra help; students' improvement patterns over time; and the application of data in the decision-making process.

Perceived Ease of Use (PEOU)

Perceived usefulness was defined as the extent to which school principals considered the data visualization tool effective and easy to utilize. PEOU was assessed based on the participants' ability to accomplish tasks with ease and without unnecessary confusion.

Usability (U)

Usability included the ability to achieve goals, the time to achieve the goal, and the perceived satisfaction. To assess the monitor's effectiveness in using the proposed model, the specific measures of accuracy, speed, and minimal effort for the five generic tasks were adopted, while satisfaction was evaluated based on participants' feedback on the model.
It is evident that the main aspects related to usability improved with the successive iterations of the tool.

Design Quality (DQ)

Design Quality is related to aspects of the real-time aesthetic appearance of the visualizations, efficiency of information flow, and consistency of the layout of the user interface. DQ was evaluated based on how effectively the visual and functional requirements of the tool facilitated users' tasks.

User Satisfaction (US)

User Satisfaction assessed users' satisfaction with the tool in the functional and perceived manner as well as the emotional and subjective factors based on PU, PEOU, U, and DQ.

Evaluation Guidelines

Based on the aforementioned context of the data visualization prototype, the assessment of the prototype was conducted by adopting the UX-TAM model. The evaluation utilized three distinct protocols: Think Aloud, A/B testing, and a follow-up interview. These protocols are designed to offer a detailed analysis of the needs and actions of the users as well as the complete picture of the usage process. The evaluation focused on three key views within the Lexplore platform:

- **School View:** Provides an overview of student literacy performance at the school level, helping principals identify trends across different groups.

- **Class View:** Focuses on literacy data within a specific class, allowing principals to analyze student performance, spot patterns, and tailor interventions accordingly.
- **Individual View:** Displays detailed insights into a single student's reading progress, offering principals a deeper understanding of individual strengths and areas for improvement.

Think Aloud Protocol

The first protocol to be implemented into the study is the Think Aloud which is aimed at observing users' cognition, decisions as well as interaction with the interface. Subjects were enlightened on the purpose of the evaluation and the Think Aloud methodologies. They were expected to express their views on the prototype as they used it and at the same time explain what they were thinking, how they felt, and what they did. Their articulation of these issues, helped in finding usability problems and evaluating Perceived Ease of Use and Perceived Usefulness, thus determining how principals may use the tool. This think-aloud approach is suitable as it avoids hindering their thinking process hence providing genuine feedback.

A/B Testing

The second process is the A/B testing protocol, another approach aimed at determining the user's preference for one over the other of two contrasting visual designs. This method compared Design Quality and User Satisfaction by briefing the participants with two different interfaces and collecting quantitative data that determines the nature of the improvement of the interface. It's important to note that A/B testing was conducted exclusively for the School View Visualization. Feedback from the initial interview revealed that many principals had trouble understanding the School View Visualization offered by the current platform. To find out which design better suited the needs of the principals, two prototypes were made instead. This protocol will also identify aspects of the dashboard that are visually and functionally appealing from the users' standpoint and hence improve Perceived Usefulness.

Dashboard Interface Design Process

The evaluation focused on three key dashboard interface views: they are the School Level View, Class Level View, and Individual Level. Each view was examined via proposed activities and corresponding questions based on the UX-TAM framework. The design of the data visualization tool followed an iterative process. After each round of testing, the tool was refined based on participant feedback.

RESULTS

The project began with a series of interviews to evaluate the current interface. Based on these interviews, participants expressed a need for clear and intuitive visualizations that effectively communicate student performance data. Many principals emphasized the importance of customizing these visualizations to better suit their specific needs and contexts.

Participant Demographics

The study involved participants with varying levels of computer literacy. Three of the participants ranked themselves as high on computer usage, while 2 ranked themselves as moderate and the final 2 ranked themselves low on computer usage. The table representing their varied usage habits can be found in Appendix 2, Table 2: Participants' computer habits.

Summary Of Interview Findings

The interviews conducted with five school principals provided valuable insights into their experiences and needs related to data visualization tools. Below is a synthesized summary of their responses to each interview question:

1. **Can you describe your role as a school principal and what your daily tasks look like?**
   - Principals highlighted their roles as multifaceted, encompassing resource allocation, strategy planning, and monitoring student performance. Their daily tasks often involved analyzing data to identify areas needing intervention and coordinating with teachers and parents to address these challenges.
2. **How often do you use any analysis or visualization tools like Excel or Tableau to make sense of data in your work?**
   - Various analysis tools were used by the principals. Some principals used Excel occasionally but found it limited in addressing their needs, such as identifying patterns in student reading performance. Tableau and other more sophisticated tools were rarely used because of their complexity and lack of adaptability to educational environments.
3. **How would you describe your computer habits?**
   - Computer proficiency levels among participants varied. Two described their proficiency as moderate, two as low, and three as high. Those with greater expertise felt more at ease experimenting with digital tools.
4. **How often do you use the existing platform, and for what specific purposes do you use it?**
   - Usage frequency differed among principals. Some only utilized the platform during designated reporting periods, while others used it frequently to track students' reading proficiency. Typical applications included monitoring development, recognizing the students who needed help, and creating meeting reports.
5. **Which aspects of the current platform do you find most helpful when assessing students' reading abilities?**
   - Participants appreciated the platform's ability to track reading progress and identify low-performing students. However, many noted that the visualizations lacked clarity and were not always actionable.
6. **Which scoring system do you use most to determine a student's reading ability—stanine scores or Lexplore scores?**
   - Preferences varied between the two scoring systems. Some participants favored stanine scores for their familiarity, while others preferred Lexplore scores for their detailed insights. Flexibility to use either scoring system was highlighted as essential.
7. **How do you assess whether a student’s decoding needs more work or if it’s their comprehension that requires attention?**

- In order to differentiate between understanding and decoding difficulties, principals relied on their knowledge and observations from teachers. They did, however, state that the platform needed more precise diagnostic features to support this evaluation.

8. **Are there any challenges or frustrations you encounter when using the platform in its current state? Is there any visualization you find misleading?**
    - Limited filtering options, confusing navigation, and poor data representation were common frustrations. Certain representations were seen to be misleading and required more work to properly interpret.
9. **How do you use filtering on the platform to quickly locate specific information?**
    - Participants emphasized the importance of efficient filtering to quickly locate specific data, such as decoding versus comprehension scores.
10. **Would you like to see the progress over time for a class presented in the results?**
    - The idea of showing students' and courses' development over time was embraced by all. According to the participants, this tool would offer insightful information for monitoring advancements and making data-driven choices.
11. **Is the portal used during development meetings with parents, where they can see the student's progress over time?**
    - The platform was frequently used during parent meetings to display student progress. However, principals stressed the need for user-friendly visual snapshots that clearly communicate key metrics to parents and other stakeholders.
12. **Are there specific areas for improvement that you would like to highlight?**
    - Suggestions for improvement included simplifying the platform layout, enhancing the clarity of visualizations, adding interactive features, and incorporating diagnostic tools to better identify and address specific student needs. Additionally, principals suggested using comparison benchmarks to put student performance in context.

