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Turning Competency Data into Actionable Insights for Teachers

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Preface

"I have never tried that before, so I think I should definitely be able to do that."
– Astrid Lindgren, Pippi Longstocking.

Pippi Longstocking was my favourite bedtime story when I was little. Pippi reminded us that if we believe in ourselves, there are no limits to what we can accomplish and that we are capable of more than we can possibly imagine. When I look back on this journey, I started with a feeling of uncertainty and a fear of failure. However, I have learned that embracing new challenges, even when they seem daunting, is an essential part of personal growth. In these past couple of months, I have both grown on academic and personal levels, but it is important to acknowledge that none of this would have been possible without the help of certain people.

First, I would like to express my gratitude to my supervisor Robin for the guidance throughout my thesis. Your constructive feedback and constant encouragement have been incredibly helpful. Also a big thank you to my promotor professor Verbert and Eummena for the opportunity to work on this project, and Jan Velghe and all the participating teachers for their time and feedback.

Lastly, I would like to thank my parents, Danny and Danielle, for their support throughout my entire school career. Your love, advice and non-stop encouragement over all these years are invaluable to me, and I cannot thank you enough for helping me to make my dreams a reality.

Lara Roosens

Contents

Abstract

Learning analytics (LA) involves collecting and analysing educational data to improve learning and teaching [2, 41]. The rise of digitalisation in schools has generated large amounts of data. However, teachers often lack the necessary tools to use and interpret this data, while also facing high administrative burdens. There is a need to develop a tool that provides teachers with continuous updates on student progress and performance to lower their workload.

This master's thesis focuses on designing, developing, and evaluating a learning analytics plugin for Moodle, specifically targeting secondary school teachers. The plugin functions as a learning analytics dashboard, providing a visual overview of essential information from learning analytics. This research presents a state-of-the-art approach as it uses a relatively new competency framework [50] as its foundation. The goal is to assist secondary school teachers by offering them the necessary information to gain a better understanding of their students, make informed decisions, and reduce administrative tasks.

This thesis also addresses research gaps (including the lack of input from stakeholders, misinterpretations of visualisations, and the limited impact of current learning dashboards) in the field of LA and tries to provide valuable insights into the design and development of a learning analytics dashboard for secondary school teachers. To achieve these objectives, an iterative and user-centred design process is followed.

The result of this research is a working learning analytics dashboard that provides teachers with helpful insights and actionable content for understanding their students' grades and progress. The dashboard's design allows for easy understanding and use of visualised learning data.

Samenvatting

Learing analytics (LA) omvat het verzamelen en analyseren van educatieve gegevens om het leren en lesgeven te verbeteren [2, 41]. De opkomst van digitalisering in scholen heeft grote hoeveelheden gegevens gegenereerd. Echter, leraren missen vaak de nodige hulpmiddelen om deze gegevens te gebruiken en te interpreteren, terwijl ze ook te maken hebben met hoge administratieve lasten. Er is behoefte aan een tool die leraren continu op de hoogte houdt van de voortgang en prestaties van leerlingen om zo (onder andere) hun werklast te verlagen.

Deze masterthesis richt zich op het ontwerpen, ontwikkelen en evalueren van een learning analytics plugin voor Moodle, specifiek gericht op leraren in het middelbaar onderwijs. De plugin fungeert als een learning analytics dashboard en biedt een visueel overzicht van essentiële informatie. Dit onderzoek presenteert een state-of-the-art benadering, omdat het een relatief nieuw competentie framework [50] als basis gebruikt. Het doel is om leraren in het secundair onderwijs te ondersteunen door hen de nodige informatie te bieden om een beter begrip van hun studenten te krijgen, weloverwogen beslissingen te nemen en administratieve taken te verminderen.

Deze thesis richt zich ook op onderzoeks tekortkomingen (waaronder het gebrek aan inbreng van de eindgebruiker, verkeerde interpretaties van visualisaties en de beperkte impact van huidige leerdashboards) op het gebied van LA en probeert waardevolle inzichten te bieden in het ontwerp en de ontwikkeling van een LA dashboard voor leraren in het middelbaar onderwijs. Om deze doelstellingen te bereiken, wordt een iteratief en gebruikersgericht ontwerpproces gevolgd.

Het resultaat van dit onderzoek is een werkend learning analytics dashboard dat leraren waardevolle inzichten en bruikbare inhoud biedt om de resultaten en voortgang van hun studenten te begrijpen. Het ontwerp van het dashboard maakt een gemakkelijk begrip en gebruik van gevisualiseerde leerdata mogelijk.

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Abbreviations

HCI	Human Computer Interaction
LA	Learning Analytics
LAD	Learning Analytic Dashboard
LMS	Learning Management System
POC	Proof-of-Concept
SUS	System Usability Scale
SWOT	Strengths, Weaknesses, Opportunities, and Threats

Chapter 1

Introduction

Learning analytics (LA) is a commonly used word in the field of education. It refers to the collection and analysis of educational data with the goal to improve learning and teaching [2, 41]. The growing interest in LA can largely be explained by the increase of digitalisation in schools [24]. This resulted in the generation and collection of large amounts of data through the use of learning management systems like Moodle and Smartschool. However, despite the availability of this data, teachers frequently miss the necessary tools to use and interpret this data. Moreover, teachers face a high administrative burden further highlighting the need for a solution that can reduce their workload [4]. Therefore, there is an important need to develop a tool for teachers that can provide continuous updates on the learning progress and performance of their students.

As a result, this master's thesis will focus on designing, developing and evaluating a learning analytics plugin for Moodle with secondary school teachers as the target group. This plugin will function as a learning analytics dashboard, which provides a visual overview of core information from LA [2]. By developing this plugin, we try to help secondary school teachers by giving them the essential information to achieve a better overview of their students, make more informed decisions, and reduce the time they spend on administrative tasks.

Although there is a growing interest in LA, there remain some noteworthy research gaps. Firstly, the majority of research in the field of LA focuses primarily on higher education, resulting in limited attention given to primary and secondary education [40]. Next, there is a need for more attention on the impact of LA dashboards, where the aim is to change behaviour and stimulate pedagogical actions [46]. Furthermore, the risk of misinterpretation of data [16] and the lack of priority for user-centred design processes [35] further highlights the need for more research in these domains. Therefore, this thesis aims to address these gaps and provide valuable insights into the development of a learning dashboard for secondary school teachers.

Chapter 2

Literature study

In order to gain a better understanding on the topic of this thesis, this chapter details the journey of how the research questions arose. Starting with the understanding of the domain and the needs of the end user up to lessons learned from previous research.

Section 2.1 defines the scope of this master thesis, which will focus on explaining learning analytics (LA) specifically for secondary school teachers. Section 2.2 discusses the needs of secondary teachers and, by extension, the importance of learning analytics. Learning analytic dashboards can be a solution to these needs. Section 2.3 will give a detailed explanation of LA dashboards and some example dashboards developed in previous research. Next Section 2.4 highlights the research gaps that are found in past research on LA dashboards. Finally, it is important to focus on how this thesis will respond to these current research gaps. This is done in Section 2.5, where the research questions are summarised and linked to the research gaps.

2.1 Learning Analytics

Learning analytics (or short LA) is a commonly used word in the field of education. The increased development of digitalisation in schools has increased interest in this field of study [24]. Although there is not one universal definition, the most commonly used definition is from Siemens and Long:

> *"Learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs."* (Siemens and Long, [41])

Another definition highlights more who the stakeholders are:

> *"Learning analytics is the collection and analysis of data from learning environments to improve student learning. This information is then made available to various stakeholders, such as the student themselves,*

> *the instructor, or program management."* translated from (Engelfriet, Manderveld, and Jeunink [14])

This second definition shows us that there is a large audience for learning analytics. However, this study will focus on teachers as end users and especially secondary school teachers. Previous research has shown that most attention in the field of learning analytics is given to higher education, leaving primary and secondary education underexposed [40]. Since many countries have different school structures, secondary school is defined in this study as the education that students between the ages of 12 and 18 follow.

When looking at the goal of learning analytics, the above definitions have a common core: to improve and optimise learning. A sentence that captures the purpose of learning analytics a bit more concretely:

> *"LA aims to bridge the gap between data and the optimisation/improvement of learning, guidance and teaching" [2]*

Mangaroska et al. summarise the potential learning analytics has: 1) explain unexpected learning behaviours, 2) identify students who are at risk, 3) highlight misunderstandings, 4) propose appropriate interventions, and 5) increase users' awareness of their own actions and development [24].

Learning analytics will be crucial for education in the future given its rising popularity and the diversity of solutions it can provide. However, due to a number of challenges (concerns about privacy and ethics, end users involvement, etc.), implementations in a real-world setting remain limited in scope [45]. Luckily every year various amount of conferences (like SOLAR, EC-TEL etc.) are hosted, to inspire and support the current and next generation of learning analytics researchers.

2.2 The needs of secondary school teachers in their educational tasks

The previous section described the potential and increasing popularity of learning analytics. Indeed, modern learning management systems like Moodle and Smartschool provide a variety of data. This study will focus on secondary school teachers. That is why it is important to understand what data they need in order to monitor their student's progress [35].

Teachers are interested to have a continuous update on their students learning progress and performance. In order to understand teachers' needs, some research explicitly asked teachers, *"If you could have any superpowers you wanted, to help you do your job, what would they be?"* [20] They discovered that teachers wanted to determine where students were misinformed and which students were actually stuck, as well as to observe students' thought processes and skill mastery. According to

other studies [44], teachers value information that helps them prepare lessons, guide them in student intervention, and assess the motivation of their students. These outcomes are not necessary needs, but rather personal needs that would make their job easier.

However, there are quality standards in the form of end-terms imposed by the government, which a teacher is obligated to achieve and document. End-terms are minimum goals that the Flemish government considers necessary and reachable for that population of pupils [1]. These end-terms used to be linked to a particular subject or learning area [28]. However, this has recently changed. End-terms are now linked to key competencies. Key competencies are "groups of content-related skills that students must learn to operate in society and grow as individuals" [50]. The renewed end-terms are associated with 16 key competencies. A curriculum or competence framework contains these 16 fundamental competencies and is created for each grade and discipline. Figure 2.1 explains the complete structure using a specific competence framework for first-level "basisvorming". Because school regulations varies by country, this study focuses foremost on secondary schools in Flanders.

When offering teachers learning analytics in which end-terms are visualised, all kinds of needs (both necessary and optional) can be satisfied. They will be capable to monitor student's progress, to evaluate the impact of their educational activities, and to help identifying interventions that will help students reach their targets.

2.3 Learning Analytics dashboard as a solution

From previous sections, it becomes clear that a tool is required to inform secondary school teachers (section 2.2) about the data and measurements obtained from learning analytics (section 2.1). Learning analytic dashboards (or short LAD) can be used to create this "presentation of information." LAD provides a visual overview of core information from LA [2].

Verbert et al. [46] specify a process model of learning analytics. This model illustrates the various steps users take when utilising a dashboard. In order to comprehend how teachers use these dashboards, this process model can be useful. Figure 2.2 provides an overview of each phase. The first stage is awareness, where the user becomes aware of the data. In the reflection state, the users begin to analyse the data and consider whether it will be helpful to them. The next stage is sensemaking. Here, users attempt to provide answers to the questions they had in the previous stage and even obtain some new insights. The impact stage is the last one, where the aim is to potentially change behaviour.

It will become clearer if these steps are used in the context of teaching. First (stage 1) the teacher becomes aware of the data and explores the displayed data [46]. Then (stage 2) the teacher starts asking questions like "Where could I find students that

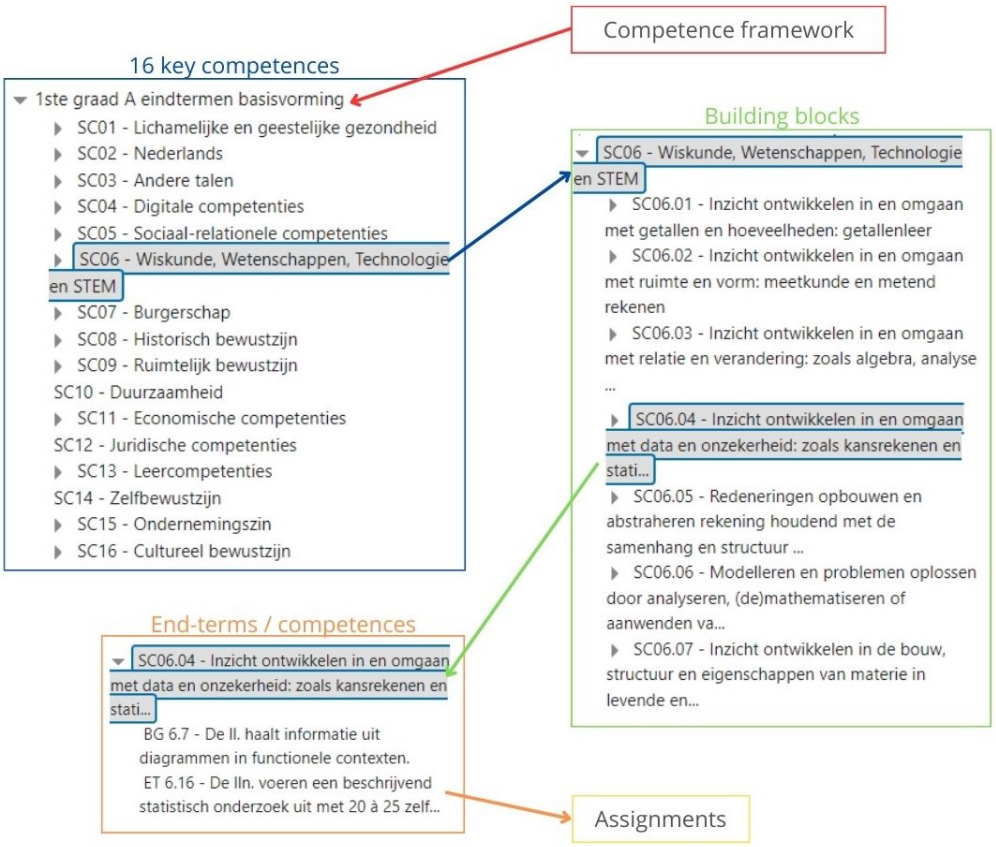


Figure 2.1: This example uses the competence framework for first-level "basisvorming" [48]. The highest level shows the name of the framework along with all 16 key competencies. To ensure consistency, each core competence (in this example 'SC06') has a set of defined building blocks [49]. Then each building block is composed of end-terms. Finally, teachers must link these end-terms to their assignments.

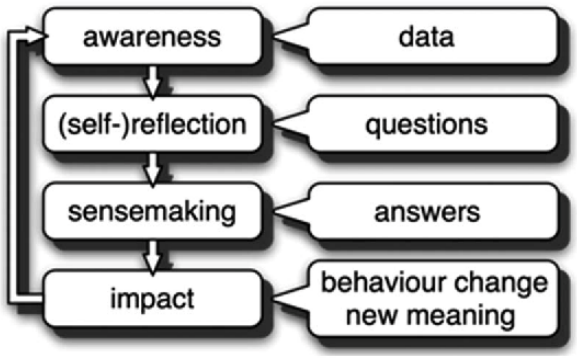


Figure 2.2: Process Model Learning Analytics [46]

are at risk". Next, (stage 3) the teacher will try to answer the previous questions by examining the dashboard visuals. When the teacher discovers an interesting conclusion in the data, pedagogical action can be taken (stage 4) [29].

2.3.1 Examples of learning analytics dashboards

Before starting to design and develop a new dashboard, it is crucial to research existing dashboards. What data are shown in the graphs, what methodology was followed, and what can be learned from these previous studies?

Two systematic reviews for LAD were consulted to see what they have learned and what they suggest to keep in mind in future dashboard designs. First, the research of Schwendimann et al. [40], which examined 55 papers, was analysed. As previously said, university settings are the most prominent in dashboard designs. They highlight the need for more attention on other educational levels (like primary or secondary schools). Moodle came up as the most often utilised platform (18% of the papers). The reason could be that Moodle is the most widely used LMS in the world and it is open-source (more information in Section 2.3.2).

Matcha et al.[25] provide the second systematic review, reviewing 29 papers. Over all those papers, bar charts were the most used visualisation type, followed up by icons and radar charts. Questionnaires and log data were the most used data gathering methods for evaluation. Only four papers employed a think-aloud study. The majority of the indicators that were utilised in teacher dashboards represented data about individual students as well as data of the entire class as a whole. Most of the indicators that were used in teacher dashboards represented individual student-related information and information as a class as a whole. Comparison of a student to the class average or peers was less common (under 10 indicators). The paper highlighted several important shortcomings. First the lack of user-centered design. 52% of the papers only referred to previously published works and 21% did not explain how the indicators were chosen.

Second, the absence in most paper of study limitations and a discussion about generalisability. This is essential information when considering potential future research. Also the shortage of experimental and mixed-methods when evaluating a dashboard, was raised. After consulting the above reviews, five LA dashboards were analysed in more detail. The dashboards where selected based on their target group. Teachers were the obvious target group to filter on. However, because secondary school teachers also play the role of study advisors, this target group was also chosen. Table 2.1 and Figure 2.3 provide an overview of the five dashboards that were detailed reviewed.

	(Dourado et al., 2021) [13]	(Millecamp et al., 2018) [27]	(Tavares et al., 2019) [44]	(Gutiérrez., 2019) [19]	(Aleven et al., 2010) [3]
What data is visualised?	Steps that students take when learning online	Grades, progress of student, comparison to other peers, predictions and how to plan next year	Student performance and interactions with interactive simulations	Students grades, chance of success, skills, historical records etc.	Skills that students have acquired and any misconceptions they may have
Target group	Teachers (higher education)	Dialogue between student and study advisors (higher education)	Teachers	Academic advising (higher education)	Teachers (school level, not college level)
Methodology	Iterative design and focus group	Iterative design, user-centered design, evaluation: questionnaire and observations	Future work will evaluate the usablitiy, usefulness and user satisfaction	User-centered design, evaluation: brainstorm session, think-aloud, questionnaire and quantitative results as number of steps and time per step	Iterative design, user-centered design: speed dating events, contextual enquiry sessions, think-aloud and classroom evaluations
Sample size	5 HCI experts	224 meetings	[no final evaluation]	University A: 12 participants, University B: 14 participants	Around 5 teachers for each study
Take away	1) Not consult the end user and instead let experts review the design 2) Too much detail	1) Natural and easily understanding flow in the design 2) Evaluation methods will be further explored in this study	An extensive theoretical framework to focus on teacher's needs	1) Usable design 2) Evaluation methods will be further explored in this study	1) Question-based design 2) Extensive analysing of teachers needs
Figure	2.3a	2.3b	2.3c	2.3d	2.3e

Table 2.1: An overview of characteristics of five selected research papers

FIGURE 2.3: Overview of dashboard designs mentioned in Table 2.1

2.3.2 Moodle

The dashboard that will be developed in this thesis will collect data from Moodle. Since Moodle is open-source, free, and the most widely used learning management system (LMS) in the world [52], it was chosen as the LMS. The result of this thesis will be a Moodle plugin that reads data from the Moodle database and visualises that data using a LA dashboard.

Moodle is a learning management system that gives teachers the ability to create online courses and distribute them to students. Additionally, it enables students to submit assignments, access materials, and engage in class discussions [52]. All of

that data is stored in a relational database and can be accessed, so working with a school that already uses Moodle is a must. Figure 2.4 gives you an idea of how Moodle looks like for a teacher.

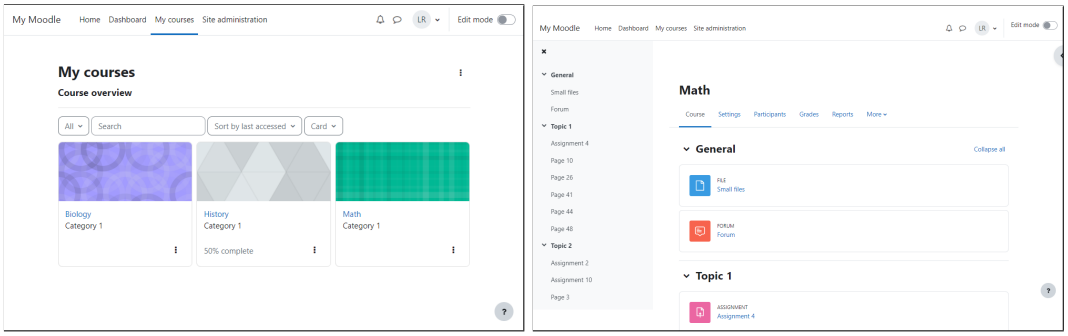


Figure 2.4: Example course overview for teacher in Moodle

2.4 Research gaps

In Section 2.3, various dashboards were analysed. This section will highlight the research gaps concerning learning analytic dashboards that were discovered in previous studies. A research gap in this context is something that many academics overlook when conducting their research on learning analytic dashboards.

2.4.1 Gap 1: Input from stakeholders

In several studies, it is acknowledged that the end user wasn't consulted enough [11, 34] or not even at all [13]. It is important to ask the end user what they want before you begin designing and to actively include them in the process of evaluating your design [35]. According to Tavares et al. [44], creating a dashboard is an iterative process in which effective communication with the end user (in this case, teachers) is crucial. As a result, the concept of iterative design process will be found throughout this study.

This problem is also mentioned in the Verbert et al. research agenda for LA dashboards [47]. They even present some approaches, such as setting up focus groups, pilot studies, and interviews, to achieve this objective. More information on a few of these tactics will be provided below.

Focus group

A focus group is a research technique that gathers a small group of individuals that can bring insights about a certain topic. Focus groups could reveal a variety of opinions that people have regarding this specific topic as well as reveal different perspectives [36].

Craps [12] offers a good suggestion on how to set up such a focus group employing a so-called "metaplan". The first step is a five-minute, individual brainstorming session where participants can write their thoughts on five post-its. Each of these post-its will be reviewed separately, with space for discussion and potential new ideas. Post-its will be arranged in groups on a large board. Finally, there will be a "dot voting" exercise where each participant can rank the importance of their own ideas. This enables everyone to express their opinions and allows those with more reserved personalities to speak as well.

Think-aloud study

An approach that is very valuable to assess the usability of a dashboard is a think-aloud study [32]. In this research technique, participants say out loud whatever thoughts they have as they work through a task on a given prototype [10]. Its goal is to evaluate the dashboard's usability.

The participants are often asked to complete an additional questionnaire after the think-aloud has been completed. The SUS (System Usabilty Scale) is a popular questionnaire used to evaluate usability. This SUS score employs a 100-point scale, wherein a score of 70 or above indicates acceptable usability of the assessed tool [6].

2.4.2 Gap 2: Misinterpretation of visualisations

The term "misinterpretation of visualisations" refers to research that failed to take into account the influence that end users have on how data is visualised and how people interpret designs. Different genders or ages may interpret a visual in a different way [47]. Many other dashboards neglected simplicity, making it too complex and time-consuming for the teachers [44]. According to Tavers et al., LAD should be simple to "read, manipulate, and interpret" for teachers.

In his handbook 'Information dashboard design' [16], Stephen Few devotes an entire chapter to visual design problems. He lists thirteen common mistakes in dashboard design: 1) exceeding the boundaries of a single screen, 2) supplying inadequate context for the data, 3) displaying excessive detail or precision, 4) choosing a deficient measure, 5) choosing inappropriate display media, 6) introducing meaningless variety, 7) using poorly designed display media, 8) encoding quantitative data inaccurately,

9) arranging the data poorly, 10) highlighting important data ineffectively or not at all, 11) cluttering the display with useless decoration, 12) misusing or overusing color, 13) designing an unattractive visual display.

These mistakes can lead to problems like confusion, misunderstanding, waste of the viewer's time and the inability to find the most important data. Therefore, it is important to keep in mind certain design principles while creating a dashboard in order to avoid misconceptions: the dashboard should provide a quick overview of all necessary information, where the eyes are drawn to the most important information and the data is easy to understand and easy to draw conclusions from. Or to quote Few *"the information can be monitored in a glance"*.