Iteration 1 Development

The first iteration of the prototype was designed to address school principals' needs for monitoring student and class performance. It included three main views: the **School Overview**, the **Class View**, and the **Individual View**. These views were created to provide both macro-level insights and detailed analysis to support decision-making. A/B testing was conducted to evaluate the School Overview only. The goal of A/B testing was to assess which design offered better clarity and ease of use for the intended tasks.

School level

Test A presented the school overview in a more complex design see (Figure 2), which was designed to track trends across classes or school years. Test A featured a line graph combined with shaded areas to indicate performance indicators over time. Test B, on the other hand, used stacked area charts with clear colour coding aiming to enhance clarity and reduce cognitive load, see (Figure 3).

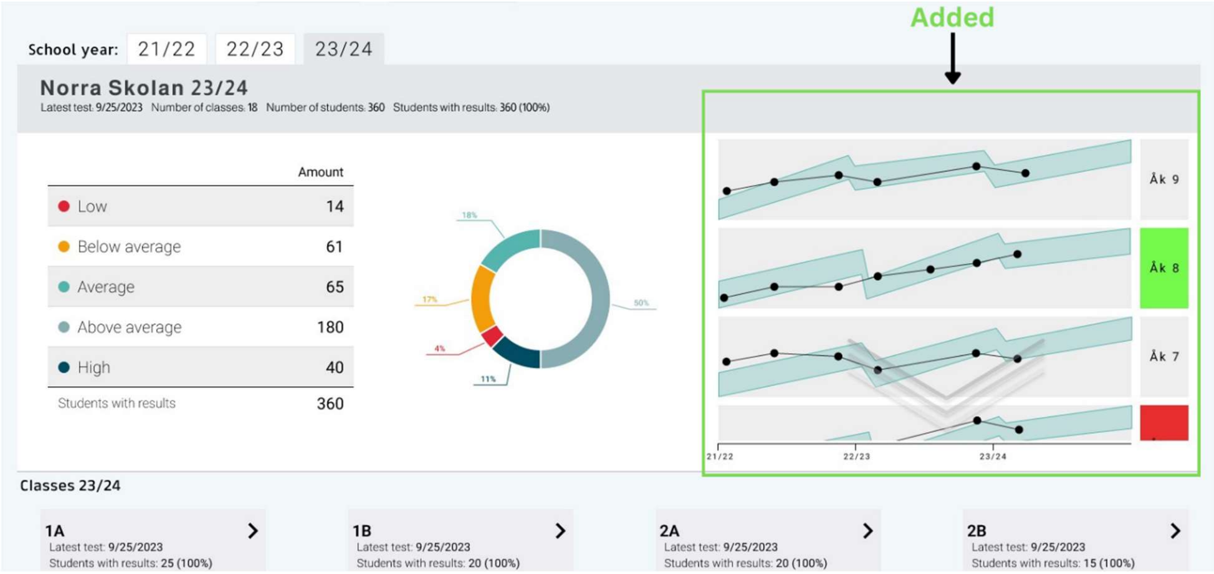

Figure 2: Simplified School Overview Design (Test A). The visualization displays the reading proficiency of different classes. The turquoise-colored curve represents a normal distribution of the average class scores across Sweden. The black line indicates the performance of a specific class in relation to the background normal distribution. Each black dot along the line represents a specific point in time when the class's score was measured. On the far right of the graph, there are boxes labeled with the grade levels. These boxes indicate which grade the data represents and whether the trend is upward or downward. Green signifies an upward trend, red indicates a downward trend, and gray represents no significant upward or downward trend.

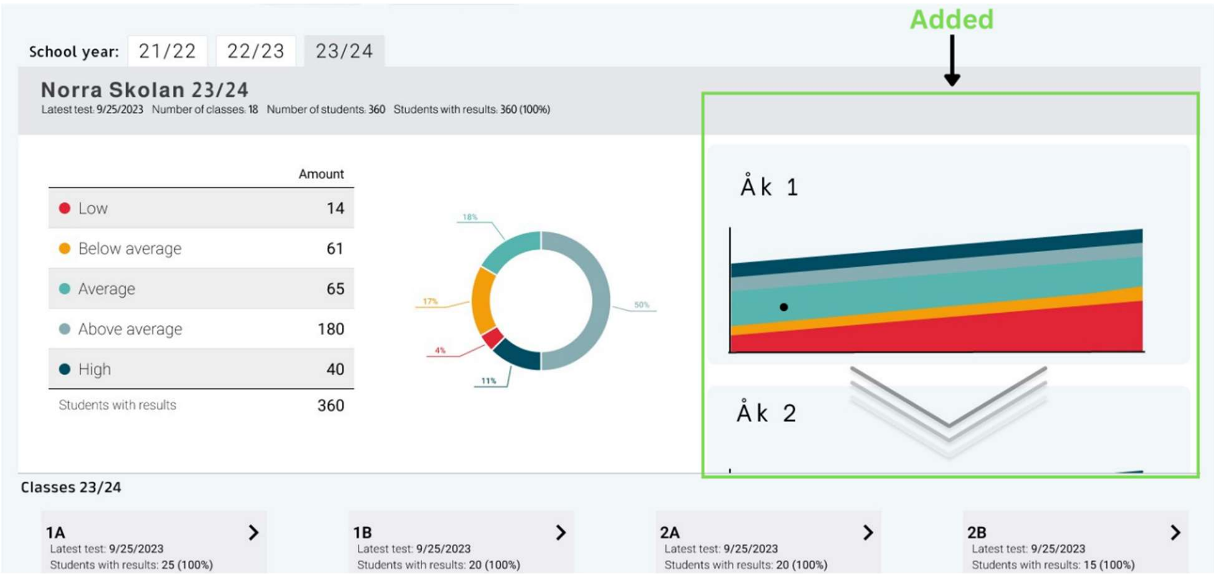

Figure 3: Simplified School Overview Design (Test B). The visualization illustrates the reading proficiency levels of different classes. Each color in the visualization represents a specific proficiency level, ranging from red for "low" to dark blue for "high". The amplitude of the color's changes over time, reflecting the natural progression of reading ability, which typically improves continuously in school settings as students advance through their education. This means that while higher proficiency levels (represented by darker colors) show improvement over time, the lower proficiency groups (represented by red) also experience growth, as all categories—low to high—progress over time. Users can scroll through all grade levels to explore the data. In the visualization, a single black dot without a connecting line indicates that the class's data was measured only once.

Class level

The Class View further isolated a particular class within the school (see, Figure 4). Here principals could monitor how a given class was ranking and compare various students within the class to identify the ones that require targeted support. The view also gave insight into how the performance of the class was changing over time. Historical data comparisons were one of the biggest features added to the prototype, where users compare the current performance with previous years or terms.

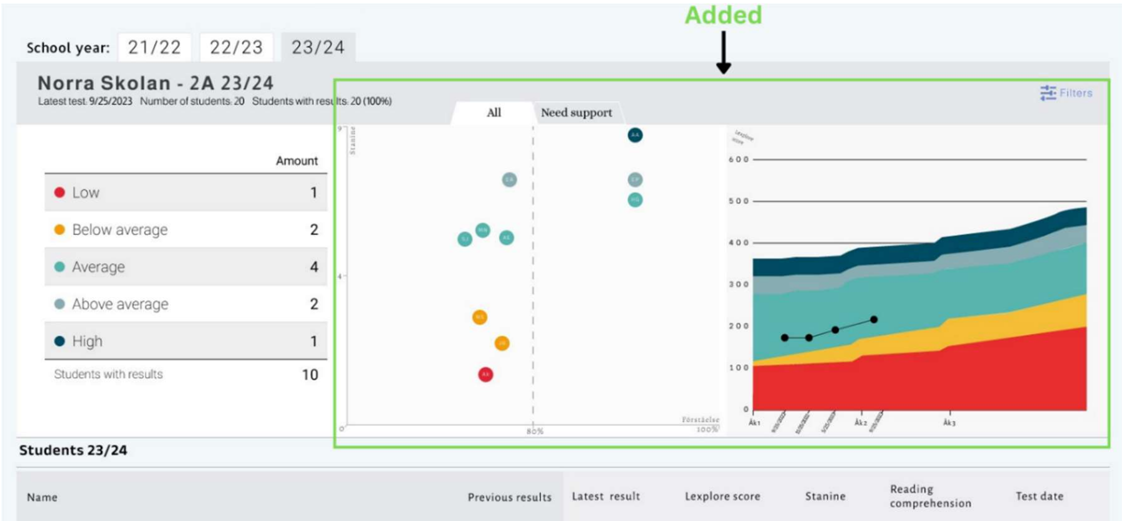

Figure 4: Class Performance Monitoring View. The central part of the visualization resembles a scatter plot displaying student results. The data takes into account both the student's reading comprehension and their stanine score. On the far right, there is another graph showing the average data of the class. The colors in the background represent the normal distribution curve for Swedish schools The amplitude of the color's changes over time, reflecting the natural progression of reading ability, which typically improves continuously in school settings as students advance through their education.

Individual level

The most detailed level of assessment was presented by the Individual View (see Figure 5), which allows learning about the progress in reading of each particular student. Once the principals identified the students that need targeted support, they could use the individual view to further get details on the particular areas that the student was struggling in. This view was necessary in making personal adjustments with regards to the needs of every learner as well as making support systems well-defined.

Figure 5: Student Performance Tracking in Individual View. The visualization displays data from the previous measurement as well as the most recent measurement of the student's reading comprehension and stanine scores.

Evaluation of Iteration 1

Feedback from participants revealed several strengths and weaknesses in Iteration 1. In the **School Overview**, Test A received mixed feedback. Four participants found the visualization clear, while two were uncertain, and one found it completely unclear. Participants noted that overlapping elements made it harder to interpret. One participant remarked, “The graph feels cluttered, making it harder to understand.” In contrast, Test B was universally preferred for its simplicity, with all participants agreeing that it was easier to understand. Comments included, “This is very intuitive,” highlighting Test B's effectiveness.

In the **Class View** (Figure 4), participants appreciated the ability to monitor class trends, compare individual students, and analyze performance over time. However, filtering for students with low reading ability revealed usability challenges. While five participants completed this task correctly, two were unsure of the filter functionality, suggesting that clearer labeling was needed. Tasks involving the normalization curve, such as identifying the class’s peak performance, were more successful, with six participants completing the task easily. One participant commented, “The spikes in the graph make it simple to read.”

The **Individual View** (Figure 5) posed the greatest challenges. Tasks requiring participants to locate decoding and comprehension scores were unclear for five participants, while two were uncertain. One participant stated, “I can’t find the score values; it’s not straightforward.” Despite these difficulties, the view was appreciated conceptually, as participants recognized its potential for detailed analysis of individual student progress. A summary of the findings from Prototype Version 1 is presented in (Figure 6).

The results from iteration 1 were mapped as follows:

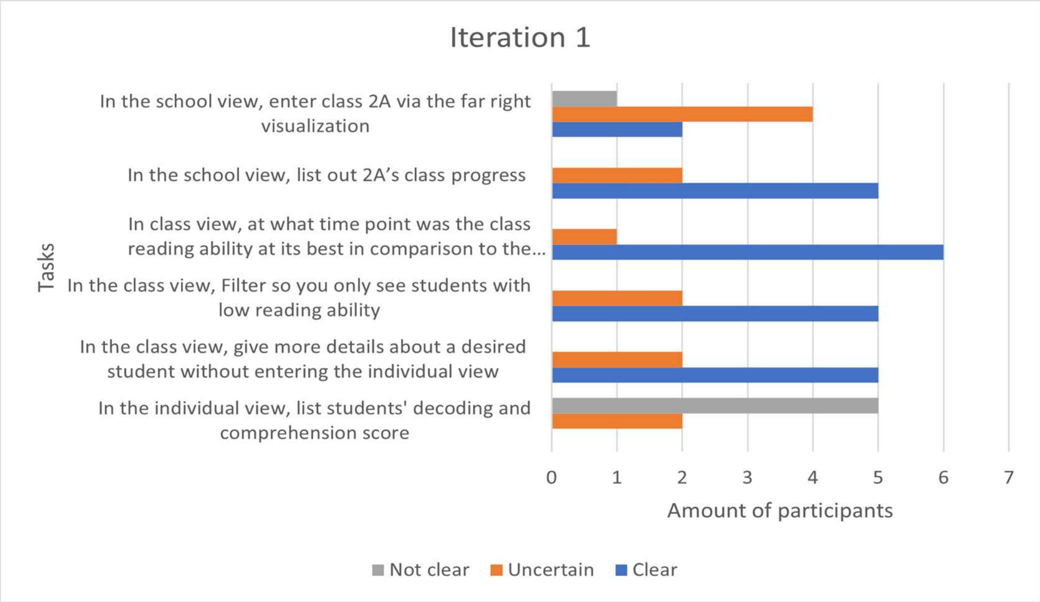

Figure 6: Evaluation summary of Prototype Version 1

Iteration 2 Development

In the second iteration, to address the challenges raised in iteration 1, the following improvements were made based on the feedback:

- **Improve Visibility** (increasing the font size, changing the color etc.).
- **Add Labels and Tooltips** (Clearly label the scores and provide tooltips).
- **Simplify Layout** (Redesign the layout to reduce clutter and make it easier).
- **Filter Descriptions** (Include a brief description or icon that explains the function).
- **Improve Interactivity Cues** (Make it obvious that the far-right visualization is interactive by adding hover effects).