These thirteen mistakes offer a general framework when thinking about visualisations and will be kept in mind along the design process in this research. However, this does not guarantee that our specific target group, teachers, would no longer struggle with the given visualisations. Therefore, it is still important to have the end user evaluate the visualisations [47]. (as mentioned above in gap 1)

2.4.3 Gap 3: Lack of impact

Section 2.3 provided a full discussion of the process model proposed by Verbert et al. However, the same research states that the first three stages can be used to classify the majority of LA dashboards. However, few address the final stage of impact.

The learning dashboard review of Schwendimann et al. [39] gives one explanation for this 'lack of impact'. They state that most papers do small proof-of-concept studies, which often cannot be used to measure impact as they are not in a finished state using real data. When looking for research that does evaluate their dashboard on impact, the same pattern is found [3, 19, 27]. First, the dashboard (obviously) needs to be in a finished/working state (not a proof-of-concept). Next, a trial period is conducted where the target group uses the dashboard. Finally, interviews are done to gather their actionable insights obtained from using the dashboard.

Hence, a precondition for measuring impact is having a working high-fidelity prototype that works with real live data. As this thesis will create a Moodle plugin using real Moodle data, these conditions are met. However, to create a dashboard that changes pedagogical behaviour, it is again important to include the end user in the design process and find the needs that could help them impact their own teaching manners and their students.

2.5 Research questions

Throughout this chapter all background information was explained with finally a summary of research gaps that are interesting to further explore. In this section the research questions of this thesis are summarised and linked to the research gaps of Section 2.4.

Previous sections reveal notable gaps in the existing literature concerning several aspects, including the focus on secondary school teachers, impact and actionable insights, the occurrence of misinterpretations of visualisations, and a user-centered design process. The primary objective of this thesis is to address these research gaps by making a dashboard that does focus on these topics. The first target is to add visuals to the dashboard that 1) teachers actually want, by listing to their needs and wishes (Gap 1: Input from stakeholders) and 2) teachers will use to create an impact on their students (Gap 3: Lack of impact). This resulted in the thesis's first research question:

Research question 1: What analytic insights does a teacher need, to have a more comprehensive view of the students current results and evolution, to support their pedagogical actions?

Goal 1: Useful and actionable content

The second goal of this thesis will be to create a dashboard that focuses on making it usable for teachers while also considering how to represent complex data in a straightforward manner. Therefore, the goal is to prevent visual misinterpretations, which was raised in gap 2. Again, for this to succeed, it is crucial that end users evaluates different prototypes (Gap 1: Input from stakeholders). This brings us to the second research question:

Research question 2: How should learning data be visualised such that all teachers, regardless of educational background or IT knowledge, can easily understand and use the dashboard?

Goal 2: Usable design

At last, the goals of this thesis can be summed up in a single sentence: this thesis aims to create a dashboard for secondary school teachers using Moodle, with a focus on usability, usefulness, and user-centered design. An overview of the research questions and their link with the research gaps and goals can found in Figure 2.5.

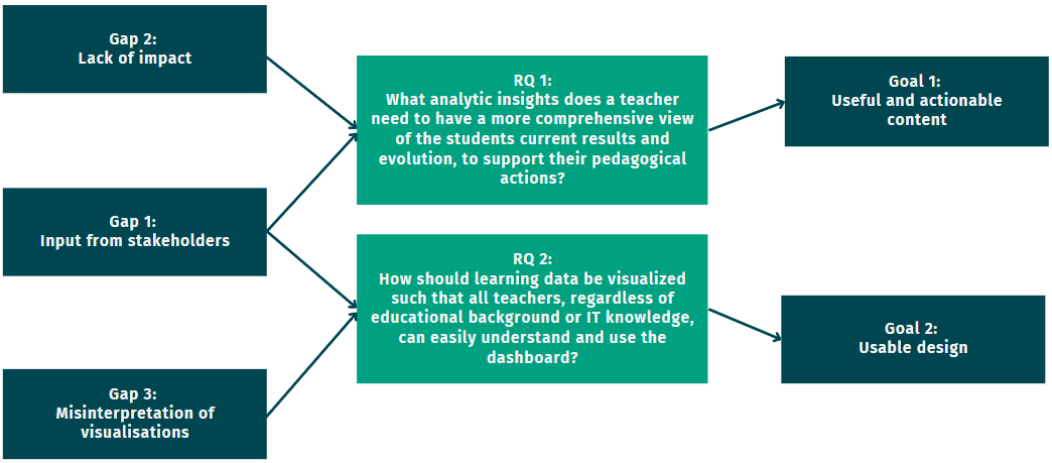


Figure 2.5: Overview of research gaps, questions and goals

Chapter 3

Methodology

This chapter discusses the design methodology used in this thesis. Section 3.1 begins by presenting a high-level overview of the methodology, the theoretical framework and the selection of studies that were chosen for this research. Section 3.2 goes into further detail on the precise approach and organisation of these studies.

3.1 General overview

The primary aim of this thesis is to develop a dashboard for secondary school teachers that provides useful and actionable content, with a user-friendly design that takes stakeholder feedback into account. In order to achieve these objectives, the decision was made to adopt an established design methodology: 'Design Activity Framework for Visualization Design' [26] This method suggests an iterative approach that consists of four activities: understand, ideate, make and deploy.

The "understand" activity involves gathering information to find the needs of the user. The "ideate" activity involves generating ideas and considering potential solutions. The "make" activity involves creating a prototype. The "deploy" activity involves implementing the final solution and ensuring that it meets the desired outcomes.

Overall, the framework provides a structured and iterative approach to visualisation design, which helps designers create visualisations that meet the needs of their intended audience. This aligns well with the goal of this research.

During these four steps, it is important not to lose sight of the stakeholder. This objective arose due to a research gap identified in the preliminary study, which revealed that stakeholder input is often overlooked. Consequently, a user-centered design process will be prioritised. This means that teachers will be involved in every step of the design process.

Each activity will be discussed further below and how it is customised for this research. Figure 3.1 provides an overview of each activity, and indicates the corre-

sponding chapters where they are discussed in detail.

Understand In this first step, a preliminary study was conducted, and a focus group and requirement analysis meeting were organised to gain a thorough understanding of the problem. These activities led to the identification of the teachers' specific requirements, which were utilised to guide the design process for creating a solution that fulfills their needs.

Ideate In the "ideate" activity, a proof-of-concept was developed and evaluated through in-depth interviews combined with a think-aloud study. The resulting output was the initial design and a list of required alterations to enhance the design of the final product. This iterative approach helped in generating ideas and improving the design.

Make In the "make" activity, the initial step involves redesigning the dashboard based on the feedback gathered from teachers and experts during the previous step. After this, the design can be transformed into a functional Moodle plugin.

Deploy In the final "deploy" activity, the finished dashboard is presented to the teachers. Two qualitative user studies are conducted here: in-depth interviews (using test data) and a trial period (using real live data). The goal is to answer the research questions.

3.2 Practical proceedings and participants

This section provides a brief explanation of each study conducted in this thesis. The studies were approved by the KU Leuven Social Ethics Committee (SMEC). Appendix A contains all the application-related paperwork (file numbers: G-2022-5775, G-2022-6099).

Focus group - understand The first study looks for teachers' needs and what information they would like to know about their students. This is accomplished through a focus group session utilising the "metaplan" technique [12], which involves individual brainstorming followed by group discussion. The study involved the participation of six secondary school teachers.

Requirement analysis meeting - understand This study again looks for the needs of teachers and the type of information they require about their students. Here, however, one school (GITO Overijse) was looked at specifically, as this thesis is done in collaboration with this school. The information is gathered through a one-on-one interview with the person responsible for blended learning.

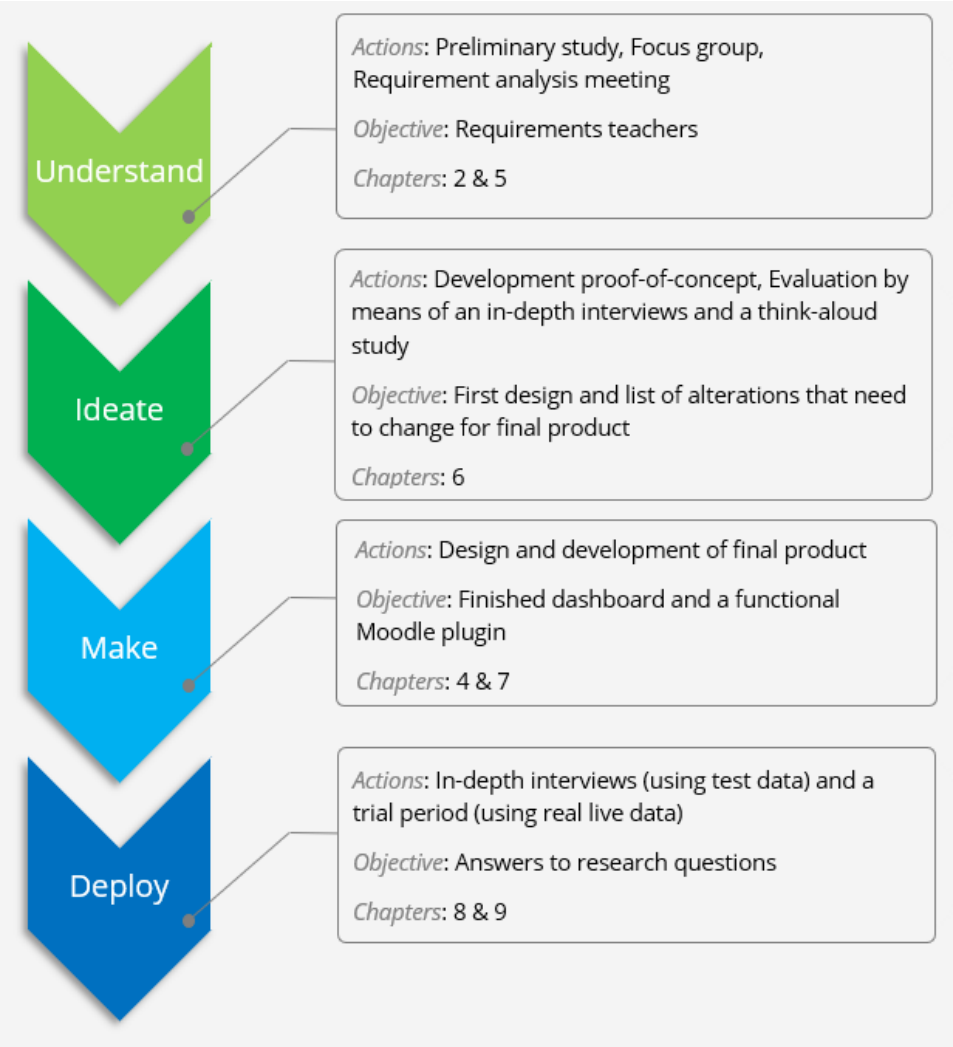


FIGURE 3.1: Graphical overview of methodology

In-depth interviews with think-aloud of proof-of-concept - ideate For this third study, a proof-of-concept was first developed. The purpose of this study is the verification of usabilty and usefulness of the POC and updated requirement analysis. This study involves individual, in-person think-aloud sessions and in-depth interviews. Feedback was obtained from five teachers and two Human-computer interaction (HCI) experts. The analysis of feedback is based on a SWOT analysis.

In-depth interviews of final product - deploy This qualitative study aims to explore teachers' perceptions towards the dashboard and its visualisations. The study employs in-depth interviews where the teachers will interact with the dashboard using test data. It consist of three parts: a tutorial, an in-depth interview, and questionnaires. A total of nineteen teachers from three different secondary schools participated in this study.

Deployment of final product - deploy In this study a one-week trail period will be held, where teachers use the dashboard with there own class data. Google Analytics is used to see how often teachers use the dashboard. An interview is also conducted after the trail period to assess the impact of using the dashboard on their teaching practices. Only two teachers participated in this study, due to the problem that there were the only two teachers linking end-terms to assignment. This issue will be further addressed and discussed in the subsequent chapters.

Chapter 4

Functionality of final design

This chapter presents the final outcome of the competence dashboard. A top-down approach has been adopted, commencing in this chapter with the final design to provide an overview of the achieved result. Subsequent chapters will delve into the complete design process, explaining in detail the rationale behind specific design decisions and outlining the iterative process leading up to the final prototype.

Section 4.1 will provide a comprehensive overview of the dashboard, reiterating its purpose and presenting all essential information. Next, Section 4.2 will delve into each component of the dashboard individually, providing detailed explanations.

4.1 High-level view on of the final dashboard

The final design of the dashboard is illustrated in Figure 4.1. This dashboard serves as a tool for presenting an overview of a particular class group for a given subject. Its target group is secondary school teachers. The primary objective of this dashboard is to introduce a new perspective by visualising student performance based on competencies, rather than solely focusing on overall results. It aims to shift away from the traditional approach of assessing students with statements like "Pupil X scored 45% (failed) in Math" and instead provides a more nuanced breakdown, highlighting specific areas such as "Pupil X achieved 65% in Geometry (competency SC06.02) and only 35% in Algebra (competency SC06.03)." This approach adds depth to the assessment process [42].

Hence, a competency dashboard has been developed to present students' performance for each competency through visual representations. The concept behind this dashboard is to assist teachers in various aspects such as lesson planning, parent meetings, and class councils, by providing them with factual information and a concise overview of their student's progress.

The foundation is based on the competency framework employed in Flemish education [50]. Section 2.2 gives a detailed explanation of the structure of this framework.

For convenience, Figure 4.2 reiterates the four levels included within this framework.

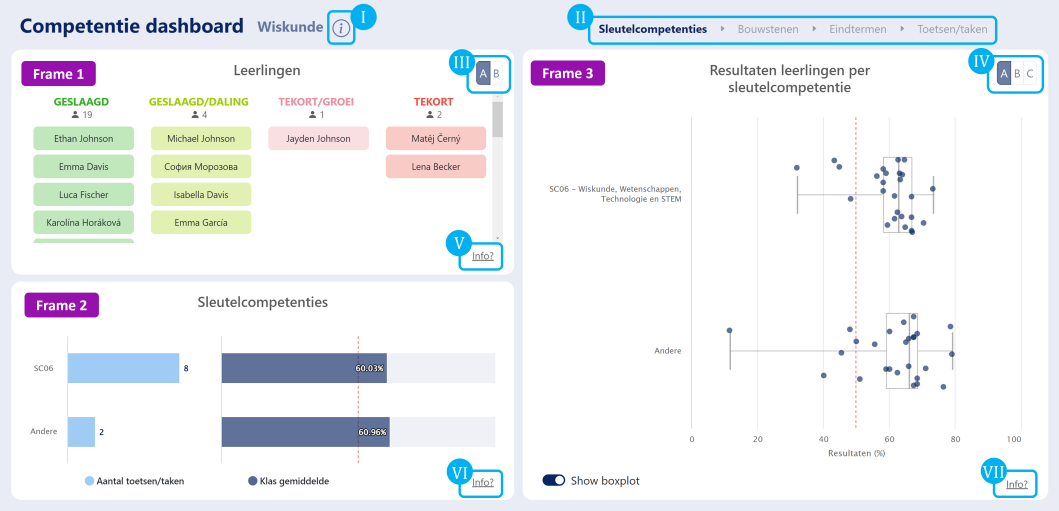


Figure 4.1: Final design of the dashboard. I) info-button whole dashboard, II) breadcrumbs, III) option-button Frame 1, IV) option-button Frame 3, V) info-button Frame 1, VI) info-button Frame 2, VII) info-button Frame 3

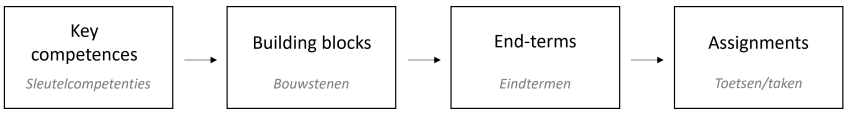


Figure 4.2: Four levels of competency framework

4.2 Detailed breakdown of all parts in the final dashboard

This section presents an analysis of the content and functionalities of the final dashboard using figures from the application. Figure 4.1 provides a general view of the competence dashboard. The dashboard is partitioned into three white frames, each of which is labelled with a purple tag. These tags were included solely for the purpose of providing easy referencing, but they are not part to the design of the dashboard. Other components of the dashboard are enclosed in blue and labelled with Roman numbers for convenient referencing. The following paragraphs will each cover a frame or component.

4.2.1 Frame 1: students

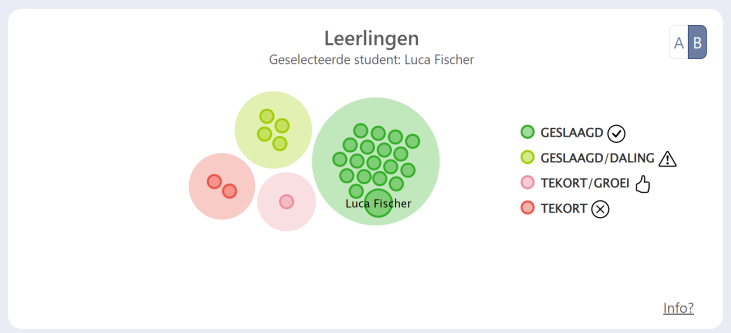
In the first frame, the teacher can find information about their class. This section addresses the questions "Which students' results have gone up or down?" and "Which students are falling behind in my subject?". To answer these questions, the class is

divided into four groups. First, the class is divided into students who have passed the subject and those who have not. Next, an analysis is made to look for students who have an improvement or decline in their grades. Then the following four groups emerge (refer to Section 6.1.1 for a detailed explanation of these four groups):

- The dark green group represents students who have successfully passed the course.
- The light green group also passed the subject, however, caution is advised as there has been a notable decline in their grades.
- The pink group denotes students who have failed the subject, yet show promising progress due to an increase in their grades.
- The final red group represent students who have failed the subject and show no signs of sufficient improvement.

In the top right corner (*component III*), the user can find the option to select a different visualisation. Option A (Figure 4.3a) presents a list of all the students in the class, while option B (Figure 4.3b) gives a more anonymous view of the class and provides a high-level view of the size of each group. Both options offer the functionality to click on a student's name. The effect of this action will be explained in the section related to Frame 3.

(A) Option A: list of students



(B) Option B: high-level overview

FIGURE 4.3: Frame 1 (final version)

4.2.2 Frame 2: competencies

In Frame 2, one can address the questions "How much time has been dedicated (in this course) to a specific competency?" and "Is there a correlation between the investment of time in competencies and the outcomes?". The bar chart on the left shows the number of completed assignments for each competency. On the right, the bar chart presents the class average for each competency, on a 100% scale. The red dotted line indicates the 50% threshold.

4.2.3 Frame 3: students' results by competency

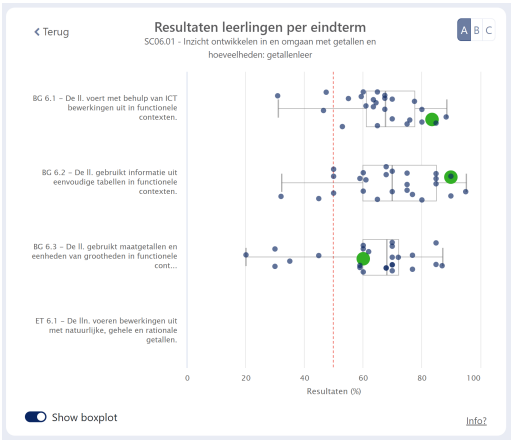
In Frame 3, the aim is to provide insights into the performance of individual students and the class as a whole regarding specific competencies. This involves visualising the results of all students in the class for a particular competency. Since one of the objectives of this research is to determine the most effective visualisations for teachers, it is interesting to present multiple options to teachers in the user studies and examine their preferences. Consequently, three visualisations were selected, each displayed in Figure 4.4. The user can switch between these options using *component IV*.

Option A The first visualisation provides an overview of the class distribution. The x-axis represents the results in percentage, the y-axis represents the different competences. The red dotted line indicates the 50% threshold. Each dot on the graph represents a student in the class and indicates their score for a specific competency. Hovering over a dot reveals the student's name and result. By clicking on a dot or when a student is selected in Frame 1, all the dots representing that student's scores for each competency will be highlighted. This feature allows the teacher to assess the student's performance in each competence more effectively.

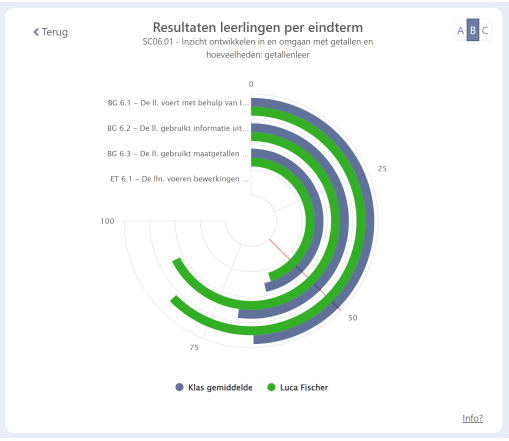
To gain a comprehensive understanding of the overall performance of the class, a boxplot has been added. The boxplot displays the score distribution, showing where most of the class is located, as well as the minimum and maximum scores. In the lower-left corner, there is an option to disable the display of the boxplot if desired.

Option B The second option shows both the class average and individual student data for each competency. This approach offers a less detailed perspective, as it focuses on comparing the score of an individual student to the class average rather than presenting the grades of the entire class. To switch between different students, Frame 1 can be used as a selection tool.

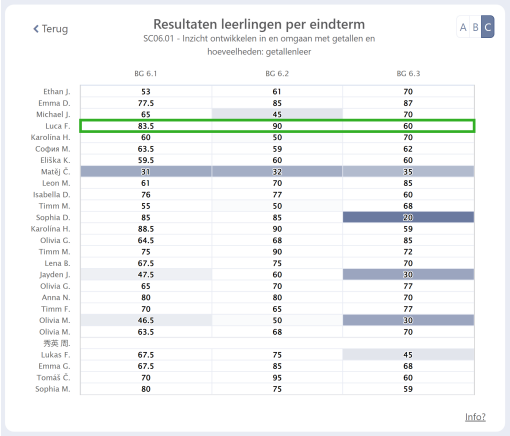
Option C The final option presents a table displaying all students' grades categorised by competency. This format resembles a gradebook, where scores below 50% are coloured. Darker shades represent lower grades. Frame 1 serves as a filter once again, enabling to switch between students. When a student is selected, their



(A) Option A



(B) Option B



(C) Option C

FIGURE 4.4: Frame 3 (final version)

grades are highlighted within a coloured frame, offering an improved overview of that particular student.

For all three options, the colours used to highlight a specific student align with the colours assigned to the four groups in Frame 1. In the examples provided in Figure 4.4, the selected student is Luca Fischer. As he belongs to the 'PASSED' group, his colour is represented by dark green. Alternatively, if a student falls under the 'FAILED/decline' group, their colour will be pink.

4.2.4 Component II: breadcrumbs

Component II consists of breadcrumbs that provide an indication of the current level the user is located on. These levels directly correspond to the levels defined in the competency framework. To navigate to a lower level, you can simply click on the name of the competency. This mechanism is illustrated in Figure 4.5. To ascend to

a higher level, use the 'Back' button positioned at the top left (*component VIII*). Alternatively, the navigation structure at the top (*component II*) can be employed to backtrack multiple levels. Please note that Figure 4.5 only shows the implementation for option A; the other options function identically.