The full table breakdown including the questions asked can be found in Appendix 4.

Evaluation of Iteration 2

In the **School View**, there were improvements. When asked to list Class 2A's progress, all participants found the task clear. This was improved from iteration 1, where many struggled with it. One participant said, *"This is a notable difference and a simple way of showing progress."*. All participants found it clear this time, due to the hover effects and updated design, which made the feature more interactive and easier to notice. Comments from participants like, *"The new visualization is more appealing,"* highlighted these changes.

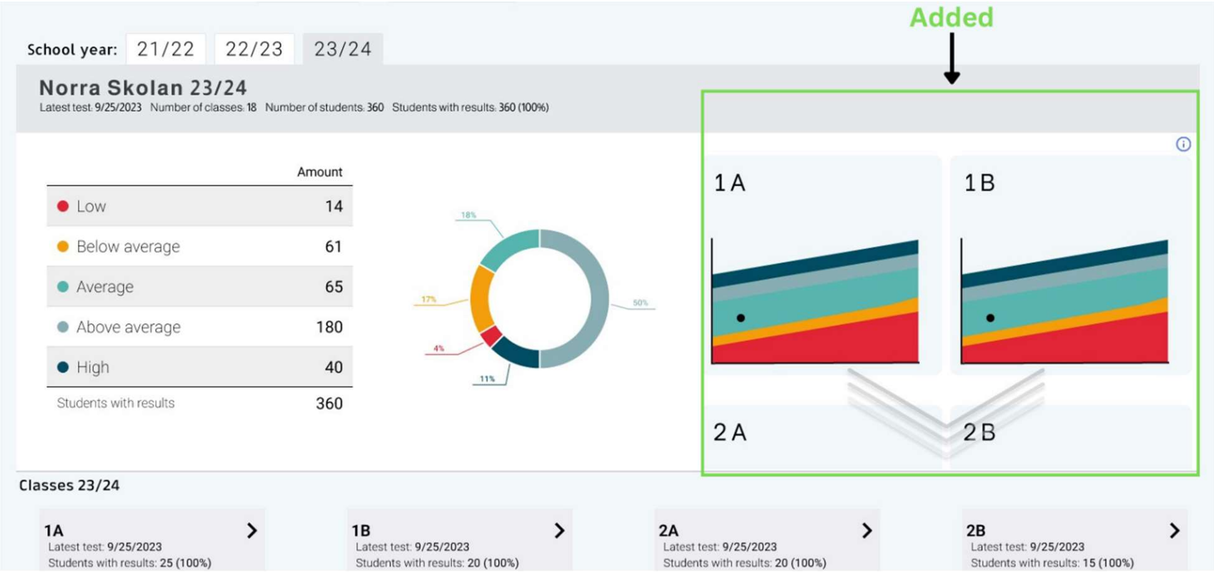

Figure 7: Modified school overview design from iteration 1. The visualization shows classes instead of grade levels. For example, it displays "1A" and "1B" instead of "Grade 1." Additionally, the visualization is more interactive, allowing users to hover over it for further details.

In the **Class View**, the task of viewing student details without opening the Individual View had similar results to the first iteration. Five participants said it was clear, but two were still unsure. On the other hand, the task of filtering students with low reading ability showed much better results. Six participants understood the task, and only one found it unclear. They appreciated the addition of presets, which made filtering easier. One participant said, *"It is better to use the presets than the current filter system,"* while another commented, *"I can get used to this."*

The task of finding when the class's reading ability was at its best compared to the normalization curve was also successful. Six participants found it clear, and one was unsure. The graph design was particularly appreciated, especially the visible spikes, which made the data easier to understand. One participant noted, *"I like how visible the line is in the graph."*

Figure 8: Modified class performance monitoring view from iteration 1. The visualization includes a simple filter that allows users to select the grade range they wish to view. The filter is located in the top-right corner.

In the **Individual View**, five out of seven participants found it much easier to visualize scores, which was a big improvement compared to the first iteration, where no one found it easy. Participants appreciated the hover effects and clearer design. For example, one said, *"Now I can see the scores easily."* However, one participant remained unsure, and another was confused, suggesting that some small adjustments might still be needed.

Figure 9: Modified student performance tracking in individual View from iteration 1. The visualization now displays both the previous and most recent results, as well as other necessary values.

Overall, many of the problems identified in the first iteration were solved, and participants found the interface easier to use. A few areas still needed some work, but the changes made so far have greatly improved the user experience. A summary of the second iteration findings is presented in (Figure 10).

Below is how the results were mapped:

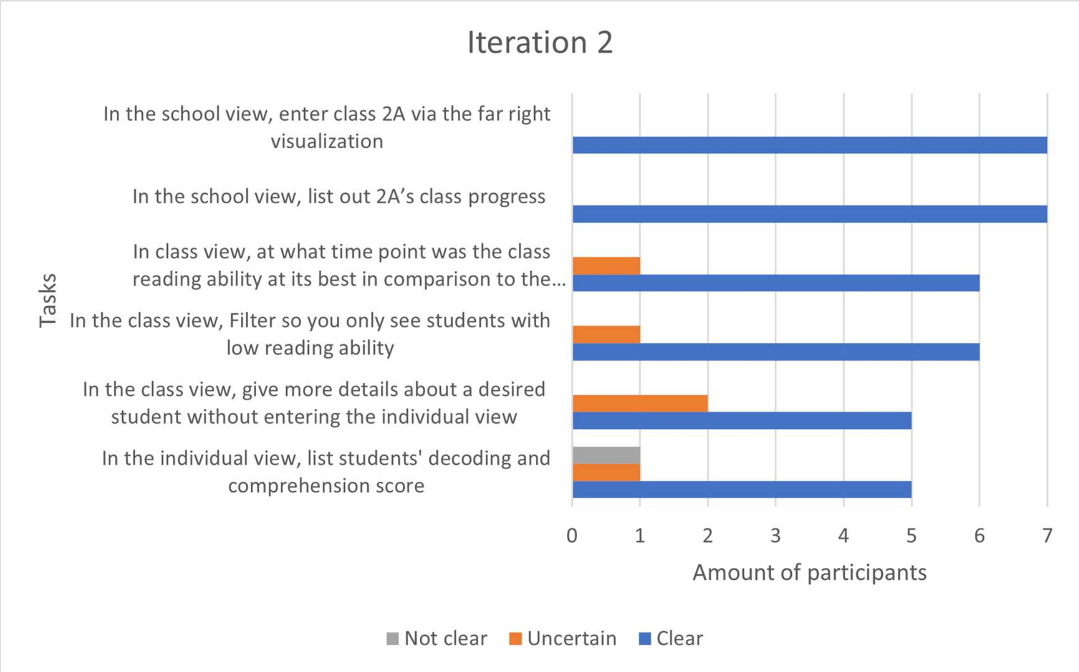

Figure 10: Evaluation summary of prototype version 2

Iteration 3 Development

In the third iteration, further refinements were made, and the results showed continued improvement. The challenges raised in iteration 2 was such as:

- **Address Confusion** (adding even clearer labels to guide users through the process)
- **User Guidance** (Introduce contextual help or tips that appear when a user hesitates)
- **Fine-Tune Presets** (further refine the presets for even more intuitive use when filtering)
- **Iterative Refinement** (Keep iterating on areas where some participants still express confusion)

The full table breakdown that includes all the questions asked can be found in Appendix 5.

Evaluation of Iteration 3

The feedback collected during the third iteration showed even more improvements in clarity and usability, with most tasks showing consistent progress or complete resolution of earlier issues.

In the **School View**, the task of listing Class 2A's progress was once again described as clear by all seven participants. This result mirrored the positive feedback from iteration 2. The visualization improvements

introduced in earlier iterations were retained, and participants continued to find the task easy and straightforward.
The School View task of entering Class 2A via the visualization saw complete clarity among all participants. The design changes successfully resolved the confusion reported in iteration 1. Participants appreciated the new, modernized appearance and the improved interactivity. As one participant commented, *"Much improved visualization and looks more interactive,"* while another noted, *"I like how the new visualization got a modern look to it."*

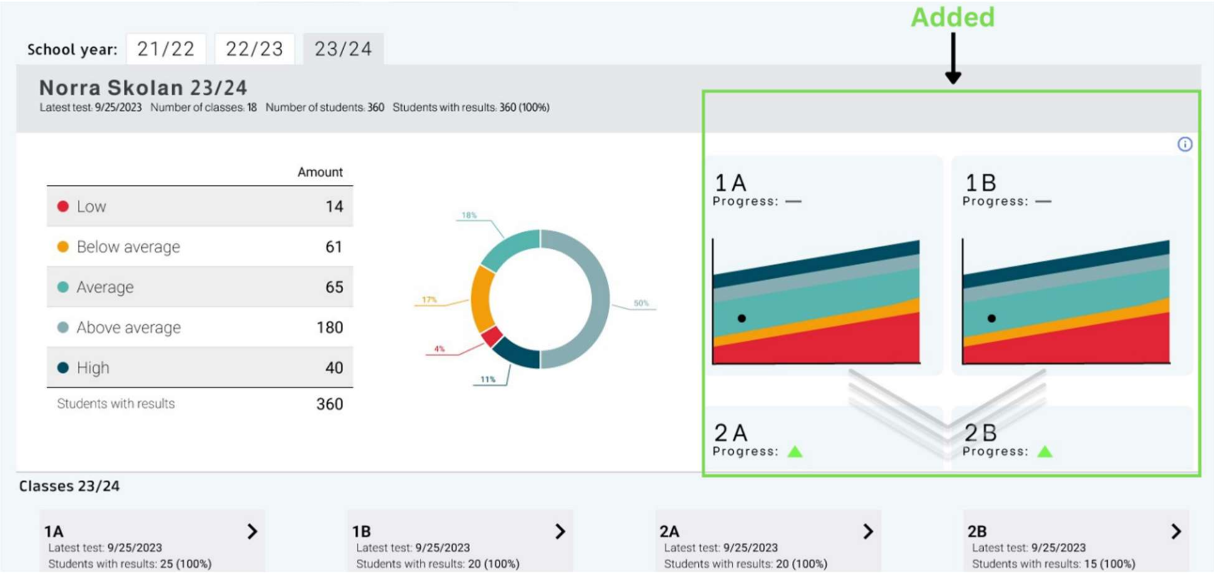

Figure 11: Final modification of school overview design. The progress in the visualization is now more visible and minimal in its representation, using green and red arrows. Red indicates a downward trend, while green signifies an upward trend.

The **Class View** task of viewing more details about a student without entering the Individual View showed consistent results, with five participants finding it clear. However, two participants were still uncertain, indicating that this task might benefit from further minor adjustments. While the overall clarity was maintained from previous iterations, slight improvements could help ensure all users are comfortable with the interaction.
For the Class View filtering task, all seven participants understood how to filter students with low reading ability. This was a major improvement, as every participant found the updated filtering system completely clear and easy to use. The refined presets contributed significantly to making this task more intuitive.
The task of identifying when the class reading ability was at its best compared to the normalization curve also remained consistent. Six participants found the task clear, and only one expressed uncertainty. Feedback confirmed that the visualization of the normalization curve continued to work well for most participants, with no major uncertainties.

Figure 12: Final modification of class performance monitoring view. When clicking on the scatter plot view, you can see the student's graph in relation to the normal distribution across Swedish schools and compare it to the class's average level. In the scatter plot view, the red hollow circles represent the student's past data, allowing for a comparison of changes over time.

Finally, in the **Individual View**, all seven participants completed the task of listing students' decoding and comprehension scores without any difficulty. This marked a complete shift from earlier iterations, where participants struggled with clarity. One participant specifically noted, *"I like how you gave an illustration to the visualization of it being hoverable"* emphasizing how the refinements had improved usability and accessibility. A summary of the findings from Iteration 3 is presented in (Figure 14).

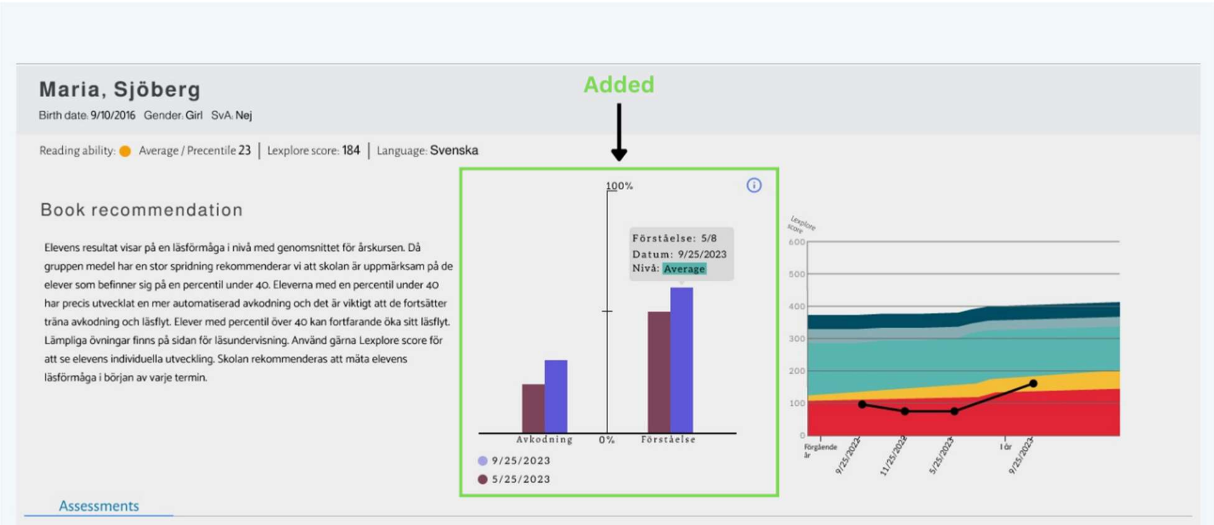

Figure 13: Final modification of student performance tracking in individual View. The tooltip displays while hovering, to displays more detailed information, allowing users to explore additional data points.