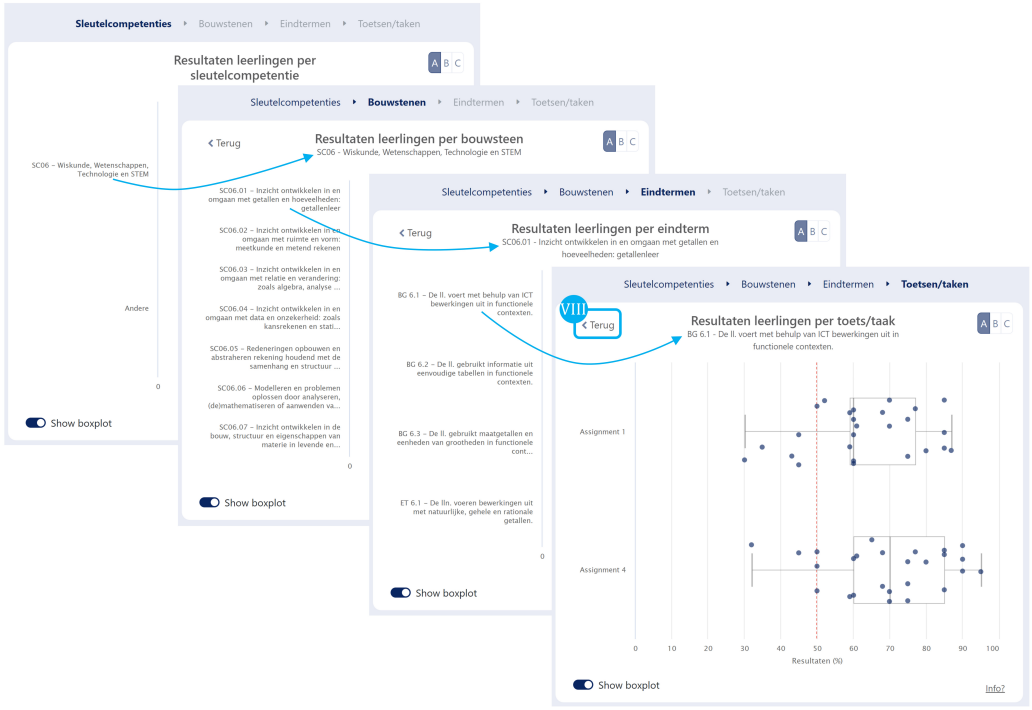


Figure 4.5: The different visualisation shown when going down the competency levels on by one for Option A. VIII) back-button

4.2.5 Components I, V, VI, VII: popups

To assist teachers while using the dashboard, four pop-ups have been added with additional explanations. Figure 4.6 shows all the pop-ups featured in the dashboard. By clicking on *component I*, *component IX* will appear, offering a global explanation of the entire dashboard. Additionally, a link to the dashboard tutorial video[1] can be found here. This pop-up also appears when the user opens the dashboard. *Components V, VI* and *VII* provide additional explanations of the three frames, respectively.

[1]This tutorial was made with Animaker and can be found at: https://app.animaker.com/animo/gMWvDy5UHKHoqO4h/

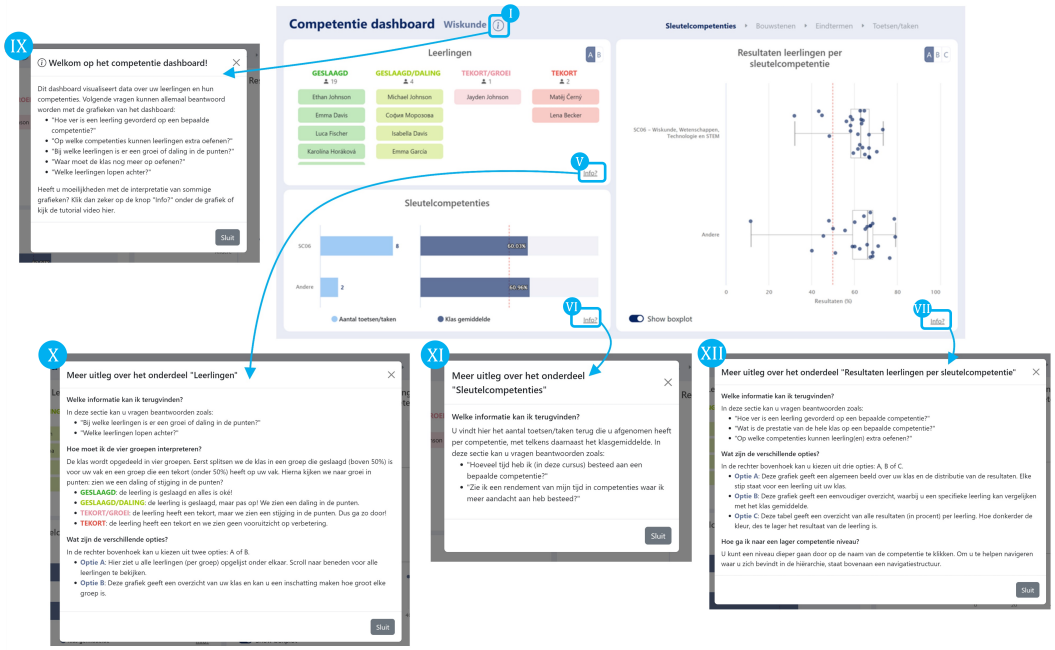


FIGURE 4.6: All popups of the dashboard. I) info-button whole dashboard, V) info-button Frame 1, VI) info-button Frame 2, VII) info-button Frame 3, IX) pop-up welcome message, X) pop-up Frame 1, XI) pop-up Frame 2, XII) pop-up Frame 3

Chapter 5

Understand: comprehending the requirements of teachers

Gathering input from the end user is essential to ensure that their requirements are taken into consideration. This is a crucial step when focusing on a user-centered design and ensuring we have input from our stakeholders. Therefore, it was decided to first consult with educators before beginning the design process. This is done in order to determine teachers' opinions about educational data visualisation.

Two studies were conducted to acquire this information. First, a focus group was held to examine the teacher's views. This approach and its outcome will be covered in Section 5.1. The second study will involve a more in-depth investigation of the requirements, covered in Section 5.2. All of the points and observations will then be relisted in Section 5.3 to arrive at the conclusion.

5.1 Focus group

5.1.1 Method

This initial study aims to gain a basic understanding of teachers' demands and the issues they have with the dashboards that are currently in use. The study will be a source of inspiration when thinking about dashboard content and what data is valuable for teachers.

Before this study could be organised, an ethics application had to be submitted to the KU Leuven Social Ethics Committee (SMEC). SMEC examined and approved this work (file number: G-2022-5775). Appendix A contains all application-related paperwork as well as the informational brochure for participating teachers.

After approval, six secondary teachers were invited to participate. The only selection criterion was that there should be a (small) variety of teachers. So not just science teachers, but also a mix of language teachers, history teachers, etc. All of

this is done to avoid obtaining a diverse perspective.

The concept of a "metaplan" (see Chapter 2 for a detailed explanation) was employed for the concrete elaboration of this focus group. Following a brief explanation of the ongoing research, each participant had the opportunity to brainstorm alone while writing their ideas on Post-its. After brainstorming, each of these was reviewed separately, with space for discussion and potential new ideas. The final outcome was a wall covered in Post-its (see Figure 5.1).

5.1.2 Results

The six teachers came up with 28 ideas (Post-its). After removing duplicates and grouping post-its with related ideas, the wall of Post-its resembled Figure 5.1. The highlighted Post-its were the ideas the teachers prioritised as highest.

A quick summary of Figure 5.1 shows that they were most interested in "how much time they spend on skills and if there was a return on investment", "which skills students should practice more" and "getting an overview of the evolution of grades". Additionally, personal factors such as the mental well-being and home situation of students were also discussed.

Although there were some good ideas when looking at the Post-its, the most valuable insights were found when everything were discussed in group. Three high-level concepts mentioned by the teachers, are important to highlight.

First, the teachers complained about the need for an overview. Currently, they must manually search through data to get a good picture of a student. However, many commented that this is very time consuming. One teacher used the following remark to emphasize the importance of having a good overview on her students: ***"Should we have more information, we could provide much more targeted feedback."*** (quote translated from Dutch).

Next, they were interested in more information than just the students' grades, saying ***"The point system is not sufficient, it does not tell us enough"***. They suggested not to look at grades alone but giving grades an extra dimension. This could translate in comparing grades with well-being, skills or number of hours studied as found in Figure 5.1. This would help teachers in better understanding students and providing more targeted and effective feedback.

The heavy administrative burden placed on teachers was a topic that came up rather frequently during the conversation. When asked about important (design) factors to consider when creating an overview of student data, they agreed that it needed to be something for which they didn't have to invest additional time.

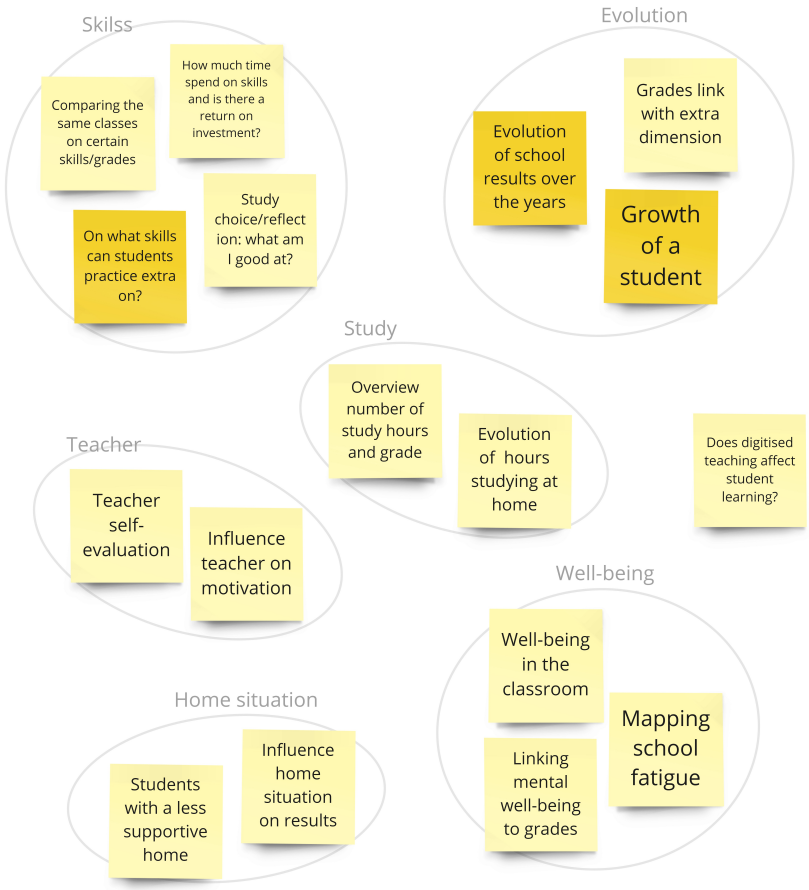


FIGURE 5.1: Result of focus group (wall of Post-its)

5.2 Requirement analysis meeting

5.2.1 Method

This thesis will be done in close collaboration with one school: GITO Overijse. As a result, it was decided to arrange an interview in order to determine the needs of this particular school. The person in charge of blended learning was contacted for this reason. The information was gathered through a one-on-one interview with the person responsible for blended learning, who also works closely with teachers.

During the requirement analysis, it became evident that the school and their teachers strongly emphasise the achievement of certain competencies. They aim to be leaders in implementing such new teaching approaches and assessing students on competencies rather than results on a course.

5.2.2 Results

The school wants to start working on a new vision. They prefer to judge a student on a competence rather than merely scholar performance. Instead of thinking "Pupil X has 45% (failed) on French," break this down and look for trends by saying "Pupil X has 65% written French and only 35% speaking French." This adds more colour to a certain grade.

Referring back to the dashboard's design, this would mean that teachers should get an up-to-date visualisation that answers the question: ***"How advanced is a student on a specific competence?"*** At the same time, the teacher should also gain a more comprehensive understanding of how the class as a whole is performing on a certain competency and where further practice is necessary.

The blended learning managers admit that they themselves have already run into some problems. To obtain this data, teachers would have to link their tasks to competencies. This feature exists in Moodle, but is barely used by teachers. This reluctance is because teachers currently get nothing in return for their extra time. So it is difficult to make this change in attitude when teachers do not see the benefits or cannot use them.

As the user studies will be done mostly in collaboration with this school, the hesitancy to add data to Moodle poses a significant challenge, making the research more complicated. The creation of a dashboard requires a lot of data, which is currently unavailable. Resolving this issue entails giving the teachers something in return for their afford. However this creates a somewhat paradoxical situation, as we need data to create the dashboard but also need the dashboard to motivate data collection. One potential solution is to use test data instead of real-time data, although this compromises the accuracy of the studies. Nevertheless, it is a necessary measure.

5.3 Conclusion: combining the results

Before designing the dashboard, it is important to get an idea of what questions teachers liked to see answered in the visualisations. Two studies were conducted to acquire this information.

The ideas in the focus group outline the most important needs of the teachers. The teachers requested a better understanding of: student growth and evolution, which skills a student or class should practise more, the time spend on a particular skill, and a way to self-evaluate themselves. But also more personal aspects like mental well-being and home situation of students came up.

The requirement analysis meeting helped to prioritise the needs from teachers. With specific questions like "How advanced is a student in a specific competency?".

But, they also requested a summary of the overall class performance on each competency.

To provide a complete view of what teachers would like to see on the dashboard, the results of the two studies will now be combined. Here, the generalisation is made that 'skills' and 'competencies' both contain the same information. There are also many good ideas that require data that are not currently available in Moodle (such as mental well-being and home situation). After being filtered, the questions were divided into three groups: questions requiring only student data, questions requiring only competence data, and questions combining these two types of data. All the ideas of the two studies are listed in Table 5.1. A positive aspect of the current findings is that these questions were also encountered during the preliminary study (see Section 2.2). Previous papers [20, 44] revealed questions about which students encountered difficulties, student processes, and skill mastery. Therefore, the outcomes of this study align with prior research.

The unavailability of sufficient data complicates the creation of a dashboard. Using test data instead of real-time data is a potential solution, although compromising accuracy, to overcome this challenge.

TABLE 5.1: Results of focus group and requirement analysis meeting (after filtering). Divided into three groups: questions requiring only student data, questions requiring only competence data, and questions combining these two types of data. Requirements with higher priority have a star behind them.

Student data
• Which students' grades have increased/decreased? ⭐
• Which students are struggling?
Competence data
• How much time did I spend (in a course) on a certain competency?
• Do I see a return of my time in competencies where I put more effort in?
Combined data
• How advanced is a student on a specific competence? ⭐
• What is the performance of the whole class on a certain competency?
• What competencies should students focus on for extra practice? ⭐

Chapter 6

Ideate: design and evaluation of proof-of-concept

This chapter presents the first design iteration, focusing on the development and evaluation of the proof-of-concept. It aligns with the **ideate phase** described in the methodology.

In Section 6.1, detailed insights are provided regarding the prototype's design process, focusing on the visualisation choices and design requirements. Section 6.2 outlines the study outline, followed by the findings and results of the user-study in Section 6.3.

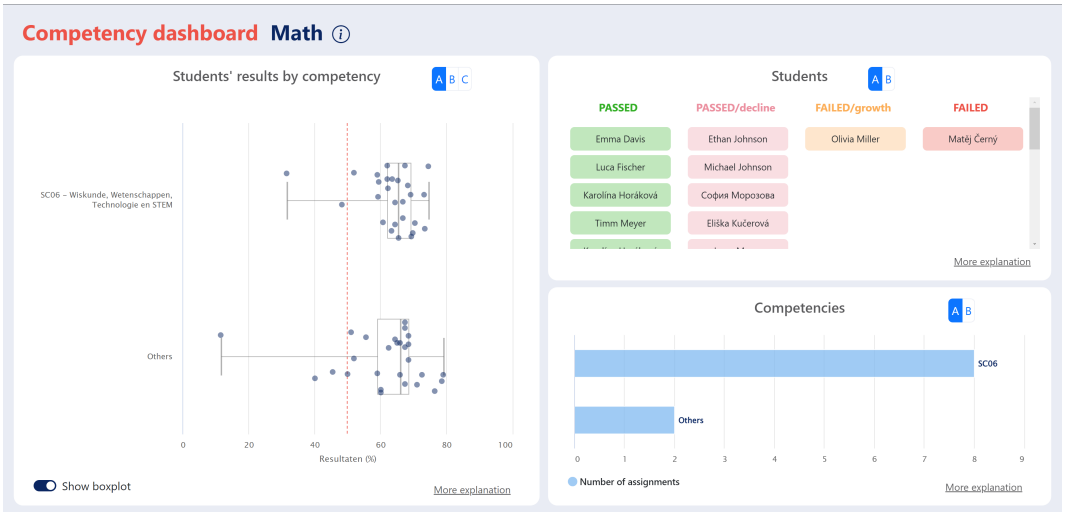


FIGURE 6.1: Design of proof-of-concept

6.1 Development of prototype

This section will take the first step toward developing a proof-of-concept (POC). The design is composed of three frames. These frames correspond to the previous findings from the **understand phase**, where three distinct groups were identified: student data, competency data, and combined data (Table 5.1). This section will go over each of the three frames individually, explaining in detail the process behind the development of each frame. The goal is to create a visualisation for each group that answers the respective questions and to show the idea behind each visualisation.

Figure 6.1 shows this first proof-of-concept. However, a considerable number prototypes where designed prior to achieving this adequate proof-of-concept. A collection of these prototypes can be found in Figure 6.2.

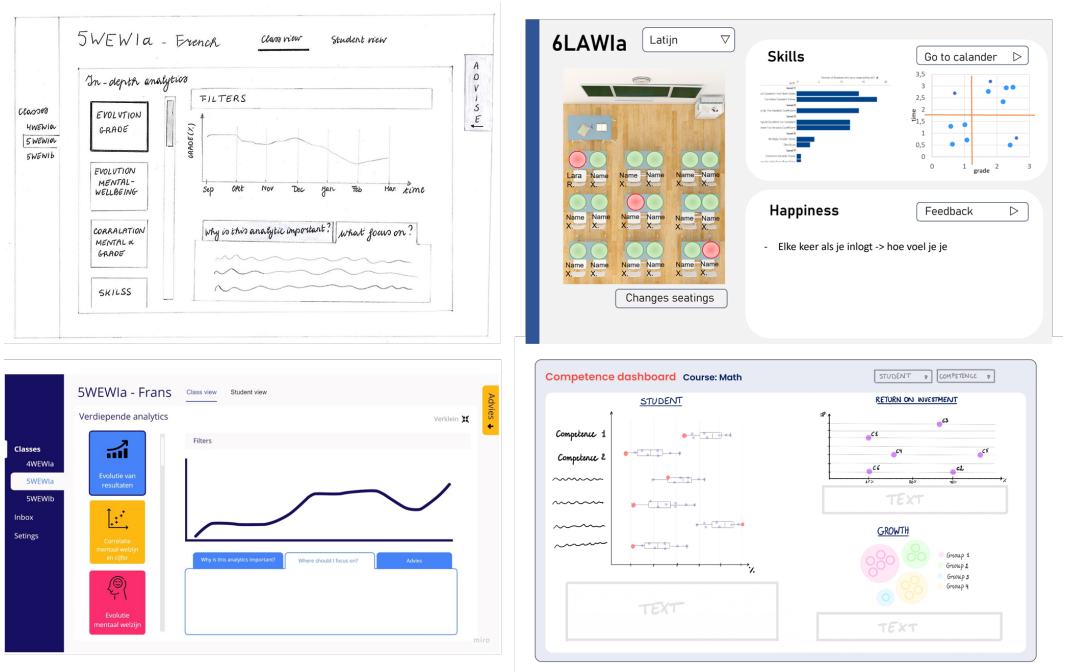


Figure 6.2: Collection of prototypes before POC in Figure 6.1

6.1.1 Frame 1: student data

The goal in this segment of the dashboard is to answer the questions *"Which students' grades have increased/decreased?"* and *"Which students are struggling?"*. To answer these questions, the evolution of students must be monitored and visualised.

The idea is to construct a graph that compares students' results against their change in grades. The steps for creating this graph are shown in the first paragraph. After constructing this graph, the next paragraph will discuss how to visualise it.

Relationship between results and progress

To begin, it is necessary to establish a definition for the x-axis. The x-axis will represent a student's average grade (as a percentage) for the given subject, thus x $\in$ [0,100]. To clearly indicate that students below 50% have failed the class and above 50% have passed, the centre of the graph is chosen at 50%.

The y-axis will display the 'change in grades' and will be further referenced as $\triangle x$. Informal, this x represents the growth of students' grades. Consequently, if $\triangle x$ is positive the grades are increasing. If $\triangle x$ is negative, the grades are decreasing. Formally $\triangle x$ will be defined as:

$$\triangle x = average\ grade_{period2} - average\ grade_{period1} \tag{6.1}$$

Formula 6.1 means that $\triangle x$ is the difference between grades from two different time periods. Period 1 begins at the start of the school year, and Period 2 ends today (the day when the teacher consults the dashboard). The split of the two time periods is made in the middle and will change dynamically as the school year progresses. Table 6.1 shows some examples of how the two time periods will be defined.

TABLE 6.1: A few examples to show the dynamic time periods

	Time period 1	Time period 2
September-October	September	October
First semester	September-October	November-December
School year	First semester	Second semester

The graph in Figure 6.3 displays the axes described above along with a few sample students. For instance, student 1 finished the first semester with an average grade of 65%. Student 1 received a score of 55% in September and October, and a score of 75% in November and December. This denotes a growth of +20% (=75%-55%).

Upon observation of Figure 6.3, it is possible to distinguish four distinct zones. Student 1 has successfully passed the course, and their grades have significantly improved. It is worth noting that despite passing, there has been a decline in the grades of Students 2 and 3. Student 4 has failed the course with no indication of improvement. However, Student 5, who has also failed, has demonstrated a positive trend with a noticeable increase in points. These four groups correspond to the four quadrants of the graph, as can be seen in Figure 6.4a.
Upon analysing Students 2 and 3, one may question the fairness of categorizing them together in Group B. Student B has a high average grade of 80% and has experienced a small decline of -5%, while Student C has an average grade of 55% and a higher decline of -10%. It seems intuitive that students with higher grades are allowed a greater margin of decline than students like Student 3, who are likely to fail if their grades continue to decline at the same rate.

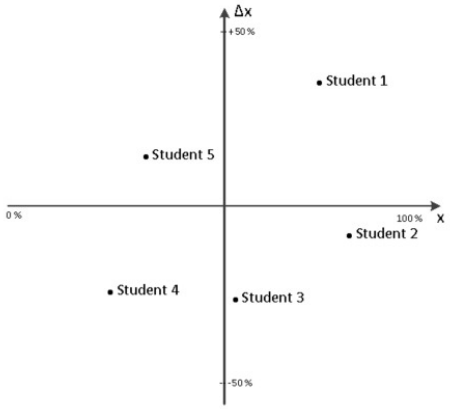
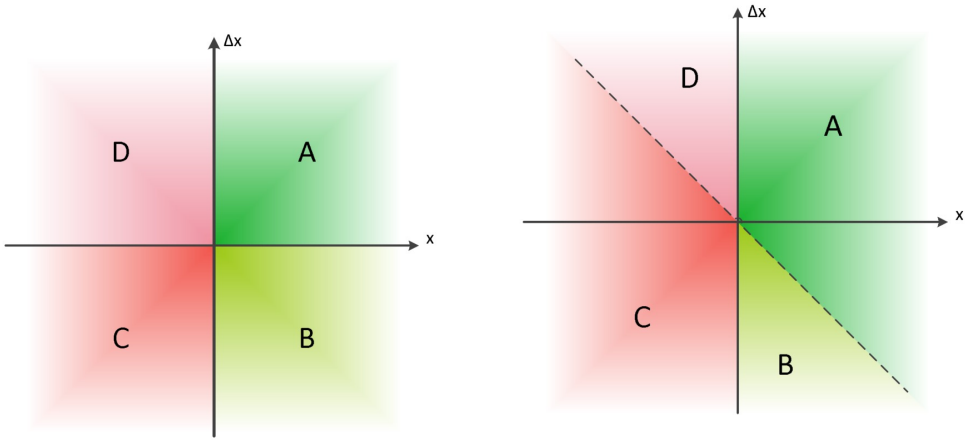


Figure 6.3: Graph that shows relationship between results and progress, where the x-axis represents the average grade in percentage and the y-axis displays the change in grades ($\triangle x$)



(a) (b)

Figure 6.4: Two versions to distinguish four groups of students

For this reason, the categorisation of the groups has been revised. The updated version can be found in Figure 6.4b. The decision was made to position the dividing line where $\triangle x = -x$. The thought process behind it, is that a student with 65% average grade and a decline of -15%, is at risk to drop below 50% (=60%-15%), if the students' results continue to follow this trend.

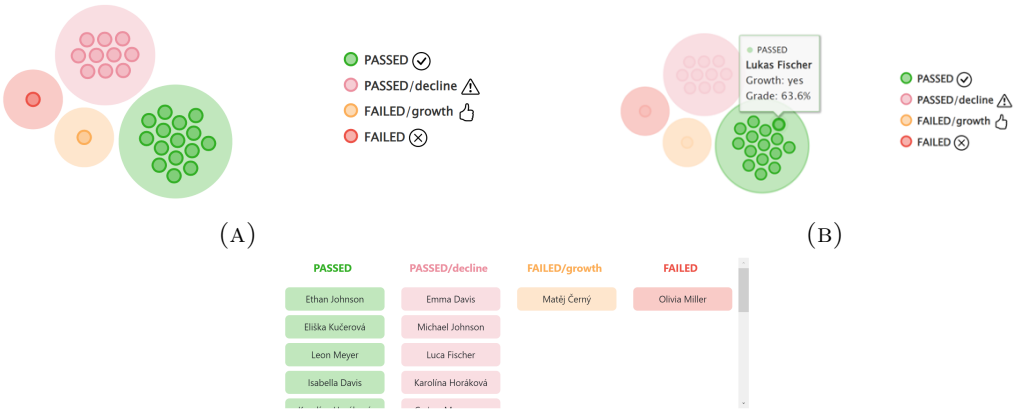
We acknowledge that there may be alternative, perhaps more effective, methods for distinguishing the evolution of students' grades. However, since this is not the primary objective of this research, the definition presented in Figure 6.4b will be retained.

Visualisation

The previous paragraph provides an overview of how the four groups are obtained. First, the class is divided into students who have successfully passed and those who have failed. Next, a further division was made based on students exhibiting a growth in their grades versus those experiencing a decline. The next step involves visualising these four groups effectively.

A search of existing research papers was conducted to explore previous attempts for group visualisation. Figure 6.6 shows the visualisation of three research papers that also visualised groups. Figure 6.6a presents two visualisations: a bar chart on the left representing the size of each group, and a list on the right showing the students and their respective group assignments. One advantage of these visualisations is their comprehensibility, which holds significant importance in this study. However, this approach consumes considerable dashboard space when both visualizations are placed side by side. In another paper (Figure 6.6b), students are represented by dots, and uses colours to show each group. Again this visualisation is very easy to understand and effectively shows the size of each group. Lastly, Figure 6.6c uses a flow chart that starts with all students on the left and progressively divides them into smaller groups as you move to the right. This chart requires further investigation and consequently more time. Moreover, individual student details cannot be observed within this particular visualisation.

With this acquired knowledge, two visualisations were designed. The first visualisation represents students as dots and organises them into a split bubble chart (Figure 6.5a). When teachers hover over a dot, it displays the corresponding student and their respective grade (Figure 6.5b). This graph gives a high-level overview of the class, illustrating the size of each group.



(A) (B)

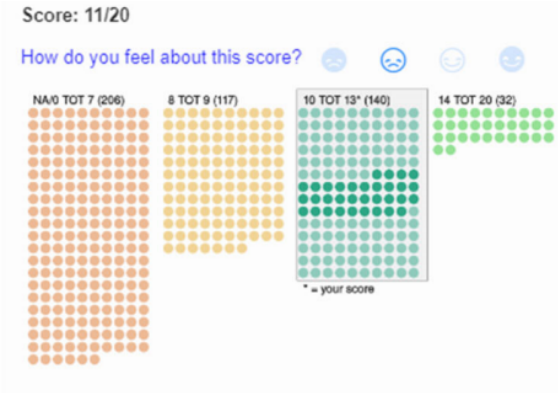
(C)

FIGURE 6.5: Visualisations of Frame 1 (students data)

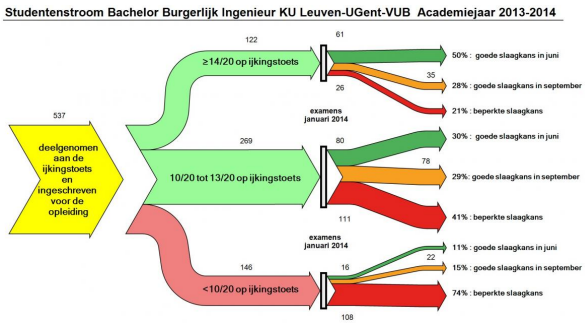
However, when a teachers wants to look for specific students, this first view is time-consuming because the teachers needs to hover over each dot. Consequently, the second visualisation shows a list of all students, grouped by their respective group (Figure 6.5c).

By integrating these two visualisations, an overview of each group's size is provided with the first visualisations, while the list serves as a more detailed reference for locating specific students. Both visualisations are easy to understand and quick to analyse. The teacher is now able to answer questions like "Which students' grades have increased/decreased?" and "Which students are struggling?".

(a) Bar chart and list (I. Nikolayeva et al, 2018, [33])



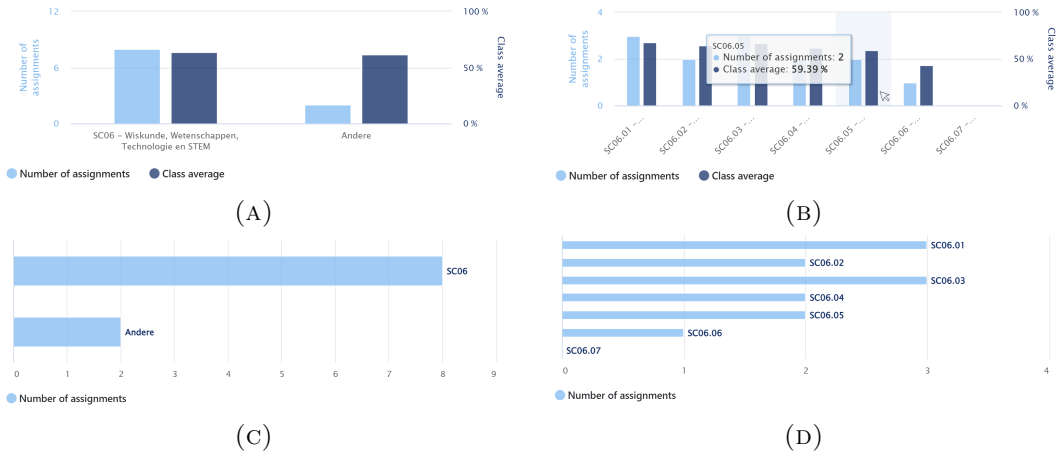
(b) Students visualised as dots (T.Broos et al., 2020, [9])



(c) Flow chart (KULeuven, 2014, [21])

Figure 6.6: Three research papers that visualise groups

6.1.2 Frame 2: competency data



(A) (B) (C) (D)

FIGURE 6.7: Visualisations of Frame 2 (competency data). Figures A end B show the dual axis, figures C and D show one axis. A light blue bar indicates the number of assignments and the dark blue show the class average.

The goal in this frame of the dashboard is to answer the questions *"How much time did I spend (in a course) on a certain competency?"* and *"Do I see a return of my time in competencies where I put more effort in?"*. It is essential to conduct a thorough search to identify the data that can provide answers to these questions. Once the appropriate data has been identified, the next step is to determine how to effectively visualise it.

The first question concerns about the quantification of 'time spent'. Ideally, the most suitable data for capturing this information would be the hours dedicated to a particular competency. However, currently, this data is unavailable. Teachers would need to manually associate their schedules and class hours with the end-terms. Given that teachers are already required to link assignments to end-terms, adding another task of linking class hours to end-of-terms would undermine the purpose of the dashboard, which aims to facilitate teachers' daily tasks.

The decision was made to address the question of 'time spend' by displaying the number of completed assignments for a particular competency, as this data is already available. Furthermore, this approach can assist in identifying the statistical relevance of competencies when examining the results in Frame 3. If a student performs poorly on a competency assessed only once, it may be attributed to a temporary setback or an off day. However, if a student consistently receives low scores on a specific competency that is already examined many times, it indicates a more significant issue.

The second question pertains to determining the return on time invested. Defining the "return of time" solely based on the number of assignments poses a challenge. In

this case, the chosen approach is to compare the time (number of assignments) with the class average. For instance, if the class average is low and a significant number of assignments have been completed, it suggests that the class may not have adequately grasped the subject. Conversely, if the class average is low but only one assignment has been completed, there is no cause for alarm as the subject is still being mastered.

The data that will be used to answer these questions are number of assignments and class average per competency. The next step involves visualising this data effectively.

Bar charts are the most popular visualisation type for learning analytics dashboards [39]. Bar charts are an ideal choice for representing this data, as they effectively plot numeric values for each categorical feature [53]. Figure 6.7a illustrates the initial visualisation, which presents the number of assignments and the class average per competency. A dual axis is used here, as the class average is expressed as a percentage (between 0% and 100%), whereas the number of assignments is a numerical value. Figure 6.7b demonstrates how the visualisation looks when having more competencies and what happens when you hover over the bar charts.

In addition, a graph displaying solely the number of assignment, has been chosen (Figure 6.7c and 6.7d). This decision was made as a dual-axis can be confusing and requires more concentration [22]. It would also be informative to find out in the next user study whether or not this information should be included on the dashboard.

Given the lower priority assigned to the questions pertaining to "How much time did I spend (in a course) on a certain competency?" and "Do I see a return of my time in competencies where I put more effort in?", a decision was made to adopt a simple bar chart approach and allocate more resources to Frame 1 and Frame 3. Both visualisations provide information on the number of assignments completed, which does approximately address the question regarding the time invested by a teacher in a specific competency. The dual axis (Figure 6.7a)shows also the class average, providing insight if there is a return of the effort you spend on a certain competency.

6.1.3 Frame 3: combined data

The objective of this third frame of the dashboard is to answer the questions "*How advanced is a student on a specific competence?*", *"What is the performance of the whole class on a certain competency?"* and *"Which competencies can student(s) practice extra on?"*. To address these questions, it is necessary to visualise all students in the class alongside their corresponding results for a specific competency. Given the high priority of this frame, a lot of thought has been given to determining the most effective approach for visualising students' results per competency.

The visualisations that were chosen to further examine are: bar charts, line charts, tables, pie charts, network graphs, scatterplots, radar plots. This selection is based

on the systematic literature review of learning dashboards [39] from Schwendimann et al. They found that these particular visualisation types were the most commonly used in the context of learning dashboards.

The next paragraphs will each analyse one visualisation and and check if they satisfy some design criteria[1]. These design criteria are summarised in Table 6.2. The first two criteria refer to the content and the objective that the visualisation must correctly communicate. This means providing both a global view of an individual student as well as a high-level view of the entire class, which correspond to the objective of this third frame (see questions at start of section). The last three criteria tell more about the structure of the visualisation. The visualisations should be straightforward to comprehend, as previous research has highlighted the importance of avoiding misunderstandings in other dashboards to promote teacher adoption [44]. Furthermore, the interpretation of the visualisations should not be time-consuming, as this requirement was identified during the understand phase (Chapter 3).

Lastly, the visualisation must align with the competency framework's structure, which consists of four levels: key competencies, building blocks, end-terms, and assignments. The size of each level can vary, with the number of items ranging from zero to over ten. It is crucial for the chosen visualisation to accommodate this structure while remaining easy and fast to understand.

TABLE 6.2: Criteria to evaluate the visualisations (inspired by [5])

Criteria	Label	Description
C1	Overview class	Provides an high-level overview of the class
C2	Overview individual student	Provides insights into the results of individual student
C3	Straightforward	Easy to interpret
C4	Time-efficient	Fast to overlook and extract data from
C5	Range of competencies	Complies with the possible ranges of competency levels

Bar chart

Bar charts are the most popular choice to visualise data [39] and are easy to understand [16]. Figure 6.8a presents a bar chart displaying both class data and individual students per competency. This figure shows a comparative view of a specific student's performance against the class average, with the ability to switch between students using a filter. The choice to make use of a radiant bar chart, as

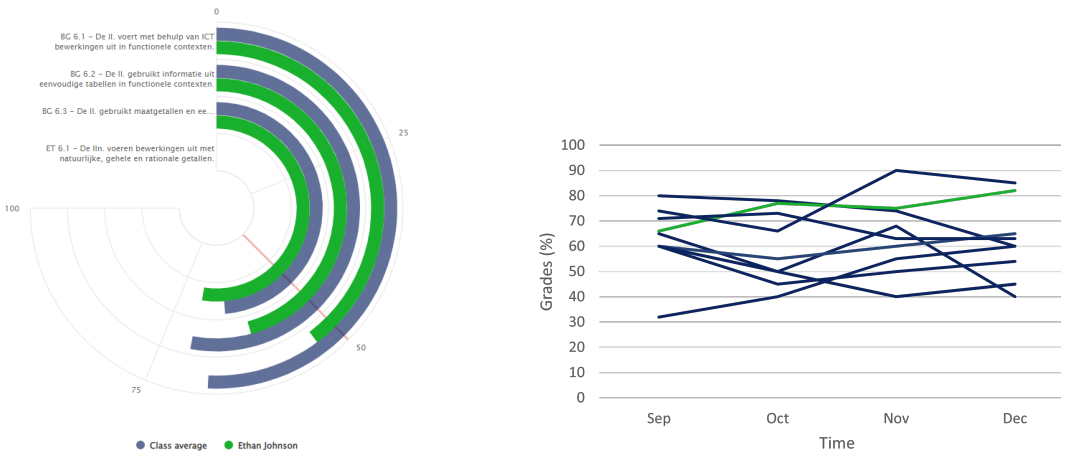
[1]This method was inspired by the study conducted by Ballarini et al. [5], where they similarly search for the best graph to represent their clinical trial data.

opposed to a straight bar chart, was based on the aim to get a greater distinction with the bar charts of Frame 2 and to enhance user engagement. By introducing variety, the dashboard becomes more visually appealing.

Line chart

Line charts are typically used for visualising continuous quantitative data [16], but in this case, the data to be visualised includes percentages of grades and a list of competencies, both not continuous. In order to use the line chart, a new approach is needed that incorporates time as a continuous variable. However, a trade-off arises when selecting the representation of lines: either lines represent students, limiting the view to one competency, or lines represent competencies, limiting the view to one student. This creates the challenge in achieving an overview of the entire class for all competencies simultaneously. Figure 6.8b provides an illustration of how the line chart would look like.

Considering the potentially large number of lines in both options, which can exceed 20 for students and around 15 for competencies, one can also question whether it will be fast to interpret.



(A) Bar chart (B) Line chart

Figure 6.8

Table

Tables organise information in rows and columns, making them suitable for displaying the required data, with each column representing a competency and each row representing a student (example of table in Figure 6.10a). Tables are familiar to teachers who already use gradebooks (see Figure 6.9 for example of a Moodle gradebook), making them easy to understand. However, tables can be time-consuming when trying to get an overview of the entire class or a specific student due to the

abundance of data. Some argue that tables may not effectively support information visualization as they require a line-by-line search that doesn't align well with users' mental models of data [43].

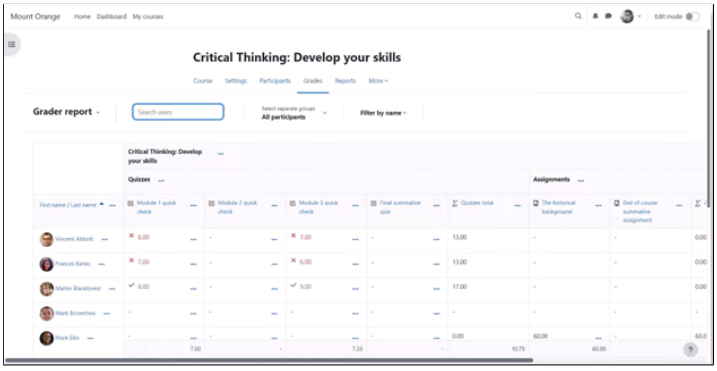
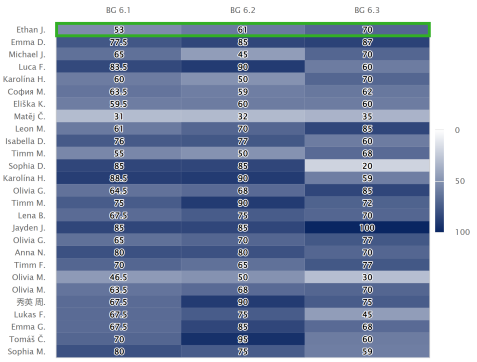
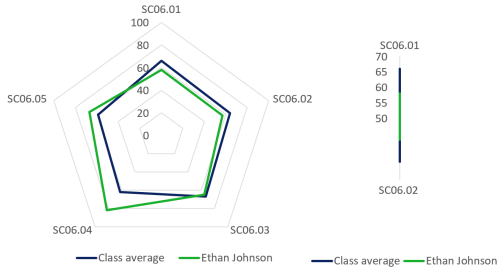


FIGURE 6.9: Example gradebook in Moodle (image from [30])

Two solutions have been implemented to address the issue. Firstly, the table has been transformed into a heatmap, using darker shades to represent lower grades for students. Secondly, a filtering option allows the teacher to focus on a single student, highlighting their grades with a colored frame for a faster look-up. Although these solutions improve the visualisation, it remains a time-consuming task to understand the data and still does not give an overview of the entire class.



(A) Table



(B) Radar plot: (left) five variables (right) two variables

FIGURE 6.10

Radar plot

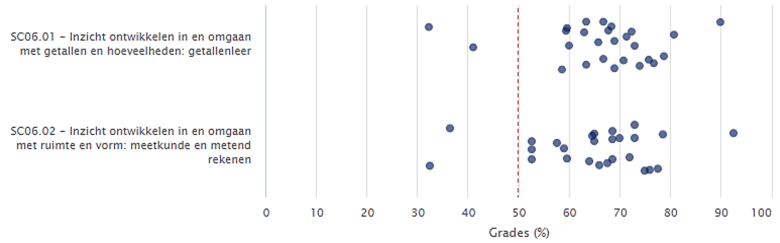
Radar plots, which are line charts with a circular axis for the category scale [16], can provide a visual representation of one student and their competencies as seen in Figure 6.10b (left). However, displaying all students simultaneously can result in a cluttered visualization due to the excessive number of lines. Additionally, bar charts have proven to be more effective in displaying data than radar plots [16]. Also, radar

plots lose their value when used with a limited number of variables, similar to the issue faced by parallel coordinates (criteria 5). This problem can is shown in Figure 6.10b (right).

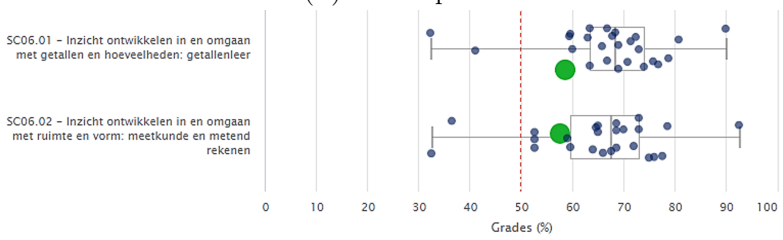
Scatterplot

Scatterplots are used to analyse bivariate data [43], in this case, representing grade percentages on the x-axis, competencies on the y-axis, and each data point corresponding to a student (Figure 6.11a). Jitter is added to prevent overlap between data points, ensuring a clear overview of the class. To provide a quicker overview, a selection option has been added that allows teachers to highlight data points for individual students. Additionally, a boxplot is included to visualise the class's grade distribution, presenting useful measures such as minimum, maximum, and median values(Figure 6.11b). However, it is worth noting that both the scatterplot and the box plot have a steeper learning curve and may require more effort to comprehend compared to the previously discussed visualisations.

Scatter plots and parallel coordinates are often compared. While parallel coordinates are useful for identifying patterns and clusters between variables, teachers did not request cluster identification nor is it time-efficient if they have to look for clusters themselves. A second problem with parallel coordinates is that they are not easily to understand [18, 51]. However, the biggest problem when parallel coordinates rises when applied to a single variable. Then they look like a scatterplot without jitter and no longer satisfy design criteria 5. Thus, parallel coordinates are not suitable in this context, although they may be useful in other scenarios.



(a) Scatterplot



(b) Scatterplot with boxplot

Figure 6.11

Others: network graph and pie chart

Network graphs and pie charts will both not be considered as visualisations. Network graphs are intended to visualise relations between data points, which does not apply here. Pie charts are often labelled as poor visualisation [17]. One of the primary reasons behind this critique is the human limitation in effectively comparing two-dimensional areas or angles. Pie charts even have a (famous) quote attached to them, which states, *"Save the pies for dessert"* (Stephen Few).

Conclusion: choosing appropriate visualisations

Table 6.3 presents an overview of the discussed visualisations and their compliance to the five criteria of Table 6.2. Given the objective of this research, which aims to identify the most effective visualisations for teachers, it is interesting to show multiple options to teachers in the next user-studies and investigate which visualisations they prefer. Therefore, the decision was made to continue with (not one, but) the top three visualisations: bar charts, scatterplots, and tables.

TABLE 6.3: Summary of the visualisations assessment (inspired by [5])

	Criteria				
	C1	C2	C3	C4	C5
Bar chart (Figure 6.8a)		✔	✔	✔	✔
Line chart (Figure 6.8b)		✔			✔
Table (Figure 6.10a)		✔	✔		✔
Radar plot (Figure 6.10b)		✔	✔		
Scatter plot (Figure 6.11b)	✔	✔		✔	✔

6.2 Study outline

This study aims to verify the usability and usefulness of the dashboard and to update the requirement analysis if necessary. This feedback implicate improvements for future dashboard iterations.

An ethics application had to be submitted to the KU Leuven Social Ethics Committee before this study could be organised (SMEC). This study was assessed and authorised by SMEC (file number: G-2022-6099). Appendix A contains all application-related paperwork as well as the informational brochure for participating teachers.

Five secondary school teachers from the school GITO Overijse participated in the study. In order to find mistakes that violated the information visualisation standards, two HCI experts provided additional feedback on the first prototype.

In particular, participants will use a functional prototype as they take part in a one-on-one physical interview. There will be three parts to this interview (see Appendix B for complete protocol). First, a think-aloud study will be conducted in which the user is given certain instructions (see Table B.1) to examine various elements of the dashboard. The participants will next engage in an oral in-depth interview to discuss the dashboard's strengths, weaknesses, opportunities, and threats. Finally, the participants fill out a questionnaire to determine the SUS score.

6.3 Results

The key findings from the interviews will be covered in this section. First, a brief analysis of the SUS score will be presented. The feedback of the teachers, which includes remarks from the think-aloud study and a verbal SWOT analysis, will be covered next. This feedback will be divided into strengths, weaknesses, opportunities, and threats. Lastly, the feedback provided by the HCI-experts will be summarised.

6.3.1 SUS score

Each teacher filled out a SUS questionnaire. The average SUS score for the dashboard was 89.5% (everything above 80.3% percent is seen as excellent [7]). However, this score has to be interpreted more carefully. The test group size is too small to generate a score that is representative or meaningful. This score nevertheless indicates a good usability result for the test group and shows that there were no significant usability issues that could affect the results.

6.3.2 Feedback teachers (SWOT-analysis)

Strenghts

1 | Interaction graphs [teachers: 4/5]

The interaction between the graphs "Students" and "Results students by competency" is very clear and easy to use. The recurrence of the colours (group that the student is in) is described as strong.