The results from iteration 3 were mapped as below:

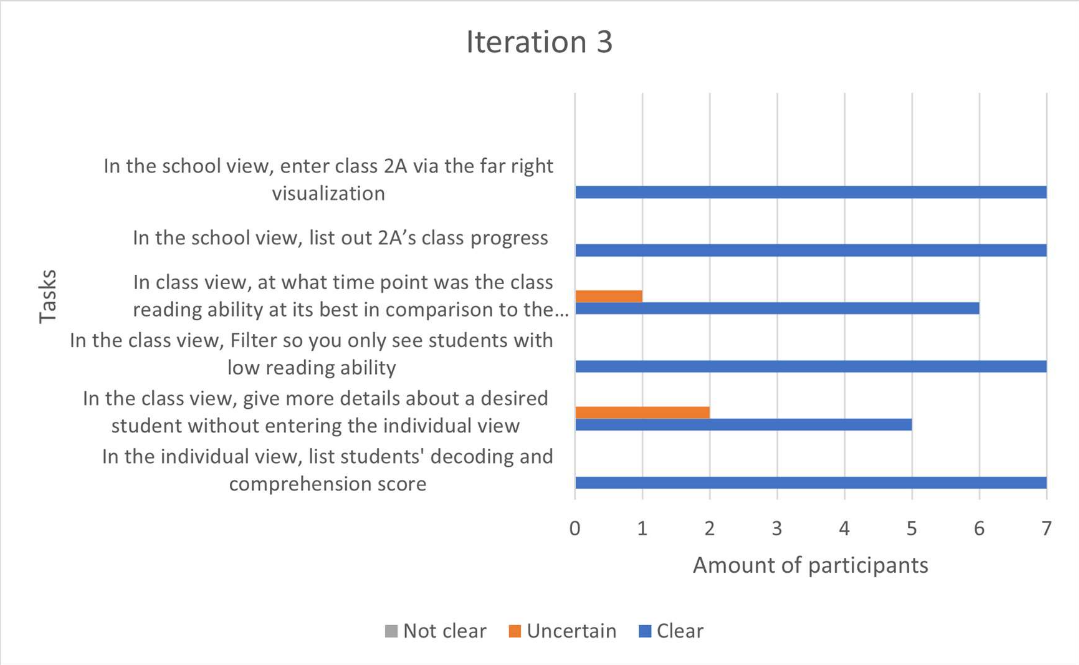

Figure 14: Evaluation summary of prototype 3

DISCUSSION

The aim of this thesis was to explore the challenges school principals face in identifying students with poor reading abilities and evaluate how an iterative design approach can enhance data visualization tools to address these issues. The results align with earlier studies that emphasize the value of user input and ongoing refining in raising the usability of data visualizations.

The thesis demonstrates that the iterative design process used in developing the data visualization tool improved its usability and effectiveness for school principals. This finding mirror [2] which indicated that clear and accessible data visualizations can enhance decision-making in educational context. Principals who used the improved visualizations were better able to identify students who were struggling with reading, aligning with earlier research that suggests data-driven insights can help teachers identify students who require more attention.

Usability testing in the original version showed that participants had trouble identifying pupils with reading challenges and comprehending raw data. This supports [2] that raw data frequently lacks the visual context required for prompt decision-making. It was difficult for principals to use the interface and comprehend important indicators like comprehension and decoding scores. These challenges emphasized the need for a more intuitive design to simplify the user experience and reduce cognitive load.

The second iteration introduced key design refinements, including a simplified layout, improved labels, and enhanced interactivity features such as hover effects and clearer filters. Participants' feedback showed that these modifications improved the tool's usability, allowing them to find student scores more quickly and apply filters with greater confidence. Some participants, however, continued to have trouble exploring huge datasets, indicating the need for additional modifications.

The third iteration incorporated additional features, such as pop-up tips, optimized presets, and further improvements to interactivity. These changes addressed many of the remaining usability challenges. By this stage, all participants were able to navigate the tool effectively and complete tasks such as identifying students with low reading ability or analysing class performance over time. Participants appreciated the tool's engagement and clarity, and comments emphasized its modern and user-friendly layout. This development demonstrates how iterative refining can improve functionality for users and remove usability barriers.

In contrast to previous studies, such as [1], is that while they identified initial user resistance to new technologies as a barrier, our research found that involving principals throughout the design process fostered a sense of ownership. This active participation reduced opposition and built confidence in using the tool, demonstrating that when users are involved in the development process, the adoption of new tools is more successful.

To address the core issues faced by school principals, the study investigated how they could be mitigated through the iterative development of visualization tools. Data collected through multiple testing phases allowed us to address these research questions comprehensively. During the first iteration, we first interviewed some participants and conducted usability tests which revealed some issues. One of the problems was general difficulties concerning the interpretation of raw data, specific to students' reading competencies. Since the available formative assessments do not include clear visual representations that pinpoint struggling learners, principals struggled to identify learners with poor reading skills. These findings align with [2], who emphasized the difficulties educators face when working with complex data sets that lack proper visual context. Effective data visualization is crucial for educators to identify struggling learners swiftly, as raw data can be overwhelming and hard to interpret [2].

The results of this study assist in highlighting the notion that school principals regularly come across usability challenges regarding identification of learners who require support. The usability challenges highlighted in our study echo [3], who stressed the importance of user-centered design in educational tools. When educational tools are not designed with intuitive interfaces, educators struggle to extract meaningful insights, which leads to inefficiencies in identifying students in need of intervention. Having a poor understanding of what these aggregations and distributions are in terms of visualizations means that time is wasted interpreting the information rather than arriving at a decision [3].

Furthermore, this project indicates that the proposed visualization prototype enhances decision making ability of school principals. For example, more user-friendly design and increased interactivity enabled participants to locate easier students' decoding and comprehension scores. On this account, the study's findings indicate that visualization-elements can address the problems that school principal's encounter. Simplicity governs the presentation of data, making it easier to manage and use to make decisions on which students need help and when such help should be offered.

While the findings of this study are valuable, it's vital to take into account any potential restrictions that might have affected the results. The very limited number of participants is one important element that might have influenced the outcomes. A larger number of participants might increase the generalizability.