Quote (translated from Dutch): *"I also find a strength is that you can look very quickly at a particular student and then interact with the big graph. That combination works well."*

2| Complete overview [teachers: 5/5]

The dashboard offers an instant, complete overview. You can quickly determine the performance of your class and if a particular student is achieving well or poorly (referring to scatter plot).

Quotes: *"I find it very visual, less is more, what you need you see. Right now, I don't see anything I would miss."*
"[With the scatterplot] I find it very quick and visual to get a picture of how students are performing, both for standard follow-up and for class councils."

3 | Boxplot [teachers: 5/5]

Despite having the option to turn the boxplot off, would use the boxplot and leave it on.

Remark: A boxplot was unknown to 3/5 of the teachers. Everyone comprehended the visualisation after a brief explanation, and they would actually use it because it provides a complete picture of their class.

4 | User-centered design process [teachers: 1/5]

Appreciates that the teachers are included in the design process and that they can provide feedback.

Weaknesses

5 | Competency level [teachers: 4/5]

It is unclear how to advance to a deeper competency level. There is also no summary of the various levels. One teacher clicked on 'more explanation' to go to a deeper competence level.

Solution: In next iteration, breadcrumbs (per competency framework level) will be added that one can consult at any time. Also, when one goes to a different level, the titles change along with it. This 'more explanation' button will be updated in terms of design and text to avoid confusion.

6 | Tutorial [teachers: 3/5]

Everything in the dashboard is new and unfamiliar upon first use. At this interview, a short explanation was given for how to use it and so everything quickly became clear. This short explanation will be helpful to other teachers (not participating in this study) as well.

Solution: A tutorial video will be created that briefly explains each graph (maximum 5 minutes). Also, each graph always has a "explain more" option that provides additional information.

7 | Competency names [teachers: 1/5]

Names of competencies are shortened due to the lack of available spaces. Ask to see the complete name when you hover over the competence.

Solution: When the user hovers over an incomplete name, the full name will become visible.

8 | Readability heatmap [teachers: 4/5]

The heatmap graph's colour contrast and text outline are unclear.

Solution: The next iteration will adjust the colours and see what can be changed to enhance the readability of the numbers.

Opportunities

9 | Comparing to current method [teachers: 2/5]

All student results are currently provided to us on paper, and there is an excessive number of (confusing) grades on them. This dashboard would be a huge help in providing an overview that students and teachers currently do not have.

Quote : *"This overview would ensure better interpretation of information."*

10 | Help students more targeted [teachers: 4/5]

You can help a learner in a more targeted way. Instead of giving extra exercises for all subjects of a course, you now know where a student is suffering and can also show the student how they are doing.

Threats

11 | Entering data into Moodle [teachers: 1/5]

A teacher should properly manage and enter the data in Moodle (linking competencies with tasks) if they wish to have an accurate picture of their class on the dashboard. Yet currently, few teachers do this consistently.

Remark: Although only one comment was made, this is a valid concern. This was also mentioned during the requirement analysis meeting. However, at this moment teachers get nothing in return for their time when adding data to Moodle. This will change when this dashboard would be made available. One teacher said to start linking his assingsments to end-terms after seeing the dashboard (see quote below).

Quote: *"Then I will start linking my assignments after all."*

6.3.3 Feedback HCI-experts

To identify any violations against the information visualisation principles, the proof-of-concept was evaluated by two HCI experts. The positive aspects of the evaluation were in line with the feedback received from teachers. Specifically, the interaction of the graphs, the well-thought-out insights and the clarity of the dashboard were mentioned as strengths. However, they also identified several flaws that go against some information visualisation principles. These flaws will now be discussed individually.

Something that both experts mentioned was the **wrong use of colour** among the four groups in Frame 1. When selecting colours, a distinction should be made between ordered and categorical data [31]. For categorical data, distinct colours such as green and red are preferred. On the other hand, for ordinal data, it is advisable to use variations in saturation of the same colour. In this case, the class is first divided into a passed and failed group (categorical), where green and red colours can be used respectively. Within each of these groups, a further distinction is made based on increasing or decreasing results (ordinal). Here saturation is preferred.

Another weakness that was identified was the **readability of the heatmap**, a concern that was also mentioned by the teachers. Colouring all the results in the heatmap creates a cluttered display. The recommendation was to highlight only the results below 50 percent for an improved overview.

An additional comment was made regarding the **dual axis** used in option B of Frame 2. It was noted that the dual axis could be challenging to comprehend and potentially lead to confusion. One of the experts suggested using two side-by-side bar charts as an alternative approach.

Lastly, one of the experts suggested **switching the location of the frames**, suggesting that Frame 3 be positioned on the right while Frame 1 and Frame 2 be placed on the left. Here, the expert cited Schneiderman's mantra, which reads,

"Overview First, Zoom and Filter, Then Details-on-Demand". The expert suggested placing the visualisation of the four groups of the class (Frame 2) on the left as the initial "overview". After obtaining this overview, one can then proceed to filter the data based on a specific student and finally, examine the details presented in the graphs of Frame 3. In this way, Schneiderman's mantra is fulfilled.

Chapter 7

Make: design and development of final product

This chapter presents the finale step to achieving the final, high-fidelity prototype as seen in Chapter 4. Section 7.1 will list all the changes that have been made opposite to the proof-of-concept made in Chapter 6. Section 7.2 will go into more detail about how the dashboard was transformed into a working Moodle plugin, explaining the technical development. These two sections align with the **make phase** described in the methodology.

7.1 Significant changes

Upon examination of the high-fidelity prototype seen in Figure 4.1, a few significant modifications can be found in contrast to the design of the proof-of-concept seen in the previous chapter. This section will discuss each change in detail. The first three modifications are part of broader adjustments to the overall dashboard, whereas the last three changes refer to specific alterations in visualisations within each frame.

Switching the location of the frames To comply with Schneidermann's mantra (*"Overview First, Zoom and Filter, Then Details-on-Demand"*) and improve the flow of the dashboard, the choice was made to mirror the frames. Consequently, the teacher is first presented with an overview of the class in Frame 1, followed by Frame 2 and 3 to the bottom and right (Figure 7.1), allowing for detailed exploration.

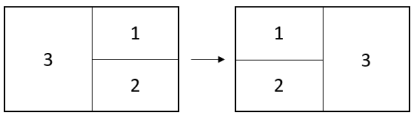


FIGURE 7.1: Sketch of how the frames are switched on the dashboard

Breadcrumbs One of the weaknesses identified in the think-aloud study was the absence of an overview of the various levels of competency framework (Section 6.3.2). For a more convenient navigation experience and to have a better understanding of this competency framework hierarchy, breadcrumbs have been added at the top (Figure 4.1, *component II*). The four levels correspond to the four levels of the competence framework. Additionally, when switching between levels, the titles at the top of the frames will be updated accordingly. These changes will improve the navigation of the dashboard and help maintain a better overview.

Tutorial and Info-button To help accelerate the learning curve required to understand the dashboard, two items have been added. Firstly, a 6-minute tutorial[1] has been developed to provide an overview of the dashboard's functionalities. This video covers the dashboard's goals, the different competency levels, each visualisation, and their interactive features. The link of the tutorial can be found in the welcome-modal of the dashboard. Furthermore, for a short summary of the tutorial, teachers can click on the Info button. This button can be found at the right bottom corner of each frame. Figure 4.6 shows the contents after clicking on the Info-button for each frame.

Change of colors (Frame 1) Another change relates to the colours of the four categories displayed in Frame 1. According to Munzner, when choosing colours, it is important to differentiate between ordered and categorical data. For categorical data the use of distinct colours is preferred, while for ordinal data, variations in saturation of a single colour are preferred [31]. This principle was not met in the POC design. Therefore, it was decided to assign green and red colours to represent the respective passed and failed groups (categorical data). To show the distinction between increasing and decreasing results (ordered data), darker and lighter shades of the same color are used.

Remove of dual-axis (Frame 2) Frame 2 consisted of two options presenting the number of tasks and the class average. To enhance simplicity, it was determined to integrate the two options into a single view. The dual axis was removed as it was specified by HCI-experts (Section 6.3.3) that it is difficult to interpret and was replaced by two side-by-side bar charts. This change makes Frame 2 clearer and faster to interprete.

Enhanced readability of heatmap (Frame 3) The heatmap in Frame 3 (option C) presented a cluttered overview due all the grades being coloured. To enhance the visualisation, a change was made to highlight only the results below 50 percent. This change results in an improved overview, allowing for better interpretation of the data.

[1]This tutorial was made with Animaker and can be found at:
https://app.animaker.com/animo/gMWvDy5UHKHoqO4h/

For a comprehensive overview of the final high-fidelity dashboard, please refer to Chapter 4.

7.2 Technical development

This research mainly focuses on the design of the various prototypes. However considerable effort was also devoted to the development of the dashboard itself. It is important to mention that this dashboard has also been implemented as a working plugin for Moodle. Consequently, secondary schools utilising Moodle will have the opportunity to incorporate this plugin into their system. This section provides a closer look at the technical development of the dashboard.

The initial step in developing the plugin involves establishing a base. Within the context of Moodle, the creation of a plugin is commonly referred to as developing a "block". To create a new "block" in Moodle, the minimal requirement requires providing four PHP files. The first file contains the class definition for the block, denoted (in this case) as "block_comp_dash.php". The second file, "access.php", allows for the specification of the block's accessibility. Next, a language file (e.g., "lang/en/block_comp_dash.php") is included to allow the development of the dashboard in multiple languages. Lastly, the "version.php" file contains information about the version and other advanced parameters. Moodle, being an open-source platform, offers detailed documentation[2] that provides further explanation on this subject.

After the four files have been created, the development of the dashboard can start. The dashboard is built using HTML, CSS, JavaScript and PHP. To create the (interactive) charts, the JavaScript library Highcharts[3] was included. Highcharts was chosen for its ease-of-use yet powerful visualisations [23].

In order to present up-to-date data, a connection to the Moodle database must be established. For this purpose, the open-source relational database management system MariaDB is employed. SQL is utilised to retrieve data from the database. However, prior to that, a thorough analysis and understanding of the database structure and its tables is required. The Moodle database contains more than 200 tables[4]. Figure 7.2 provides an entity-relationship model of the different tables that were used.

Combining all of the above, the result is a zip file. This zip file can be easily uploaded in Moodle by an administrator of a school and by this one upload, all teachers of the school can access the new block. After installing the plugin, Figure 7.3 shows that the competency dashboard can be accessed by opening the right panel and clicking on the blue button.

[2] https://docs.moodle.org/dev/Blocks
[3] https://www.highcharts.com
[4] A complete summary of all these tables can be found at: https://moodleschema.zoola.io

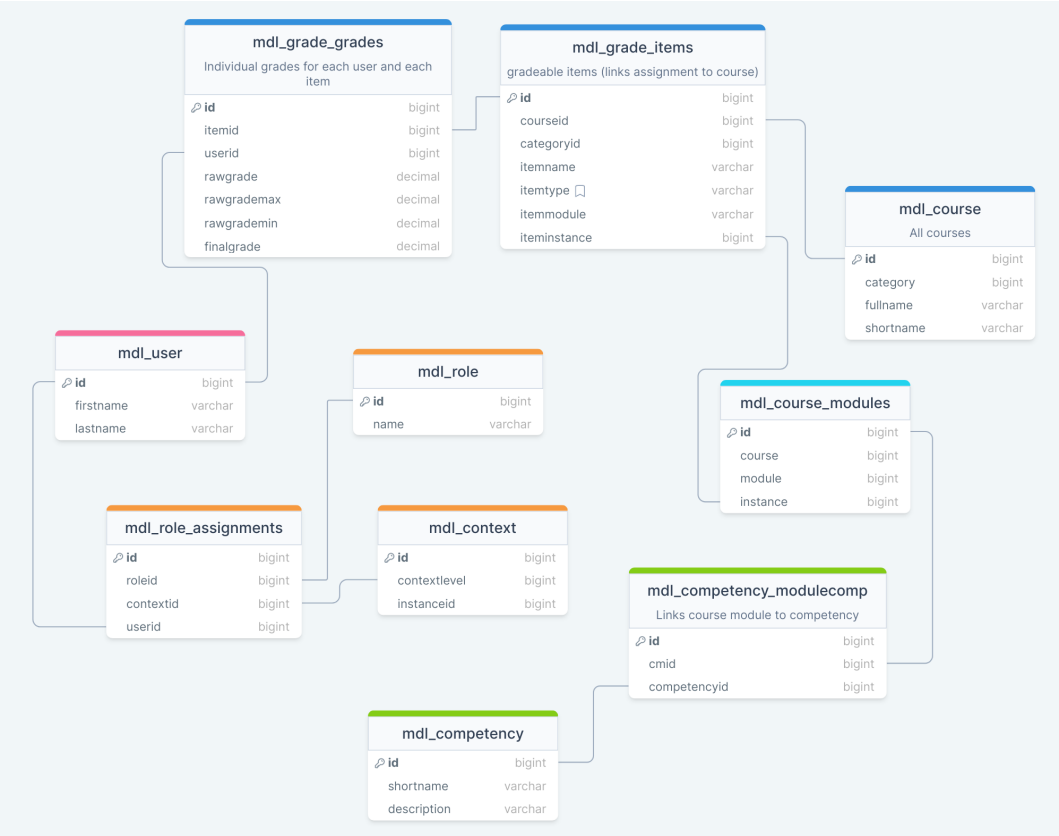


Figure 7.2: An entity-relationship model of the different database tables that were used (made with drawSQL.app)

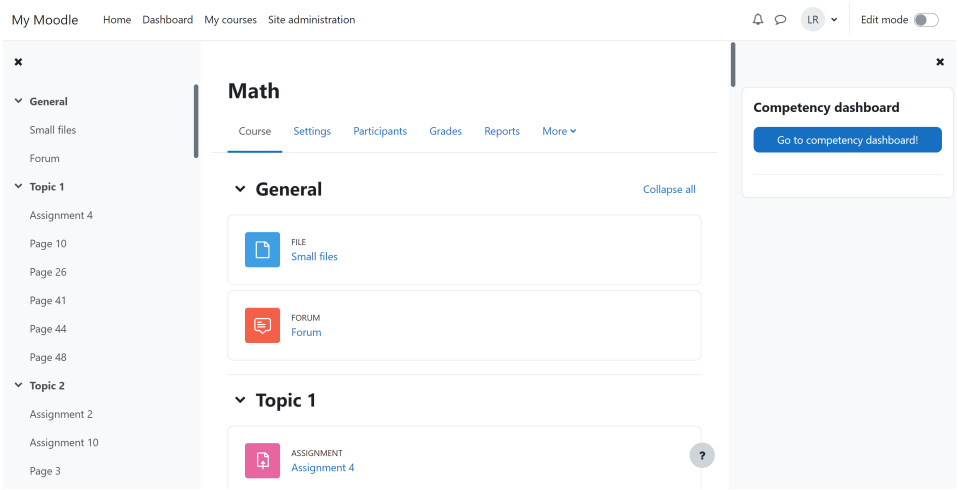


Figure 7.3: The Moodle block can be opened in the right side panel. (example course overview for math teacher in Moodle)

Chapter 8

Deploy: results

This chapter presents the results of the last two user studies conducted with the final, high-fidelity prototype discussed in the previous chapter. Section 8.1 provides an overview of the two user studies carried out to evaluate the dashboard. In Section 8.2, the findings of a thematic analysis performed on the collected data are presented. Finally, Section 8.3 highlights the key findings related to the three different visualisations of Frame 3 in the dashboard. This chapter aligns with the **deploy phase** described in the methodology.

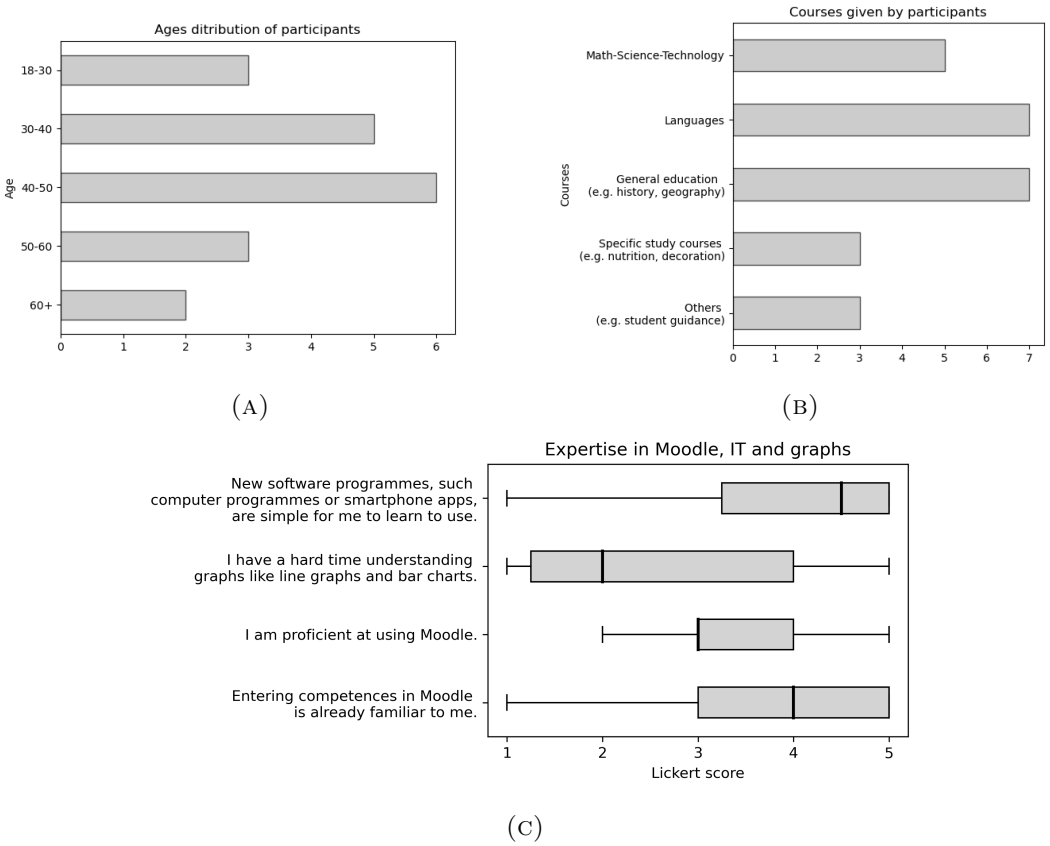
8.1 Study outline

Two studies will evaluate the final high-fidelity prototype through qualitative user studies. The first study will involve in-depth interviews, where teachers will interact with the dashboard using test data. The second study will be a trial period with a smaller group of two teachers, using real live data. This distinction was necessary due to the fact that (at this moment) teachers do not link end-terms with assignments, a problem that was already mentioned a few times. Consequently, when teachers would consult the dashboard, there would have been no available data to visualise. Both studies attempt to assess opinions towards the dashboard and towards its various visualisations, aiming to address the research questions effectively.

Nineteen teachers from three different secondary schools participated in the first user-study. The research was carried out on-site at each respective school. The approach of this first study consists of three parts. First, the participating teachers will be provided with a tutorial to enhance their understanding of the dashboard's visualisations. Next, an in-depth interview was conducted, going over each visualisation (using the "within-subjects" design strategy) to explore preferences and potential use cases. Finally, a questionnaire with four parts was filled in to strengthen the qualitative study with qualitative results.

The first part of the questionnaire consisted of demographic questions targeting the participants' age, the courses they teach, and their proficiency in Moodle, IT, and

graph comprehension. These results can be found in Figure 8.1. The second part was a SUS questionnaire [6] to assess the dashboards user-friendliness. The third part involved a questionnaire, adapted from Gutiérrez et al.'s [19] study, to evaluate the dashboard's usefulness (further referred to as the LADA questionnaire). Lastly, the participants were requested to complete the EFLA questionnaire [37], specifically designed to measure the impact of learning analytic tools for teachers. The findings from these last three parts will be discussed in the next section.



(A) (B)

(C)

Figure 8.1: Detailed information about the participants of first user-study

The second user study was a trial period where two teachers interacted with the dashboard for a week, using their own class data. To gather the outcomes of this study, an interview was conducted after the trial period. Additionally, Google Analytics[1] was employed to record data on the frequency of dashboard usage by the teachers.

[1] https://analytics.withgoogle.com

8.2 Thematic analysis

This section presents the outcomes of a thematic analysis conducted on the collected data. The analysis identified six prominent themes: Usability and user experience, Usage, Helpful Insights, Actionable content, Problems and threats, and Extensions. Figure 8.2 provides an overview of these themes and subthemes, including their relationships. The thematic analysis was made with the notes and recordings of the nineteen in-depth interviews. Moreover, certain findings are strengthened by the inclusion of quantitative data. The results of three questionnaires – SUS, LADA, and EFLA – are presented in Figures 8.3, 8.4, and 8.5, respectively.

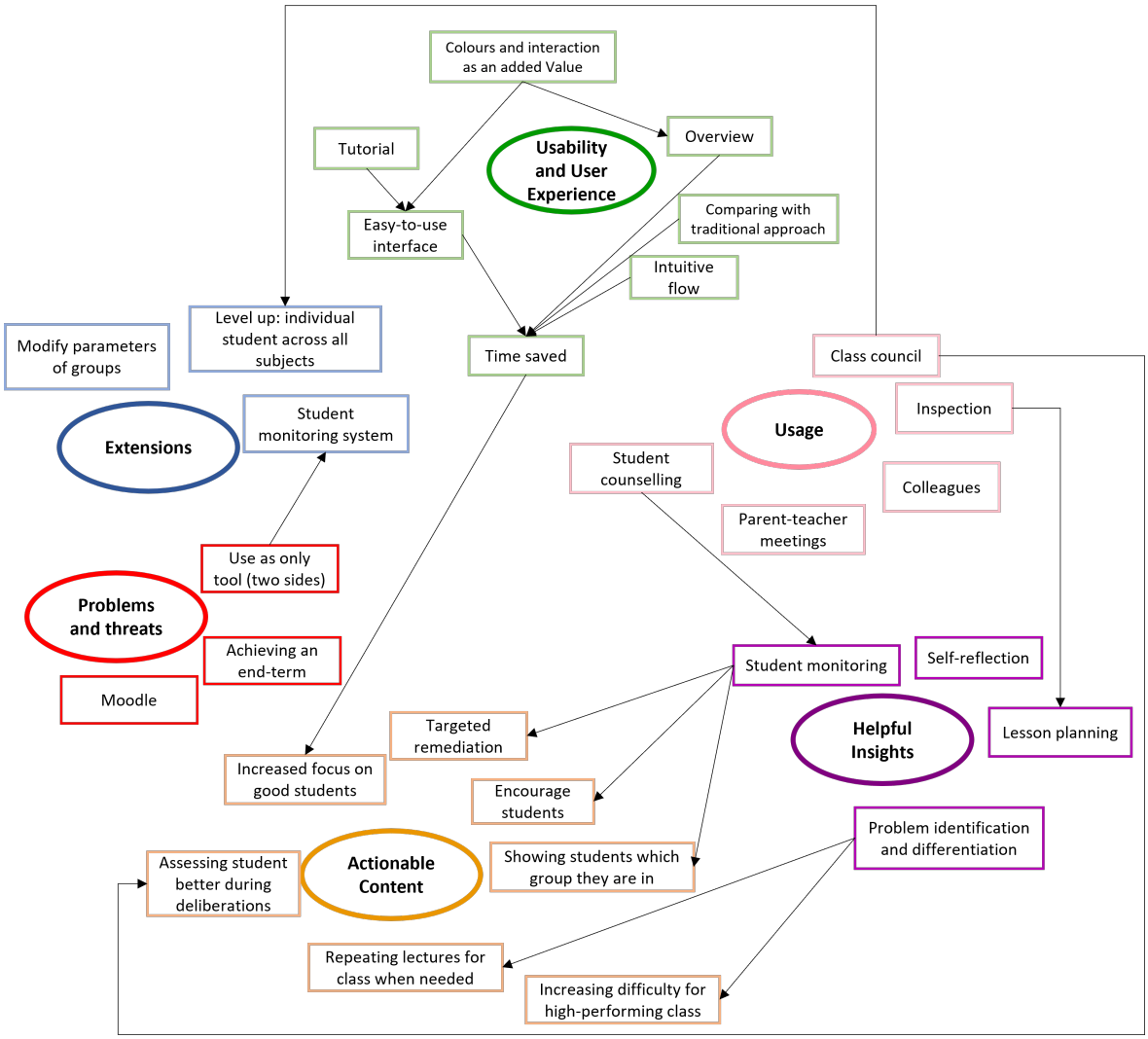


FIGURE 8.2: Thematic analysis scheme

8.2.1 Usability and user experience

This section explores the participants' responses related to the usability and user-friendliness of the dashboard. The SUS score gives a good initial picture about the usability of the dashboard. The result on the SUS questionnaire is 85.7, as shown in Figure 8.3, this result falls within the 'excellent' group.