Furthermore, the study's participants' varying degrees of technological expertise might have incorporated biases into how they interacted with the platform. The results might have been different if the participants' technical skills had been distributed more evenly, especially when it came to how users interacted with the technology and thought it was easy to use. This issue might be addressed in future studies by examining the impact of knowledge on technology acceptability.

The evaluation of data visualization tools using the UX-TAM methodology provides variable but typically good results. Principals considered the tools beneficial for identifying students who needed additional reading support, which aligns with the model's emphasis on perceived usefulness. However, perceived ease of use varied; some principals struggled with navigation and required additional instruction. This underscores the importance of user-friendly design, as stressed by the UX-TAM approach. Overall, usability was good, while some users found the data complicated, prompting ongoing adjustments. Principals praised the design's clarity and organization. Overall, user satisfaction was high, indicating that the tools were useful in helping principals make decisions and improve students reading skills. The UX-TAM paradigm was effective in identifying both strengths and places for improvement.

Study limitations

The study has significant limitations, as the small sample size of seven school principals may not accurately represent the broader population of school principals, limiting the generalizability of the findings. Furthermore, the study was done in a specific geographic area, which may limit the application of the findings to other contexts.

The use of self-reported data increases subjectivity, as individuals' responses may be impacted by personal biases. Furthermore, the emphasis on usability may neglect other crucial elements, such as school culture and available training resources, that influence decision-making.

Finally, time restrictions throughout the iterative design process may have resulted in certain unresolved usability difficulties. These limitations highlight the need for additional research on the broader implications for educational practice.

Ethical considerations

In this study, ethical factors were carefully considered to ensure that the research was fair and respectful to everyone involved. All academic records and personal information were handled securely, and data was anonymized to prevent the identification of specific students. In some cases, the prototype displayed false data. Principals were fully informed about the study's goal and methodology prior to participating. With the knowledge that they might withdraw from the study at any moment, each participant provided their consent. The study's data was only utilized to enhance instruction. It was made clear that the information wouldn’t be used for other purposes.

Method Discussion

The used method was suitable for the given work, as it implied the evaluation of the designed interfaces’ prototypes by real users and the subsequent modifications based on the results. The approach enabled the identification of usability problems and their correction in real-time, which is important when creating easy-to-use data visualizations. The theoretical framework, UX-TAM [25], was very useful in determining the satisfaction of users too. Their satisfaction with usability and functionality is what informed their overall scores with the tasks. If, however, other methods like eye tracking were employed in the testing sessions, it could have provided more detailed insights into how users interact with specific elements and their level of engagement, leading to a more informed research outcome.

A/B testing offered significant benefits in making comparisons of several design aspects at once, which led to a quicker definition of the most effective features. Extra methods like eye-tracking data from principals during testing sessions and questionnaires could have provided additional understanding regarding users' engagement with the graphic components in the interface and unobvious usability issues that can be reported orally only.

As the chosen method served its purpose to enhance the results in terms of clarity and usability, it is possible that the inclusion of these extra methods would have enriched the data and could have led to different conclusions about the users' interactions and preferences.

Future Research

There are several directions for future research. A closer look at the reactions of various user categories, such as parents with varying levels of experience at schools or familiarity with data visualization tools, could reveal valuable insights. For instance, experienced users might provide feedback on the tool's usability and effectiveness, while less experienced users may highlight areas of confusion. Additionally, understanding their preferences for customization can help tailor the tool to better meet the diverse needs of all users. Moreover, exploring the effects of such visualizations on decision-making and learners' performances in the long run can provide useful information about the effectiveness of data visualizations in the education context.

Besides, there are improvements that can be made in future work, including the addition of other functionalities such as predictive analysis in order to forecast student performance moving forward or even integration of machine learning features to the given prototype. Integrating AI functionality for predictive analysis could contribute to more advanced advice and monitoring: This application might lead to even higher effectiveness of data visualizations by school principals.

Future research could elaborate upon the current findings and extend the investigation into the efficacy of visualization-elements in influencing as well as identify other functions that could increase the effectiveness of the tools. In summary, this thesis reveals possibilities of data visualizations for the educational decision-making process and underscores the importance of a continuous focus group discussion to improve those tools.

Study's Contribution

This work advances educational data visualization by offering visualization tools designed specifically for school principals. Such visualization tools could facilitate school leaders' sensemaking of student reading data for students' improved reading skills in schools. The study's originality stems from its emphasis on user-centered design and iterative testing, which ensure that the visualizations are not only functional but also intuitive and user-friendly. Overall, the study highlights the critical role of user-centered design in creating educational tools and lays the groundwork for future advancements in data representation techniques.

CONCLUSION

This study demonstrates the effectiveness of iterative design in improving the data visualization tool for school principals. Through continuous user feedback, the prototype evolved to become more user-friendly, enabling better insights into students' reading abilities. The iterative process addressed both specific usability issues and broader enhancements, making the tool more practical for school administrators.

The findings emphasize the importance of friendly user interfaces and feedback in developing effective educational resources. This research not only provides a real-world example of how iterative design enhances educational tools but also offers suggestions for future improvements in data visualization for educational purposes.

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APPENDICES

Appendix 1: Interview questions (translated to English)

1. Can you describe your role as a school principal and what your daily tasks look like?
2. How often do you use any analysis or visualization tools like Excel or Tableau to make sense of data in your work?
3. How would you describe your computer habits?
4. How often do you use the existing platform, and for what specific purposes do you use it?
5. Which aspects of the current platform do you find most helpful when assessing students' reading abilities?
6. Which scoring system do you use most to determine a student's reading ability—stanine scores or Lexplore scores?
7. How do you assess whether a student's decoding needs more work or if it's their comprehension that requires attention?
8. Are there any challenges or frustrations you encounter when using the platform in its current state? Is there any visualization you find misleading?
9. How do you use filtering on the platform to quickly locate specific information?
10. Would you like to see the progress over time for a class presented in the results?
11. Is the portal used during development meetings with parents, where they can see the student's progress over time?
12. Are there specific areas for improvement that you would like to highlight?

Appendix 2: Participant Demographics

Participants	**Computer habits**
P1	Moderate
P2	High
P3	High
P4	High
P5	Low
P6	Low
P7	Moderate

Table 1: Participants computer habits

Appendix 3: Questions and Results for Iteration

Iteration 1	Clear	Uncertain	Not clear
In the individual view, list students' decoding and comprehension score	0	2	5
In the class view, give more details about a desired student without entering the individual view	5	2	0
In the class view, Filter so you only see students with low reading ability	5	2	0
In class view, at what time point was the class reading ability at its best in comparison to the normalization curve	6	1	0
In the school view, list out 2A's class progress	5	2	0
In the school view, enter class 2A via the far-right visualization	2	4	1

Table 2: Questions and Results for iteration 1

Appendix 4: Questions and Results for Iteration 2

Iteration 2	Clear	Uncertain	Not clear
In the individual view, list students' decoding and comprehension score	5	1	1
In the class view, give more details about a desired student without entering the individual view	5	2	0
In the class view, Filter so you only see students with low reading ability	6	1	0
In class view, at what time point was the class reading ability at its best in comparison to the normalization curve	6	1	0
In the school view, list out 2A's class progress	7	0	0
In the school view, enter class 2A via the far-right visualization	7	0	0

Table 3: Questions and Results for iteration 2

Appendix 5: Questions and Results for Iteration 3

Iteration 3	Clear	Uncertain	Not clear
In the individual view, list students' decoding and comprehension score	7	0	0
In the class view, give more details about a desired student without entering the individual view	5	2	0
In the class view, Filter so you only see students with low reading ability	7	0	0
In class view, at what time point was the class reading ability at its best in comparison to the normalization curve	6	1	0
In the school view, list out 2A's class progress	7	0	0
In the school view, enter class 2A via the far-right visualization	7	0	0

Table 4: Questions and Results for iteration 3

Appendix 6: Overview on Lexplore's current dashboard

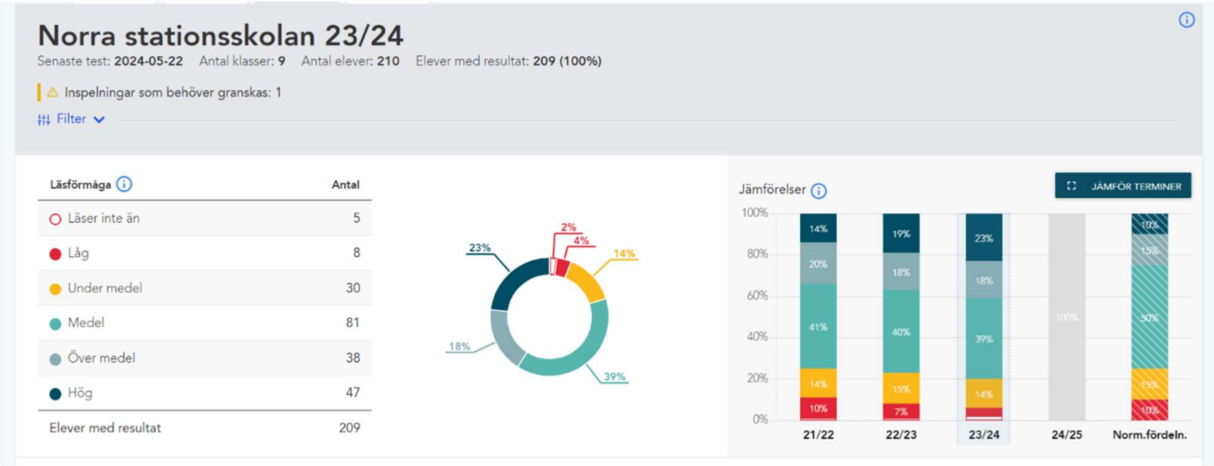

Figure 15: Shool overview of current dashboard

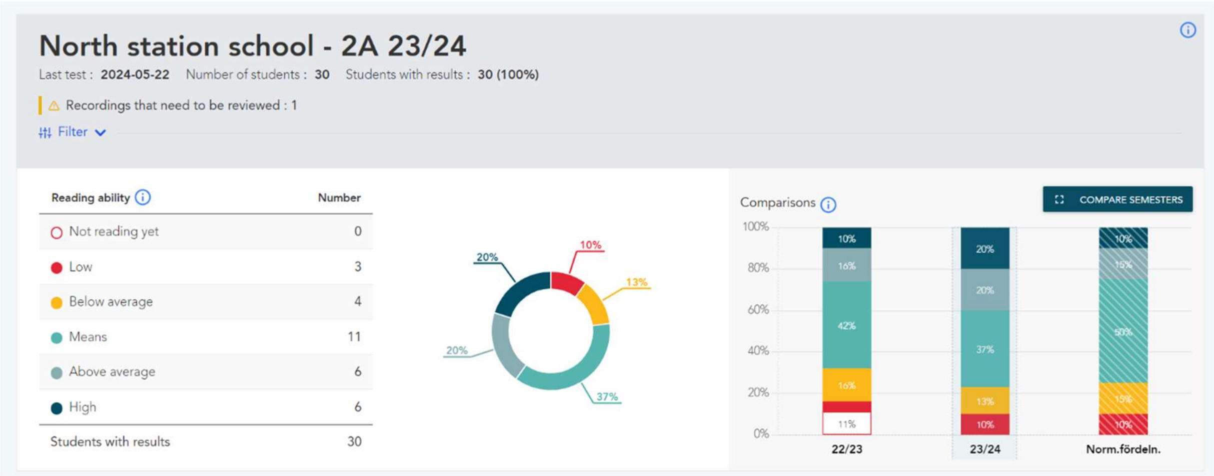

Figure 16: Class overview of current dashboard

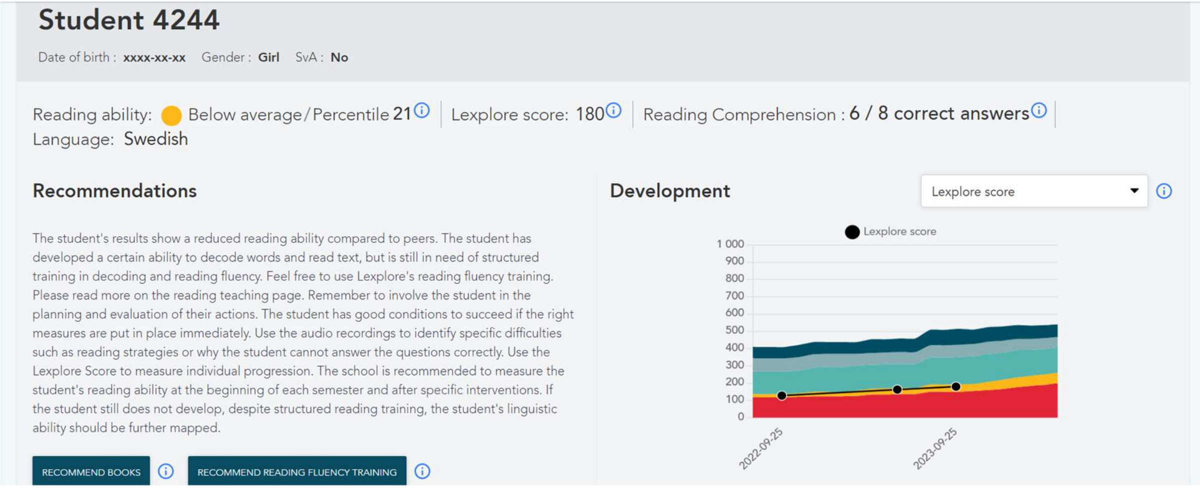

Figure 17: Student overview of current dashboard

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