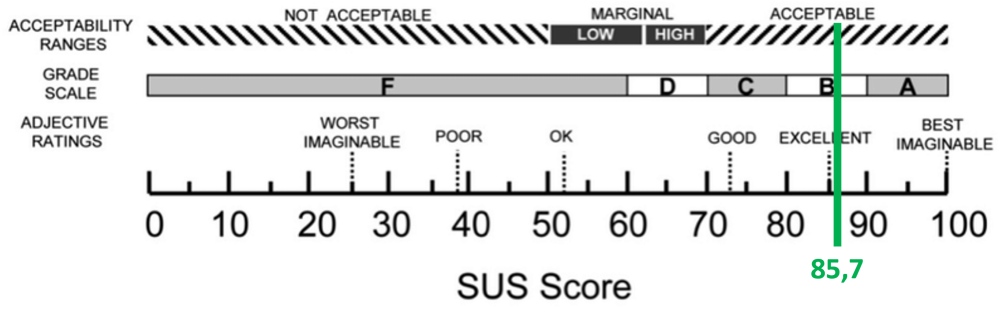


Figure 8.3: SUS score (image from [6])

Overview The participants consistently praised the dashboard's ability to provide a quick and comprehensive overview of their class (16/19). This feature proved particularly valuable for teachers managing a large number of students. When discussing the overview aspect, the teachers highlighted the convenience of having everything accessible in one view, eliminating the need for additional tabs or windows. Additionally, they expressed appreciation for the four groups in Frame 1 (13/19), which condensed the essential information and allowed for a clear and concise understanding of the data.

Easy-to-use interface Observing how effortlessly the teachers interacted with the dashboard indicated their familiarity with its interface. Eight teachers explicitly mentioned their ease in navigating the dashboard.

Furthermore, two teachers emphasised the importance of a simple interface, considering it a prerequisite for teachers to fully engage with such a tool. One teacher said: *"The KISS [Keep it simple, stupid!] principle is extremely applicable here for my colleagues"*. The dashboard's design took this into account and provided a user-friendly interface, ensuring a smooth on-boarding experience for teachers.

Time saved Many teachers (10/19) emphasised the time-saving benefits provided by the dashboard. They mentioned their preparation time of daily work (7/10), class councils (9/10) or parent-teacher meetings (6/10) would decrease a lot. The ability to gather relevant insights efficiently ultimately resulted in significant time savings for teachers.

This time-saving advantage is also evident when examining the qualitative results (*question 2*, Figure 8.4). A significant majority indicate that it would accelerate

their decision-making process compared to their usual approach. However, 35% of respondents provided a neutral response to this question. They explained that the extent of time saved depends on the additional data entry required to link end terms with competencies.

Intuitive flow The navigation and structure of the dashboard were frequently brought up by the participants. They appreciated the logical thought process between Frame 1 and Frame 3. Starting with an overview in Frame 1 and gradually diving into more detailed information in Frame 3 (4/19). Additionally, the presence of breadcrumbs (4/19) was mentioned as a helpful feature to prevent users from getting lost within the dashboard's interface.

Colours and interaction as an added value Participants consistently noticed the colours located in Frame 1 (14/19). These colors were described as highly visual and easy to comprehend. Furthermore, the interaction between the visualisations within the dashboard was repeatedly mentioned as a positive feature (3/19). Both colour and interaction enhanced user engagement.

Comparing with traditional approach The benefits of the dashboard are further confirmed when compared with the current approach. Now, teachers use a grade list in Moodle. However, the dashboard provides a quicker summary in a clearer way (9/19). These findings are further supported by the results of *question 1* (Figure 8.4) in the qualitative responses.

Tutorial Some teachers (4/19) explicitly mentioned the tutorial provided for the dashboard. They found the video tutorial to be well-structured and appreciated that it effectively delivered all the necessary information in just 6 minutes.

Lesson learned 1 (simple and time-efficient): In order for teachers to adopt a new tool, it is crucial that it offers a high degree of simplicity and time efficiency. The inclusion of breadcrumbs, color-coded elements, an intuitive user flow, and a concise class overview (Frame 1) can contribute to fulfilling these requirements.

8.2.2 Usage

When looking at *question 7* (Figure 8.4), 64% of the teachers express their preference to incorporate the dashboard into their daily work. Conversely, the remaining respondents answer opposite or neutral. They prefer only to employ the dashboard during significant occasions such as class councils and parent-teachers meetings. These "larger events" are further discussed in this section.

Student counselling Teachers (3/19) found the dashboard to be a valuable resource for student counselling. The insights and actionable content can be find in the next themes.

Parent-teacher meetings Teachers (9/19) reported that the dashboard would help in the preparation process for parent-teacher meetings. By having an overview of each student performance, teachers could effectively communicate student progress, strengths, and areas for improvement to parents. Some teachers even expressed a desire to show Frame 1 of the dashboard during parent-teacher meetings, enabling them to address parental concerns and demonstrate students' academic performance.

Class Council/Deliberations The dashboard can serve as a preparation tool for class councils (13/19). Also during deliberations the dashboard could be helpful. See the subtheme 'Assessing student better during deliberations' for insights that could help students assessment.

Collaboration with colleagues Teachers found the dashboard valuable for collaborating with their colleagues (5/19). It helps transfer knowledge when passing on a class to a colleague for the next academic year. Additionally, teachers who shared teaching responsibilities for a specific subject found the dashboard beneficial in gaining insights into their colleague's areas of focus and what had already been covered.

Inspection The dashboard can help in preparation for inspections (3/19). See the subtheme 'Lesson planning' for the helpful insight.

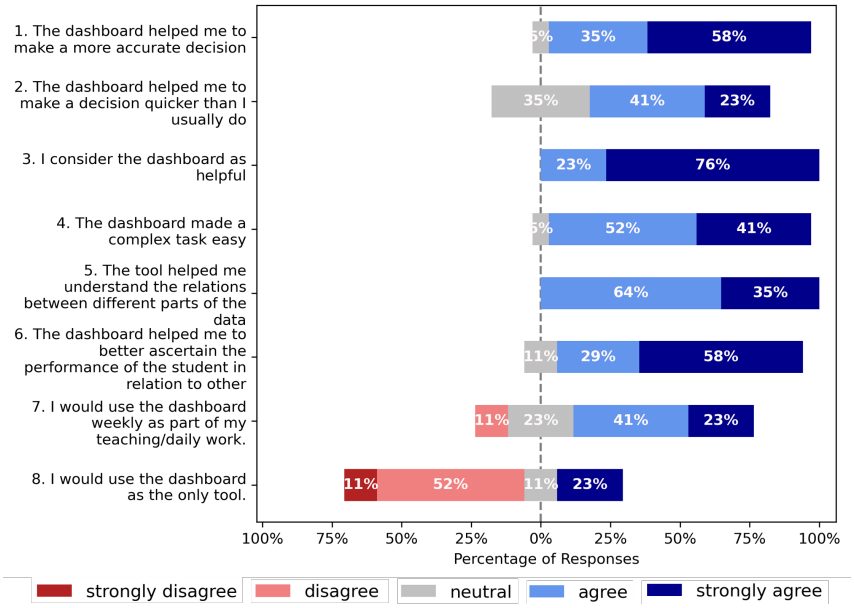


Figure 8.4: Quantitative results (LADA)

8.2.3 Helpful insights

Problem identification and differentiation Teachers used the scatter plot to identify problem for a specific competency (8/19). They distinguished between whole-class problems and individual problems. If a competency was not understood by the entire class, teachers would repeat the content in class. However, when only some students struggled, they would provide individual extra exercises.

Student monitoring The four distinct groups in Frame 1 were primarily used by teachers to quickly assess the overall class and determine the position of individual students (10/19). The differentiation between growth and decline was highlighted as a valuable feature. This allowed teachers to identify students who required additional support and closely monitor their progress. The qualitative results (*question 11*, Figure 8.5), provide additional evidence that teachers are indeed more aware of their students' learning situations.

Self-reflection Many teachers (10/19) regarded the dashboard as a feedback tool for their own teaching practices. By analysing the results of the students, teachers could reflect on their teaching strategies and identify areas for improvement. *Question 13* (Figure 8.5), which indicates that teachers will engage in greater reflection on their teaching style, aligns with these findings.

Lesson planning Teachers used Frame 2 to look how much a certain competency was already covered in their lesson plans (6/19). By reviewing the data, they gained insights into which competencies had been addressed and where they need to invest additional time. One teacher also addressed that it is important that all final end-terms have been covered at the end of the year due to inspection, the dashboard would also help with this process.

8.2.4 Actionable Content

Repeating lectures for class when needed Teachers (4/19) indicated that they would repeat lectures for the class when it becomes clear that a specific topic was not well understood. This action aims to address gaps in understanding.

Increasing difficulty for high-performing class Two teachers expressed their intention to use the dashboard to adjust the level of difficulty for high-performing classes. By recognising that the assignments may be too easy, they can raise the bar and provide more challenging content.

Showing students which group they are in Teachers (5/19) mentioned using Frame 1 with the four groups to show students their position in the class. This is particularly useful for students in the declining trend (light green group or red group) as it allows teachers to intervene quickly.

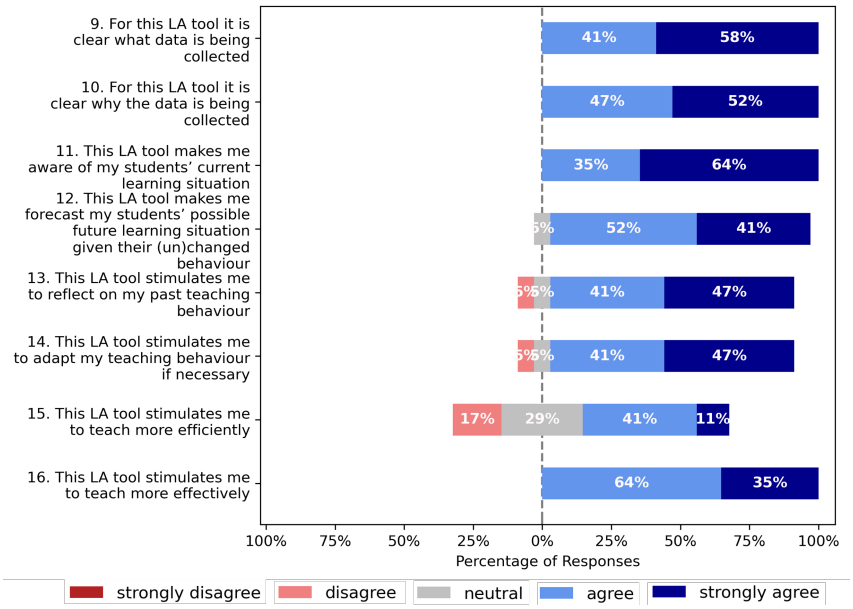


Figure 8.5: Quantitative results (EFLA)

Encourage students The "FAILED/GROWTH" group (pink) in the dashboard is used by teachers to encourage students (4/19). This information is otherwise not available.

Targeted remediation Nearly half (9/19) of the teachers reported using the dashboard to provide targeted remediation. By gaining insights into specific areas of weakness, tasks can be much more precisely targeted.

These findings can be further strengthened when looking at the results of *question 16*. All teachers feel that the dashboard can encourage them to teach more effectively. However, when assessing the question related to "efficiency" (*question 15*) the scores are notably lower. In this context, effectively refers to the willingness to modify the content of their teaching based on the provided information. Nevertheless, it does not imply a willingness to alter their teaching style in the sense of their personality, as this is how they interpret 'teach more efficiently'.

Increased focus on good students Two teachers mentioned that the availability of the dashboard allowed them to allocate time to focus on the high-achieving students in the class, which is now not the case due to lack of time. Teachers can provide more targeted feedback for these students to.

Assessing student better during deliberations Some teachers (4/19) emphasised the potential benefit of the dashboard for student assessments during deliberations. These days, failing a class can results in a student not being allowed to go to following year. However, in the event that a student successfully attains the

competencies necessary for the next year and only struggles with competencies of less significance for the following years, they might let the student pass.

Lesson learned 2 (benefits for students): The dashboard also provides significant benefits for students, including targeted remediation, increased encouragement, and improved assessment during deliberations. Even high-performing students can now receive enhanced support, thanks to the increased time available to teachers, allowing them to better assist all students.

8.2.5 Problems and threats

Use as only tool (two sides) The quantitative data analysis revealed that the question regarding the dashboard as the only tool (*question 8*, Figure 8.4) obtained a significantly lower score compared to other questions. Several arguments were provided by teachers to explain why they do not prefer using the dashboard as the sole instrument. Participants highlighted the following concerns:

- The inability to give comments or take notes within the dashboard, requiring the use of other documents to write that information down (2/19).
- The essential role of the teacher in the assessment process, emphasising the importance of not only relying on grades. Teachers stressed the need to consider other factors such as behavior and student monitoring systems. (5/19).

However, it is important to note that some teachers interpreted the question differently, considering it as the only instrument for viewing results. In this context, they were favourable to using this dashboard as the only tool.

Achieving an end-term Two teachers found it less clear to determine when a student has achieved a specific end-term. For instance, if a student begins with four low grades but afterwards achieves two good grades, teachers argued that the student should be considered to have attained the competency. However, in the dashboard, only the deficiency would be visible, leading incomplete assessments.

Resistance towards Moodle Strong resistance (10/19) was encountered regarding the acceptance and use of Moodle as a LMS, which poses a potential obstacle to the use of the dashboard. Comments regarding the current Moodle system indicated a lack of comprehensive overview, absence of visualisations, poor user-friendliness, challenges to enter data, and difficulty to retrieve information due to the variety of different windows. However, several teachers (5/19) expressed their willingness to embrace Moodle if the dashboard could be integrated into the platform.

8.2.6 Extensions

Level up: individual student across all subjects Teachers (7/19) expressed the interest in having the option to view student performance at a higher level,

where they could see the progress of an individual student across all subjects. This extension would allow for the inclusion of cross-disciplinary end-terms, providing insights into whether a student is struggling in a specific subject or facing challenges across the board. This extension is valuable in helping head teachers and for class councils to get a clear overview of a student's academic trajectory.

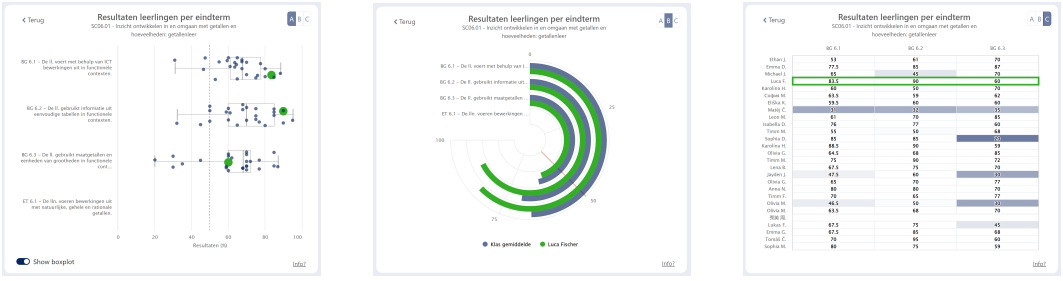
Modify parameters of groups In Frame 1, some teachers (3/19) expressed the desire to have the ability to modify the parameters of growth and decline for different subject groups. By allowing this customisation of these parameters, teachers could set more precise thresholds based on the unique requirements of each subject.

Student monitoring system Teachers (3/19) indicated that when selecting a student, it would be beneficial to have access not only to the student's results and competencies but also to a brief overview of the student's monitoring system. This overview could include information such as challenging home situations, ADHD, dyslexia, etc. Having such information would provide teachers with a better understanding of the context and needs of each student.

Lesson learned 3 (not only assessing on results): The dashboard provides a complete overview of student performance in the class based on results. However, teachers have highlighted the importance of considering additional factors such as behavior and student monitoring systems to properly assess a student. These elements are currently missing in the dashboard, limiting its ability to provide a complete evaluation.

8.3 Visualisation-based analysis for Frame 3

This section presents the key findings related to the three different visualisations of Frame 3 (recap in Figure 8.6). The structure for this section was inspired by a paper by Schnabel et al. [38], where each visualisation and its respective key findings were discussed following a qualitative study.



(A) Scatterplot with boxplot (B) Bar chart (C) Table

Figure 8.6: Recap visualisation of Frame 3

8.3.1 Scatterplot with boxplot as favourite boxplot

Teachers (15/19) widely regarded the scatterplot as their preferred visualisation within the dashboard. The scatterplot stood out due to being the only visualisation to display both the distribution of an individual student and the distribution of the entire class. Participants expressed their appreciation for its clarity and ability to provide a comprehensive overview. Quotes from participants highlight their positive views:

- P7: "I find this one very clear because you can see where the class and the student are situated."
- P8: "It's very easy because you can click on a student and see their position in comparison to the class without revealing the identities of other students."
- P17: "I would use this one the most; everything is clear at a glance."

Boxplot During the study, four participants expressed curiosity about the boxplot visualisation, as they were unfamiliar with its representation. An explanation of the boxplot's meaning and functionality was given to those participants during the study and where offered the ability to enable or disable the display of the boxplot. However, none of the participants opted to disable the boxplot, indicating a preference for its inclusion alongside the scatterplot.

Lesson learned 4 (scatterplot): The scatterplot emerged as the preferred visualisation among teachers. Teachers appreciated its ability to display both individual student performance and the distribution of the entire class, providing a comprehensive overview at a glance.

8.3.2 Bar chart as least favourite visualisation

The bar chart emerged as the least preferred visualisation tool among teachers. Teachers (9/19) expressed that it required more effort to extract information compared to other visualisations.

- P10: "For me, this is more difficult."
- P16: "It doesn't say much. I will use it less, but it's not difficult or anything."
- P17: "I find it very difficult to read, I have to think harder about it."
- P19: "I would extract less information from this."

Two teachers suggested a potential solution to enhance the comprehension of the bar chart by making it vertical instead of using a radiant format.

- P6: "I don't find the circular format convenient, the 100% is placed strangely. The circle creates an extra difficulty."

Class average not representative Many comments (10/19) centered around the class average, which was highlighted as a reason not to use this visualisation. Teachers emphasised that relying solely on the class average could provide a biased picture and that the distribution displayed in the scatterplot option (Option A) allowed for a clearer understanding of the class performance.

- P12: "The class average can give a distorted image."
- P3: "The class average doesn't say much, I prefer Option A for the class distribution."

Usage When asked if and when they would use this visualisation, the answers where divided. Some (5/19) said they would use it to show to an individual student if they need to let them see where it goes wrong. However, three of teachers expressed a stronger opinion, suggesting the removal of the bar chart altogether.

- P5: "I would remove that bar."
- P9: "I find it of little added value, I would leave it out."
- P10: "Option A [Scatterplot] says enough for me."

Lesson learned 5 (class average): Teachers raised concerns about the class average displayed in the bar chart. They felt that the class average could give a biased or distorted image of student performance.

8.3.3 Divided opinion about the table visualisation

Opinions regarding option C, the table, are divided into two groups. The first (10/19) group finds it too crowded and overwhelming, and they do not see the added value compared to option A (scatterplot). Quotes from this group include:

- P6: "Too crowded, it doesn't convey much."
- P7: "It's a bit overwhelming and requires more searching. I find it the least organised, the others were more visual."
- P17: "Raw data doesn't convey much."
- P18: "More traditional, but a dashboard should provide an overview, so I choose option A."

On the other hand, the second group (6/19) holds the opposite view. They find the table the easiest to understand because it closely aligns with their traditional way of working (using a gradebook). This visualisation feels the most familiar and trustworthy to them. They would use it to obtain a detailed overview, particularly useful during deliberations. However, some teachers in this group acknowledge that the table can present too much information at once, so they would only use it to look at one specific student. Quotes from this group include:

- P3: "I would start with option C. [...] it resembles what we now use."
- P18: "This is my favorite, it's the easiest and feels more familiar to me."

Since there is a clear dichotomy present, it is meaningful to examine the trends between these two groups. Table 8.1 provides a comparison of the two groups based on their responses to the demographic questionnaire filled out during the user study. Six teachers expressed a preference for the table, while 10 teachers opposed the visualisation. For the sake of clarity, the three teachers who did not provide a specific opinion were omitted. The analysis focuses on four categories: age, teaching STEM subjects, IT expertise (referring to the question "New software programmes, such computer programmes or smartphone apps, are simple for me to learn to use."), and graph comprehension (referring to the question "I have a hard time understanding graphs like line graphs and bar charts.").

Due to the small number of participants, strong conclusions cannot be drawn from the analysis. However, interesting trends can still be observed in Table 8.1. In terms of age, it is not necessarily the case that older teachers prefer the more traditional table (which one might think at first). All teachers of STEM subjects expressed a dislike for the visualisation. When it comes to IT expertise, it is challenging to draw meaningful insights as many participants indicated high IT expertise although there was clearly a reluctance and difficulty when they had to work with the computer during the user-study. Therefore, it would be valuable to ask more specific questions to gain a better understanding. Regarding graph comprehension, no significant patterns can be identified from this category.

Examining these differences between groups is only feasible using the findings obtained from the table visualisation. Other findings, derived from the thematic analysis or the two other graphs of Frame 3, did not reveal a distinct dichotomy among the participants and, therefore, cannot be subjected to such analysis.

Lesson learned 6 (table): Opinions on the table visualisation (option C) were divided. Some participants found it overwhelming and lacking in added value compared to other visualisations. However, another group favored the table as it was familiar and gave more trust. STEM teachers generally disliked the visualisation, and older teachers did not show a preference for the traditional table.

Table 8.1: Demographic questionnaire responses split into two groups: those who preferred the table visualisation and those who did not.

		Likes table Total: 6	**Dislikes table** Total: 10
Age	18-30	1	2
	30-40	3	1
	40-50	1	4
	50-60	1	1
	60+	0	2
Teaching STEM	Yes	0	3
	No	6	7
IT expert	Yes	5	7
	No	1	3
Graph expert	Yes	3	8
	No	3	2

Chapter 9

Discussion

This chapter aims to analyse and interpret the results obtained in Chapter 8. Section 9.1 discusses each research question, presenting the corresponding results and their link to prior research. In Section 9.2, the limitations of this research are listed.

9.1 Research questions

This section explores the findings related to the two research questions outlined in Section 2.5, providing an interpretation of the results and link these with previous research.

Research question 1: What analytic insights does a teacher need to have a more comprehensive view of the students current results and evolution, to support their pedagogical actions?

Goal 1: Useful and actionable content

To address this research question, the study employed a user-centered design approach, emphasising the importance of gathering input from end users. This approach aligns with the **understand phase** of the methodology. Two studies, namely a focus group and a requirement analysis meeting, were conducted to ensure that teachers' perspectives and requirements were taken into consideration. The outcomes of these two studies identified insights as: a better understanding of individual students' struggles, gain insights into their competencies, and assess overall class performance across different competencies. These insights were then incorporated into the dashboard in the next step of the design process (ideate phase).

The results presented in Section 8.2 demonstrated that the dashboard successfully addressed the requested insights and, in fact, additional insights were highlighted by the teachers. The competency dashboard provided helpful insights as well as actionable insights to the teachers, fulfilling the goal of this research question.

The **helpful insights** included problem identification and differentiation, student

monitoring, self-reflection, and lesson planning. These findings are consistent with prior research that highlights the importance of providing teachers with information regarding student progress, guide their interventions, lesson preparation, and student support [20, 44]. One interesting finding (lesson learned 2) was that the competency dashboard not only benefited teachers but also had significant advantages for students (including targeted remediation, increased encouragement, support for high-achieving students), thanks to the insights teachers can obtain and the increased time they have available.

Furthermore, the dashboard provided **actionable content** that allowed teachers to take specific pedagogical actions. Examples of these actions included repeating lectures when necessary, adjusting the difficulty level for high-performing students, informing students about how they are doing, providing encouragement, offering targeted remediation, focusing on high-achieving students, and enabling better assessment during deliberations. Due to the underexposure of 'impact' and 'actionable content' in existing research [39, 46], the findings of this study make a valuable contribution to the field of HCI.

A valuable finding (lesson learned 3) highlighted the significance of taking into account factors other than results when evaluating students. The dashboard provided an overview of student's performance based on results, however, teachers highlighted the need to incorporate other aspects such as **behaviour and student monitoring systems**. This suggestion is confirmed by research, which indicates an important relationship between the affective state and student performance [8], and highlights the importance of teachers anticipating and responding to student emotions for successful learning outcomes [15]. Currently, the dashboard does not integrate these elements, limiting its ability to provide a complete assessment.

This research successfully answered the first research question by identifying the analytic insights required by teachers to gain a comprehensive view of their students' results and evolution. The objective of developing a learning analytics dashboard that offers useful insights and actionable content benefiting teachers (and even students), has been achieved. Nevertheless, future improvements could take into account the inclusion of additional factors, such as student behaviour, to enable a more complete evaluation of students.

Research question 2: How should learning data be visualised such that all teachers, regardless of educational background or IT knowledge, can easily understand and use the dashboard?

Goal 2: Usable design

To address this research question, the study applied an iterative design process, starting from the insights gathered during the understand phase. This research question was mainly addressed in the **ideate phase** and **make phase**. The aim was

to visualise these insights in an understandable way. Multiple visualisations were considered in Section 6.1.3, eventually narrowing down to three main visualisations: a scatterplot, a bar chart, and a table.

The thematic analysis conducted in Section 8.2 revealed a high SUS score (of 85.7) and positive feedback regarding the usability of the dashboard. The importance of **simplicity and time efficiency** in the adoption of a new tool by teachers (lesson learned 1) was found as an important design requirement. Dashboard that are too complex or are time-consuming to retrieve insights from, was also mentioned by Tavers et al. [44] as a problem that lead to teachers not using the dashboard. Features such as breadcrumbs, colour-coded elements, an intuitive user flow, and a concise class overview in Frame 1 contributed to meeting these requirements. These features and the entire design of the dashboard were created with the design principles of Stephen Few [16] in mind because it was important to limit the visualisation mistakes.

In terms of the specific visualisations, several lessons were learned. Lesson learned 4 highlighted the preference for the **scatterplot** among teachers. The scatterplot was appreciated for its ability to present individual student performance as well as the overall class distribution, providing an overview at a glance.

Concerns were raised about the **bar chart**, being the least favourite visualisation. As bar charts are the most popular graph to visualise data in learning analytics dashboards [39], this is a conflicting finding. However, the dislike of the bar chart is a result of two issues: the class average and the radiant shape. Teachers felt that the class average could give a biased or distorted image of a student's performance (lesson learned 5). The radiant shape of the bar chart made it difficult to extract information and insights. These two issues could be avoided in future development.

Opinions on the **table** visualisation (option C) were divided (lesson learned 6). Some participants found the table overwhelming and saw no added value compared to the other visualisations. These comments are in line with prior research, stating that tables are time-consuming and do not have a clear benefit [43]. However, another group favoured the table because it was familiar and gave more trust. As teachers currently use gradebooks, this is not an abnormal finding. When looking for trends between these two groups, we found that STEM teachers generally disliked this visualisation, and more experienced teachers did not show a preference for the traditional table. The takeaway that can be retrieved from these findings is that the designer must take into account the different preferences of teachers, as some are pro changes and others like to stick with traditional approaches.

The findings indicate that a usable design for the learning analytics dashboard was achieved, enabling teachers to easily understand and use the visualised learning data. The scatterplot emerged as the preferred visualisation, providing an overview of individual student performance and class distribution. Nevertheless, future developments should be cautious using radiant bar charts and class averages. Additionally,

it is important to remember that although there is a specific target group of secondary school teachers, some of them prefer sticking to traditional approaches while others are open to new visualisations. However, this tendency towards traditional methods does not extend to the dashboard, as almost all teachers wanted the use the dashboard next school year.

9.2 Limitations

It is crucial to acknowledge the limitations of this research. This section discusses three limitations of the thesis:

1. Lack of available data: This research presents a state-of-the-art approach as it uses a relatively new competency framework as its foundation. However, due to the newness of this concept, there is a limited amount of available data. The hesitancy to add competency data into Moodle presented a significant challenge, which made the research more complicated. The development of a dashboard relies heavily on data availability, which was unavailable. Resolving this issue entails giving the teachers something in return for their afford. However, this creates a paradoxical situation where we need data to create the dashboard, but we also need the dashboard to motivate data collection. As a solution, test data was used instead of real-time data, although this compromises the accuracy of the studies. At the end of this research we can conclude that this problem is solved, as teachers were genuinely motivated to enter data due to the perceived benefits of using the dashboard.

2. Time constraint: The two final evaluations should ideally be conducted over a longer period. The trial period for the dashboard was only one week, and the in-depth interviews captured teachers' first impressions of the dashboard. The results of these studies indicated that teachers also expressed interest in using the dashboard for larger events such as parent-teacher meetings, deliberations, and student counselling, among others. The use and impact of the dashboard in these situations should be further investigated. This constraint is directly linked to the previous data limitation and is also a result of the time limitations of the thesis.

3. Need for affective state: The importance of considering the affective state of students has been highlighted by teachers and supported by research [8, 15]. Factors such as behaviour, challenging home situations, ADHD, dyslexia, and student emotions contribute to gaining a correct understanding of students. While the initial prototypes aimed to incorporate this data into the dashboard, limitations arose due to the unavailability of this data in Moodle. That is why this idea could not be further elaborated.

Chapter 10

Conclusion

This master's thesis focused on designing, developing, and evaluating a learning analytics plugin for Moodle, specifically targeting secondary school teachers. The plugin functions as a learning analytics dashboard, providing a visual overview of essential information from learning analytics. The goal was to assist secondary school teachers by offering them the necessary information to gain a better understanding of their students, make informed decisions, and reduce administrative tasks.

10.1 Results of research questions

This thesis addressed research gaps in the field of LA and tried to provide valuable insights into the design and development of a learning analytics dashboard for secondary school teachers. These gaps include the lack of input from stakeholders, misinterpretations of visualisations, and the limited impact of current learning dashboards.

To achieve these objectives, an established design methodology, the "Design Activity Framework for Visualization Design" [26], was adopted. This iterative approach consists of four activities: understand, ideate, make, and deploy. Through preliminary studies, focus groups, and requirement analysis meetings, teachers' specific requirements were identified. Multiple prototypes were developed and one proof-of-concept was evaluated through interviews and think-aloud studies. The final design was implemented and deployed into a functional Moodle plugin and evaluated through qualitative user studies.

The first research question, regarding the analytic insights needed by teachers to comprehend their students' results and progression, has been successfully answered. The learning analytics dashboard developed in this thesis provided useful insights and actionable content, benefiting teachers and students. However, future improvements could consider incorporating additional factors, such as student behaviour, to enable a more complete evaluation.

The findings reveal that a usable design for the learning analytics dashboard has been achieved, enabling teachers to easily understand and utilize the visualized learning data. The scatterplot visualisation came up as the preferred choice, offering an overview of an individual student as well as class performance. However, we learned that one should be cautious with radiant bar charts and class averages. Additionally, secondary school teachers have diverse preferences, with some favouring traditional approaches and others being open to new visualisations.

These contributions will be made available in a paper, with the goal of submitting this paper to the LAK conference of 2024.

10.2 Contribution to human-computer-interaction field

The list below shows what this research has contributed to the field of human-computer-interaction:

1. The visualisation techniques and usability improvements stated in the results and discussion of this research can be useful to gain new insights into the development of tools specific to secondary school teachers.

2. By employing a user-centred design, the first step of this research was to understand what the requirements of secondary teachers were (understand phase). Next research could use these findings to ensure it meets the specific needs of teachers, resulting in a more helpful tool.

3. The source code of the dashboard is available on GitHub, contributing to the open-source Moodle community and their developers to get inspired for future research. The code is available at: *https://github.com/LaraRoosens/Competency-Dashboard*

10.3 Contribution to the educational field

The competency dashboard is a working and functional Moodle plugin that can be installed for schools using the Moodle LMS. During the research, the teachers and school of GITO Overijse (one of the participating schools) expressed great enthusiasm, **leading them to make the decision to adopt the dashboard starting from the next school year**. The dashboard will provide teachers with an enhanced overview of their students, thereby saving valuable time in the preparation of deliberations, parent-teacher meetings, and daily administrative tasks. Additionally, students will benefit from this, as teachers said they can do more targeted remediation, improved student monitoring, and increased attention for high-performing students, as the dashboard facilitates a quick and efficient overview.

10.4 Suggestions for future work

During the many conversations with teachers, we have come across ideas that are interesting to further explore. This section outlines some potential paths for future research.

1. During the last survey, teachers themselves indicated a valuable extension. They asked to extend the dashboard to an 'individual student' view. This view would show the same data for one student over multiple courses (as now the dashboards shows all students of one course). This extension would allow for the inclusion of cross-disciplinary end-terms, providing insights into whether a student is struggling in a specific subject or facing challenges across the board.

2. Another extension that was already pointed out by teachers themselves was making data available about students' behaviour and their student monitoring systems. Research also shows that there is an important relationship between a student's performance and their emotional state [8].

3. This research specifically examines the competency framework imposed by the Flemish government [50]. However, further investigation is required to explore the structure of other international frameworks and their potential integration into the dashboard. This may involve adapting the dashboard as the structure of different frameworks can differ.

Appendices

Appendix A

Ethics committee

Before this studies of this thesis could be organised, an ethics application had to be submitted to the KU Leuven Social Ethics Committee (SMEC). SMEC examined and approved this work (file numbers: G-2022- 5775, G-2022-6099). This appendix contains all application-related paperwork as well as the informational brochure for participating teachers.

DOSSIER: G-2022-5775-R2(MAR)

Versie 1.3
Status: Accepted

Datum goedkeuring: 14/11/2022 20:08:12

2.ALGEMEEN

ONDERZOEKERS

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Promotor: Katrien Verbert
Departement Computerwetenschappen
Mens-Machine Interactie (HCI), Leuven (Arenberg)
katrien.verbert@kuleuven.be
u0040828

Oefent de promotor een gezondheidszorgberoep uit in de zin van de wet van 10 mei 2015? nee

Andere KU Leuven onderzoekers:

FINANCIER

Wordt het onderzoek gefinancierd (bijvoorbeeld in het kader van een onderzoeksproject/ contract/ mandaat)? nee

Dienst die instaat voor afgesloten of nog af te sluiten contracten:

VOORNAAMSTE / LEIDENDE ETHISCHE COMMISSIE

De voornaamste / leidende ethische commissie: SMEC

3.ONDERZOEK

TITEL, BESCHRIJVING EN DOELSTELLINGEN

Unieke en volledige titel van het onderzoeksproject / protocol:

Het omzetten van leergegevens naar betekenisvolle learning analytics dashboards (Turning learning data into meaningful learning analytics dashboards)

Beschrijving van het onderzoeksproject / protocol:

Dit onderzoek is onderdeel van de bovengenoemde masterproef 'Turning learning data into meaningful learning analytics dashboards'. Deze masterproef wordt uitgevoerd door Lara Roosens, student ingenieurswetenschappen aan KU Leuven. Het doel van dit onderzoek zal een dashboard zijn, waarbij leerkrachten informatie kunnen terugvinden van hun klas en individuele studenten. Deze informatie kan variëren van bepaalde vaardigheden die de klas niet goed beheerst, de vooruitgang van een individuele leerling tot eventueel het mentaal welzijn van de klasgroep. Het is belangrijk dat het dashboard de leerkrachten geen extra taken oplegt, maar net de werkdruk kan verlichten.
Meer specifiek zal deze studie zich focussen op het middelbaar onderwijs, mits veel onderzoek vooral tijd hecht aan hoger onderwijs en dit een 'research gap' vormt in de studie rond learning analystics.

Deze aanvraag heeft enkel betrekking tot het organiseren van een focusgroep van vijf deelnemers (zie hieronder voor meer uitleg).

Doelstellingen van het onderzoek(sproject):

Deze voorstudie zal uitwijzen wat de problemen zijn waarmee leerkrachten worstelen en welke informatie hierbij zou helpen om dit op te lossen. Met als doel een learning analytics dashboard te maken die informatie geeft die voor leerkrachten echt nuttig kan zijn in hun dagelijks werk. En hopelijk als resultaat de zware werkdruk kan verlichten.
Deze informatie zal vergaart worden door een focusgroep te organiseren, waar vijf leerkrachten samen brainstormen in één lokaal.

ETHISCHE RECHTVAARDIGING ONDERZOEK

Omschrijving ethische rechtvaardiging onderzoek:

Sociale waarde - Doordat leerkrachten van het middelbaar onderwijs niet vaak de kans krijgen hun noden te verwoorden, geeft dit onderzoek hun een platform om hun problemen aan te kaarten en hier zelf eventuele oplossingen voor aangeboden te krijgen.
Wetenschappelijk geldig - Door dit onderzoek uit te voeren zal er een bijdrage zijn in zowel het onderzoek domein van Mens-Machine-interactie als meer specifiek het domein van learning analytics.
Eerlijke selectie van testpersonen - Er zijn geen selectiecriteria gehanteerd, de eerste 5 leerkrachten die toezeggen zijn geselecteerd.
Risk-benefit ratio - Niet van toepassing, mits er geen risico's verbonden zijn aan een onderzoek waarbij enkel gebrainstormd wordt.
Respect – Alle deelnemers zullen met respect behandelt worden)

Mogelijke nadelen/risico's en voordelen/bijdragen van het onderzoek op zowel individueel (bv. het risico dat een deelnemer besmet raakt met COVID-19):

ONDERZOEKSTECHNIEKEN, INSTRUMENTEN & APPARATUUR

Interview: ja

Niet-gevalideerd interview: ja

Geen bijlage beschikbaar: Vragenlijst voor het aantal jaren tewerkstelling in het onderwijs, de demografische informatie en het e-mail adres op te vragen.

Video/audio-opnames: ja

Tijdens de brainstorm sessie zal er een audio recording aanwezig zijn. Met als doel de sessie te kunnen herbeluisteren om de data efficiënt en correct te kunnen verwerken.

ONDERZOEKSMETHODOLOGIEËN

Methodologieën en praktische procedures:

De focus groep zal maximum één uur duren en zal volgende procedure volgen:
Inleiding – De deelnemers krijgen een kort overzicht van het lopende onderzoek en krijgen enkele voorgaande designs te zien van dashboards om een beeld te krijgen wat er verwacht wordt.

Brainstorm a.d.h.v. metaplan [1]– De start is een individuele brainstorm van 5 minuten waarbij de deelnemers hun ideeën mogen neerschrijven op 5 post-its. Deze post-its zullen één voor één overlopen worden met ruimte voor discussie en eventuele nieuwe ideeën. Alle post-its worden uiteindelijk gegroepeerd op een groot bord. Finaal zal er nog een 'dot voting' gebeuren waarbij elke deelnemer mag aanduiden welke ideeën de meeste prioriteit hebben voor hem/haar.

Eerste schets – Met deze ideeën in het achterhoofd zullen de deelnemers samen met mij een eerste schets maken van een dashboard. Met de vraag: 'hoe zien jullie deze ideeën samen komen op een dashboard?'.

Aspecten van het onderzoek die een eventuele verstrenging van de maatregelen rond COVID-19 zouden bemoeilijken:

Voor deze techniek is het vereist dat alle deelnemers in één ruimte te zitten. Indien er striktere Covid maatregelen worden opgelegd, kan deze sessie volledig online plaatsen vinden via een online call.

VERWACHTE BEGIN- EN EINDDATUM

De verwachte begindatum van het experiment / de studie (dient in de toekomst te liggen) en de verwachte einddatum voor de deelnemers:

Begindatum: Het onderzoek start van zodra ethische goedkeuring wordt gegeven door SMEC.
Einddatum: 8/06/2023

4.VERZAMELEN EN DELEN VAN PERSOONSGEGEVENS IN DE STUDIE

PRIMAIRE/SECUNDAIRE GEGEVENSWERWERKING

Verzamelt u nieuwe gegevens (primaire verwerking) en/of gebruikt u enkel eerder verzamelde gegevens (secundaire verwerking)?
Primaire verwerking: ja
Secundaire verwerking: nee

EXTERNE PARTNERS

Andere niet KU Leuven onderzoekers:

Het betreft een niet-commerciële studie.
Is er naast KU Leuven nog een andere universiteit, onderzoeksinstelling of andere partner betrokken bij het onderzoek? nee

ROLLEN VAN DE BETROKKEN PARTIJEN

Wie bepaalt de doelstellingen van het onderzoek?
Dit wordt binnen KU Leuven bepaald.

Is er een andere partij betrokken die als verwerker in opdracht van KU Leuven (al dan niet samen met anderen) persoonsgegevens verwerkt (zoals bv. data verzamelen; analyses uitvoeren)? nee

DOORGIFTEN EN DELEN VAN PERSOONSGEGEVENS

Zullen de verzamelde persoonsgegevens worden doorgegeven aan/gedeeld met personen/instanties buiten KU Leuven?
nee

PLAATS DATAVERWERKING

Waar zal de dataverzameling worden uitgevoerd?
België: ja

5. DEELNEMERS EN CATEGORIEËN VAN GEGEVENS

CATEGORIEËN VAN BETROKKENEN

Persoonsgegevens die u onderzoekt / verwerkt:

De leerkrachten die deelnemen aan de focusgroep.

Zijn er kwetsbare personen betrokken? nee

Selectiecriteria:

De deelnemers moeten leerkrachten zijn die onderwijs geven in het middelbaar. Verder zijn er geen andere criteria waar de deelnemers over moeten beschikken.

CATEGORIEËN PERSOONSGEGEVENS

Welke categorieën van gegevens verzamelt u of gebruik u?
Gewone persoonsgegevens: ja
Identificatiegegevens (bv. namen, (e-mail)adressen)
Persoonlijke kenmerken (bv. leeftijd, geslacht)
Beroep en professionele bezigheden
Audio- en beeldopnames
Andere

demografische informatie

Identificatiegegevens: e-mailadres
Opnames: audio-opnames
Beroep: anciënniteit

GROOTSCHALIGHEID/ KLEINSCHALIGHEID VAN DE VERWERKINGEN

Wat is het verwachte aantal personen wiens persoonsgegevens worden verzameld?
Elke focusgroep zal bestaan uit 5 deelnemers.

Hoe verhoudt deze steekproef zich tot de relevante populatie?
Na wat research over focusgroepen komt een gemiddelde van vijf tot acht deelnemers vaak terug. Hieronder enkel papers waar ik deze informatie heb teruggevonden:
• Gutiérrez, Francisco, Sven Charleer, Robin De Croon, Nyi Nyi Htun, Gerd Goetschalckx, and Katrien Verbert. 2019. "Explaining and Exploring Job Recommendations: A User-Driven Approach for Interacting with Knowledge-Based Job Recommender Systems." In Proceedings of the 13th ACM Conference on Recommender Systems, 60–68. RecSys '19. New York, NY, USA: Association for Computing Machinery.
• Verbert, Katrien, Xavier Ochoa, Robin De Croon, Raphael A. Dourado, and Tinne De Laet. 2020. "Learning Analytics Dashboards: The Past, the Present and the Future." In Proceedings of the Tenth International Conference on Learning Analytics & Knowledge, 35–40. LAK '20. New York, NY, USA: Association for Computing Machinery.

Hoeveel gegevens verwerk je van één betrokkene en hoe divers zijn deze gegevens?
Zoals hierboven vermeld enkel volgende zaken: het aantal jaren tewerkstelling in het onderwijs, de demografische informatie en het e-mail adres. En daarnaast ook de resultaten van de brainstormsessie.

Wat is de geografische reikwijdte van de persoonsgegevens die je verwerkt?
Alle data blijft binnen KU Leuven.

WERVING, BELONING EN VOORDELEN

Wie werft de deelnemers, hoe, waar en door wie gaan de deelnemers benaderd worden voor inclusie en het verkrijgen van de geïnformeerde toestemming:

Ik zal contact opnemen met het secretariaat van een bepaalde school met als bijlage een informatiebrochure (bijlage 1). Zij zullen deze mail doorsturen naar enkele leerkrachten. Hierna kunnen de deelnemers mij zelf contacteren en indien zij akkoord gaan krijgen ze een geïnformeerde toestemming toegestuurd (bijlage 2).

Zullen deelnemers een beloning of een compensatie krijgen voor hun deelname? nee

Zijn er andere voordelen verbonden aan deelname aan deze studie / project? ja
Doordat leerkrachten van het middelbaar onderwijs niet vaak de kans krijgen hun noden te verwoorden, geeft dit onderzoek hun een platform om hun problemen aan te kaarten en hier zelf eventuele oplossingen voor aangeboden te krijgen.

RISICO'S, ONGEMAKKEN EN COUNSELING

Beschrijf mogelijk risico's en desgevallend of deelnemers een gevoel van ongemak (fysiek of psychisch), schaamte, verwarring, etc. kunnen ervaren in de loop van de studie:

Niet van toepassing

Wordt enige steun of counseling aangeboden na de deelname?

Niet van toepassing

6. TECHNISCHE EN ORGANISATORISCHE MAATREGELEN BIJ VERWERKING EN BEHEER VAN GEGEVENS

BEWARING VAN DE GEGEVENS

Waar worden de digitale gegevens bewaard?

Anders, namelijk …

MS Teams gelinkt aan een KU Leuven account

Waar worden papieren gegevens bewaard?

Tijdens de studie worden papieren gegevens bewaard door de betrokken student in een afgesloten lade of kast die enkel voor hem/haarzelf toegankelijk is. Na afronding van de thesis of het OPO worden alle papieren gegevens doorgegeven aan de promotor die deze verder bewaard in zijn/haar kantoor in een afgesloten lade of kast die enkel voor hem/haarzelf toegankelijk is.

Wie heeft toegang tot de (persoons)gegevens tijdens de studie?

De betrokken KU Leuvenonderzoekers (zie pagina 2)

Wie heeft toegang tot de (persoons)gegevens na de studie?

De betrokken KU Leuvenonderzoekers, behalve eventuele betrokken studenten. (**)

Hoe lang zullen de (persoons)gegevens bewaard worden na het onderzoek?

De (persoons)gegevens worden verwijderd na 10 jaar (KU Leuven RDM-richtlijn).

ANONIMISERING / PSEUDONIMISERING GEGEVENS

Is er een ogenblik in uw onderzoek waarop u persoonsgegevens gaat anonimiseren of pseudonimiseren?

Niet geanonimiseerde of niet gepseudonimiseerde gegevens: nee

U gaat zelf persoonsgegevens pseudonimiseren.: ja

De ideeën die uit deze brainstorm sessie verzameld worden, zullen niet gelinkt worden met de deelnemers. De enige persoonlijke informatie dat zal worden bijgehouden is: het aantal jaren dat de deelnemers al in het onderwijs staan, leeftijd, naam en e-mail adres. De audio opname zal na transcriptie verwijderd worden.

OVERIGE TECHNISCHE EN ORGANISATORISCHE MAATREGELEN

Neemt u nog andere maatregelen ter bescherming van de privacy van de betrokkenen?

Nee

7.INFORMATIEVERSTREKKING AAN DE BETROKKENEN/DEELNEMERS

ONDERZOEK DAT MISLEIDING INHOUDT

Zullen de deelnemers misleid worden? nee

INFORMATIEVERSTREKKING AAN DE BETROKKENEN/ DEELNEMERS

Zal de nodig informatie aan de betrokkenen worden verstrekt of werd dit reeds gedaan?

In geval van primaire verwerking: ja

Informatiebrochure Focusgroep.pdf
40,19 kB

PROCEDURE VOOR GEÏNFORMEERDE TOESTEMMING VOOR DEELNAME AAN HET ONDERZOEK.

Beschrijf uw procedure voor de ethische geïnformeerde toestemming in detail:

Alle deelnemers krijgen voor de start een informatiebrochure (bijlage 1) en een geïnformeerde toestemming (bijlage 2) per mail doorgestuurd. Indien er extra vragen zijn, worden deze zo spoedig mogelijk beantwoord. Op de dag van de focusgroep, zal de onderzoeker aanwezig alle informatie nog kort overlopen met alle deelnemers.

Geïnformeerde toestemming.pdf
118,35 kB

NABESPREKING ("DEBRIEFING")

Welke informatie krijgen deelnemers tijdens de debriefing en hoe wordt deze informatie voorzien?

Na afloop van de focusgroep, zal elke deelnemers bedankt worden voor hun aanwezigheid en indien er nog deelnemers na het onderzoek vragen hebben, ze de hoofdonderzoeker altijd mogen contacteren. Er zal ook gevraagd worden of de deelnemers de paper van de masterproef toegestuurd willen krijgen op het einde van het academiejaar.

INFORMATIEVERSTREKKING OVER DE RESULTATEN VAN DE STUDIE

Welke informatie wordt aan deelnemers gegeven over de resultaten van het onderzoek? Ontvangen deelnemers hun individuele resultaten of alleen de algemene studieresultaten? Hoe wordt deze informatie aan deelnemers verstrekt?

De deelnemers zullen de de masterproef toegestuurd krijgen op het einde van het academiejaar.

8. RECHTEN VAN BETROKKENEN EN RECHTMATIGHEID VERWERKING

AFWIJKING OP RECHTEN VAN BETROKKENEN

Wordt uw onderzoek ernstig belemmerd indien de betrokken personen hun recht van inzage, rectificatie, beperking van de verwerking en recht van bezwaar willen uitoefenen?

nee

RECHTMATIGHEID VAN DE VERWERKING

Geselecteerde rechtsbasis:

Universitair onderzoek wordt doorgaans gevoerd in het algemeen belang: ja

9. RISICO-ANALYSE DOOR ONDERZOEKER

Houdt het onderzoek een hoog privacy-risico in voor de betrokkenen?

Indien de gegevens openbaar gemaakt zouden worden, zou dit een grote impact hebben op de betrokkenen? nee
Werkt u met bijzondere categorieën van persoonsgegevens? nee
Verwerkt u persoonsgegevens van kwetsbare groepen? nee
Verwerkt u gegevens op grote schaal? Hou voor het beantwoorden rekening met de absolute hoeveelheid persoonsgegevens, maar ook met de grootte van de steekproef t.a.v. de relevante populatie (zie vraag 4)? nee
Worden de gegevens doorgegeven aan een land buiten de EU dat niet op de 'witte lijst' staat? nee
Gaat u verschillende (bijzondere categorieën van) persoonsgegevens aan elkaar koppelen? nee
Hebben de verwerkingen juridische gevolgen of een gelijkaardig effect voor de betrokkene zoals uitsluiting of discriminatie van de betrokkene? nee
Hebben de verwerkingen het gevolg dat de betrokkene wordt belet om zijn rechten uit te oefenen, of gebruik te maken van een dienst of contract? nee
Gaat u op systematische wijze toezicht houden op personen in openbare ruimten? nee
Dienen de verwerkingen om profielen van personen op te stellen en voorspellingen te maken? nee
Maakt u innovatief gebruik van technologische toepassingen (bijvoorbeeld het gecombineerd gebruiken maken van vingerafdruk en gezichtsherkenning voor toegangscontrole)? nee
Werkt u met niet-gepseudonimiseerde persoonsgegevens? nee

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2.ALGEMEEN

ONDERZOEKERS

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Promotor: Katrien Verbert
Departement Computerwetenschappen
Mens-Machine Interactie (HCI), Leuven (Arenberg)
katrien.verbert@kuleuven.be
u0040828

Oefent de promotor een gezondheidszorgberoep uit in de zin van de wet van 10 mei 2015? nee

Andere KU Leuven onderzoekers:

FINANCIER

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Dienst die instaat voor afgesloten of nog af te sluiten contracten:

VOORNAAMSTE / LEIDENDE ETHISCHE COMMISSIE

De voornaamste / leidende ethische commissie: SMEC

3.ONDERZOEK

TITEL, BESCHRIJVING EN DOELSTELLINGEN

Unieke en volledige titel van het onderzoeksproject / protocol:

Het omzetten van leergegevens naar betekenisvolle learning analytics dashboards (Turning learning data into meaningful learning analytics dashboards)

Beschrijving van het onderzoeksproject / protocol:

Dit onderzoek is onderdeel van de bovengenoemde masterproef 'Turning learning data into meaningful learning analytics dashboards'. Deze masterproef wordt uitgevoerd door Lara Roosens, student ingenieurswetenschappen aan KU Leuven. Het doel van dit onderzoek zal een dashboard zijn, waarbij leerkrachten informatie kunnen terugvinden van hun klas en individuele studenten. Deze informatie kan variëren van bepaalde vaardigheden die de klas niet goed beheerst, de vooruitgang van een individuele leerling of de evolutie van behaalde eindtermen. Het is belangrijk dat het dashboard de leerkrachten geen extra taken oplegt, maar net de werkdruk kan verlichten.
Meer specifiek zal deze studie zich focussen op het middelbaar onderwijs, mits veel onderzoek vooral tijd hecht aan hoger onderwijs en dit een 'research gap' vormt in de studie rond learning analystics.
Deze think-aloud studie is een vervolg van de studie goedgekeurd door SMEC met dossiernummer G-2022-5775.

Doelstellingen van het onderzoek(sproject):

Voor dit onderzoek zal er een learning analytics dashboard ontworpen, ontwikkeld en geëvalueerd worden voor educatieve doeleinde. In deze think-aloud studie zal het dashboard nagekeken worden op gebruiksvriendelijkheid (betrekking op onderzoeksvraag 1) en nuttigheid (betrekking op onderzoeksvraag 2).

Dit onderzoek bevat volgende onderzoeksvragen:

1. Welke resultaten heeft een leraar nodig om een vollediger beeld te krijgen van de evolutie van een leerling, geleverd door Moodle's gegevens?
2. Wat zijn de ontwerpuitdagingen om (IT onervaren) leerkrachten te betrekken?

ETHISCHE RECHTVAARDIGING ONDERZOEK

Omschrijving ethische rechtvaardiging onderzoek:

Sociale waarde - Doordat leerkrachten van het middelbaar onderwijs niet vaak de kans krijgen hun noden te verwoorden, geeft dit onderzoek hun een platform om hun problemen aan te kaarten en hier zelf eventuele oplossingen voor aangeboden te krijgen.
Wetenschappelijk geldig - Door dit onderzoek uit te voeren zal er een bijdrage zijn in zowel het onderzoek domein van Mens-Machine-interactie als meer specifiek het domein van learning analytics.
Eerlijke selectie van testpersonen - Er zijn geen selectiecriteria gehanteerd, de eerste 5 leerkrachten die toezeggen zijn geselecteerd.
Risk-benefit ratio - Niet van toepassing, mits er geen risico's verbonden zijn aan een onderzoek waarbij enkel gebrainstormd wordt.
Respect – Alle deelnemers zullen met respect behandelt worden)

Mogelijke nadelen/risico's en voordelen/bijdragen van het onderzoek op zowel individueel (bv. het risico dat een deelnemer besmet raakt met COVID-19):

ONDERZOEKSTECHNIEKEN, INSTRUMENTEN & APPARATUUR

Vragenlijst: ja

Gevalideerde vragenlijst: ja

Vragenlijst.pdf
108,52 kB

Niet-gevalideerde vragenlijst: ja

Geen bijlage beschikbaar: Vragenlijst voor het aantal jaren tewerkstelling in het onderwijs, de demografische informatie en het e-mail adres op te vragen.

Video/audio-opnames: ja

Tijdens de think-aloud sessie zal er een audio opname gebeuren. Met als doel de sessie te kunnen herbeluisteren om de data efficiënt en correct te kunnen verwerken.

ONDERZOEKSMETHODOLOGIEËN

Methodologieën en praktische procedures:

Het onderzoek zal een papieren low-fidelity prototype evalueren a.d.h.v. een think-aloud studie:

Bij elke deelnemer wordt er individueel een think-aloud studie afgenomen. Hierbij zal de deelnemer enkele taken moeten voltooien met als doel de gebruiksvriendelijkheid van het dashboard te testen. De tijd die de deelnemer doet per taak en het aantal stappen de deelnemer nodig heeft per taak zullen gemeten worden. Een audio opname zal gebeuren tijdens deze sessie voor betere evaluatie nadien. Hierna zal de deelnemer nog een vragenlijst (zie bijlage) invullen. Deze vragenlijst bestaat uit twee delen: SUS (Systems Usablilty Scale) en vragen over de bruikbaarheid (met Lickert scale).

Deze technieken kunnen wetenschappelijk onderbouwd worden door onderstaande bronnen:

• Gutiérrez, F., Seipp, K., Ochoa, X., Chiluiza, K., De Laet, T., & Verbert, K. (2020). LADA: A learning analytics dashboard for academic advising. Computers in Human Behavior, 107, 105826.
• Scheers, Hanne, and Tinne De Laet. 2021. “Interactive and Explainable Advising Dashboard Opens the Black Box of Student Success Prediction.” In Technology-Enhanced Learning for a Free, Safe, and Sustainable World, 52–66. Springer International Publishing.

Aspecten van het onderzoek die een eventuele verstrenging van de maatregelen rond COVID-19 zouden bemoeilijken:

Bij dit onderzoek zal de deelnemer en onderzoeker in één ruimte zitten. Indien er striktere Covid maatregelen worden opgelegd, kan deze sessie volledig online plaatsen vinden via een online call.

VERWACHTE BEGIN- EN EINDDATUM

De verwachte begindatum van het experiment / de studie (dient in de toekomst te liggen) en de verwachte einddatum voor de deelnemers:

Begindatum: Het onderzoek start van zodra ethische goedkeuring wordt gegeven door SMEC.
Einddatum: 8/06/2023

4.VERZAMELEN EN DELEN VAN PERSOONSGEGEVENS IN DE STUDIE

PRIMAIRE/SECUNDAIRE GEGEVENSWERWERKING

Verzamelt u nieuwe gegevens (primaire verwerking) en/of gebruikt u enkel eerder verzamelde gegevens (secundaire verwerking)?
Primaire verwerking: ja
Secundaire verwerking: nee

EXTERNE PARTNERS

Andere niet KU Leuven onderzoekers:

Het betreft een niet-commerciële studie.
Is er naast KU Leuven nog een andere universiteit, onderzoeksinstelling of andere partner betrokken bij het onderzoek? nee

ROLLEN VAN DE BETROKKEN PARTIJEN

Wie bepaalt de doelstellingen van het onderzoek?
Dit wordt binnen KU Leuven bepaald.

Is er een andere partij betrokken die als verwerker in opdracht van KU Leuven (al dan niet samen met anderen) persoonsgegevens verwerkt (zoals bv. data verzamelen; analyses uitvoeren)? nee

DOORGIFTEN EN DELEN VAN PERSOONSGEGEVENS

Zullen de verzamelde persoonsgegevens worden doorgegeven aan/gedeeld met personen/instanties buiten KU Leuven?
nee

PLAATS DATAVERWERKING

Waar zal de dataverzameling worden uitgevoerd?
België: ja

5. DEELNEMERS EN CATEGORIEËN VAN GEGEVENS

CATEGORIEËN VAN BETROKKENEN

Persoonsgegevens die u onderzoekt / verwerkt:

Zowel leerkrachten als experten die deelnemen aan het onderzoek.

Zijn er kwetsbare personen betrokken? nee

Selectiecriteria:

De deelnemers moeten leerkrachten zijn die onderwijs geven in het middelbaar. Verder zijn er geen andere criteria waar de deelnemers over moeten beschikken. Het onderzoek zal ook gedaan worden bij enkele experten in het vakgebied van Mens en Machine communicatie.

CATEGORIEËN PERSOONSGEGEVENS

Welke categorieën van gegevens verzamelt u of gebruik u?
Gewone persoonsgegevens: ja
Identificatiegegevens (bv. namen, (e-mail)adressen)
Persoonlijke kenmerken (bv. leeftijd, geslacht)
Beroep en professionele bezigheden
Audio- en beeldopnames
Andere

demografische informatie

Identificatiegegevens: e-mailadres
Opnames: audio-opnames
Beroep: anciënniteit

GROOTSCHALIGHEID/ KLEINSCHALIGHEID VAN DE VERWERKINGEN

Wat is het verwachte aantal personen wiens persoonsgegevens worden verzameld?
5 experten en 5 leerkrachten
Hoe verhoudt deze steekproef zich tot de relevante populatie?
Na wat research over Think-aloud studies komt een gemiddelde van 8 deelnemers vaak terug. Nielsen en Landauer zien 5 test gebruikers het beste wanneer men kijkt naar de “benefit/cost ratio”:

J. Nielsen and T. K. Landauer. Mathematical model of the finding of usability problems. In Conference on Human Factors in Computing Systems - Proceedings, pages 206–213, New York, New York, USA, 1993. Publ by ACM.
Hoeveel gegevens verwerk je van één betrokkene en hoe divers zijn deze gegevens?
Zoals hierboven vermeld enkel volgende zaken: het aantal jaren tewerkstelling in het onderwijs, de demografische informatie en het e-mail adres. En daarnaast ook de resultaten van de think-aloud sessie.
Wat is de geografische reikwijdte van de persoonsgegevens die je verwerkt?
Alle data blijft binnen KU Leuven.

WERVING, BELONING EN VOORDELEN

Wie werft de deelnemers, hoe, waar en door wie gaan de deelnemers benaderd worden voor inclusie en het verkrijgen van de geïnformeerde toestemming:

Ik zal contact opnemen met het secretariaat van een bepaalde school met als bijlage een informatiebrochure (bijlage). Zij zullen deze mail doorsturen naar enkele leerkrachten. Hierna kunnen de deelnemers mij zelf contacteren en indien zij akkoord gaan krijgen ze een geïnformeerde toestemming toegestuurd (bijlage).

Bij de experten zal ik zelf opzoek gaan binnen het departement computerwetenschappen. Ook zij krijgen een informatiebrochure en geïnformeerde toestemming toegestuurd.

Zullen deelnemers een beloning of een compensatie krijgen voor hun deelname? nee

Zijn er andere voordelen verbonden aan deelname aan deze studie / project? ja
Doordat leerkrachten van het middelbaar onderwijs niet vaak de kans krijgen hun noden te verwoorden, geeft dit onderzoek hun een platform om hun problemen aan te kaarten en hier zelf eventuele oplossingen voor aangeboden te krijgen.

RISICO'S, ONGEMAKKEN EN COUNSELING

Beschrijf mogelijk risico's en desgevallend of deelnemers een gevoel van ongemak (fysiek of psychisch), schaamte, verwarring, etc. kunnen ervaren in de loop van de studie:

Niet van toepassing

Wordt enige steun of counseling aangeboden na de deelname?

Niet van toepassing

6. TECHNISCHE EN ORGANISATORISCHE MAATREGELEN BIJ VERWERKING EN BEHEER VAN GEGEVENS

BEWARING VAN DE GEGEVENS

Waar worden de digitale gegevens bewaard?

Anders, namelijk …

MS Teams gelinkt aan een KU Leuven account

Waar worden papieren gegevens bewaard?

Tijdens de studie worden papieren gegevens bewaard door de betrokken student in een afgesloten lade of kast die enkel voor hem/haarzelf toegankelijk is. Na afronding van de thesis of het OPO worden alle papieren gegevens doorgegeven aan de promotor die deze verder bewaard in zijn/haar kantoor in een afgesloten lade of kast die enkel voor hem/haarzelf toegankelijk is.

Wie heeft toegang tot de (persoons)gegevens tijdens de studie?

De betrokken KU Leuvenonderzoekers (zie pagina 2)

Wie heeft toegang tot de (persoons)gegevens na de studie?

De betrokken KU Leuvenonderzoekers, behalve eventuele betrokken studenten. (**)

Hoe lang zullen de (persoons)gegevens bewaard worden na het onderzoek?

De (persoons)gegevens worden verwijderd na 10 jaar (KU Leuven RDM-richtlijn).

ANONIMISERING / PSEUDONIMISERING GEGEVENS

Is er een ogenblik in uw onderzoek waarop u persoonsgegevens gaat anonimiseren of pseudonimiseren?

Niet geanonimiseerde of niet gepseudonimiseerde gegevens: nee

U gaat zelf persoonsgegevens pseudonimiseren.: ja

De ideeën die uit deze think-aloud sessie verzameld worden, zullen niet gelinkt worden met de deelnemers. De enige persoonlijke informatie dat zal worden bijgehouden is: het aantal jaren dat de deelnemers al in het onderwijs staan, leeftijd, naam en e-mail adres. De audio opname zal na transcriptie verwijderd worden.

OVERIGE TECHNISCHE EN ORGANISATORISCHE MAATREGELEN

Neemt u nog andere maatregelen ter bescherming van de privacy van de betrokkenen?

Nee

7.INFORMATIEVERSTREKKING AAN DE BETROKKENEN/DEELNEMERS

ONDERZOEK DAT MISLEIDING INHOUDT

Zullen de deelnemers misleid worden? nee

INFORMATIEVERSTREKKING AAN DE BETROKKENEN/ DEELNEMERS

Zal de nodig informatie aan de betrokkenen worden verstrekt of werd dit reeds gedaan?

In geval van primaire verwerking: ja

Informatiebrochure Think-Aloud.pdf
40,11 kB

PROCEDURE VOOR GEÏNFORMEERDE TOESTEMMING VOOR DEELNAME AAN HET ONDERZOEK.

Beschrijf uw procedure voor de ethische geïnformeerde toestemming in detail:

Alle deelnemers krijgen voor de start een informatiebrochure (bijlage 1) en een geïnformeerde toestemming (bijlage 2) per mail doorgestuurd. Indien er extra vragen zijn, worden deze zo spoedig mogelijk beantwoord.

Geïnformeerde toestemming.pdf
106,14 kB

NABESPREKING ("DEBRIEFING")

Welke informatie krijgen deelnemers tijdens de debriefing en hoe wordt deze informatie voorzien?

Na afloop van de think-aloud studie, zal de deelnemer bedankt worden voor zijn/haar aanwezigheid en indien ze nog na het onderzoek vragen hebben, ze de hoofdonderzoeker altijd mogen contacteren. Er zal ook gevraagd worden of de deelnemers de paper van de masterproef toegestuurd willen krijgen op het einde van het academiejaar.

INFORMATIEVERSTREKKING OVER DE RESULTATEN VAN DE STUDIE

Welke informatie wordt aan deelnemers gegeven over de resultaten van het onderzoek? Ontvangen deelnemers hun individuele resultaten of alleen de algemene studieresultaten? Hoe wordt deze informatie aan deelnemers verstrekt?

De deelnemers zullen de de masterproef toegestuurd krijgen op het einde van het academiejaar.

8. RECHTEN VAN BETROKKENEN EN RECHTMATIGHEID VERWERKING

AFWIJKING OP RECHTEN VAN BETROKKENEN

Wordt uw onderzoek ernstig belemmerd indien de betrokken personen hun recht van inzage, rectificatie, beperking van de verwerking en recht van bezwaar willen uitoefenen?

nee

RECHTMATIGHEID VAN DE VERWERKING

Geselecteerde rechtsbasis:

Universitair onderzoek wordt doorgaans gevoerd in het algemeen belang: ja

9. RISICO-ANALYSE DOOR ONDERZOEKER

Houdt het onderzoek een hoog privacy-risico in voor de betrokkenen?

Indien de gegevens openbaar gemaakt zouden worden, zou dit een grote impact hebben op de betrokkenen? nee
Werkt u met bijzondere categorieën van persoonsgegevens? nee
Verwerkt u persoonsgegevens van kwetsbare groepen? nee
Verwerkt u gegevens op grote schaal? Hou voor het beantwoorden rekening met de absolute hoeveelheid persoonsgegevens, maar ook met de grootte van de steekproef t.a.v. de relevante populatie (zie vraag 4)? nee
Worden de gegevens doorgegeven aan een land buiten de EU dat niet op de 'witte lijst' staat? nee
Gaat u verschillende (bijzondere categorieën van) persoonsgegevens aan elkaar koppelen? nee
Hebben de verwerkingen juridische gevolgen of een gelijkaardig effect voor de betrokkene zoals uitsluiting of discriminatie van de betrokkene? nee
Hebben de verwerkingen het gevolg dat de betrokkene wordt belet om zijn rechten uit te oefenen, of gebruik te maken van een dienst of contract? nee
Gaat u op systematische wijze toezicht houden op personen in openbare ruimten? nee
Dienen de verwerkingen om profielen van personen op te stellen en voorspellingen te maken? nee
Maakt u innovatief gebruik van technologische toepassingen (bijvoorbeeld het gecombineerd gebruiken maken van vingerafdruk en gezichtsherkenning voor toegangscontrole)? nee
Werkt u met niet-gepseudonimiseerde persoonsgegevens? nee

Informatiebrochure Focusgroep
Masterproef Lara Roosens

KU LEUVEN

Turning learning data into meaningful learning analytics dashboards

Bedankt voor uw interesse om deel te nemen aan deze voorstudie voor de masterproef van Lara Roosens. Hieronder vindt u kort overzicht omtrent het onderzoek.

Doel van de studie

Deze voorstudie zal uitwijzen wat de problemen zijn waarmee leerkrachten worstelen en welke informatie hierbij zou helpen om dit op te lossen. Met als doel een learning analytics dashboard te maken dat informatie biedt over de klas en individuele studenten. Dit dashboard zal hopelijk bruikbaar zijn in de dagelijkse activiteiten van leerkrachten en als resultaat de zware werkdruk verlichten.

Hoe verloopt het onderzoek?

Na een korte inleiding, zal een groep van vijf leerkrachten samen brainstormen. Dit zal op een gestructureerde manier verlopen die zal uitgelegd worden vóór de sessie. Hierna overlopen we samen alle ideeën en is er ruimte voor discussie. De focusgroep zal doorgaan de week na de herfstvakantie. Andere praktische regelingen worden doorgestuurd na akkoord van deelname.

Wat gebeurt er met mijn gegevens?

Alle gegevens worden veilig en discreet behandeld door de hoofdonderzoek. De brainstormsessie zal worden opgenomen (enkel audio). Deze opname zal worden vernietigd als alle data schriftelijk verwerkt is. Buiten uw e-mailadres en het aantal jaren tewerkstelling in het onderwijs, worden er geen andere persoonlijke gegevens van u bewaard. De resultaten van de focusgroep worden enkel gebruikt in het kader van wetschappelijk onderzoek en zullen gepubliceerd worden.

Hoe kan ik deelnemen?

Indien u bovenstaande informatie begrijpt en hiermee akkoord gaat, mag u mij per mail een bevestigingsmail sturen. U krijgt dan alle praktische informatie doorgestuurd.

Nog vragen? Aarzel niet om mij te contacteren lara.roosens@student.kuleuven.be

Deze studie werd beoordeeld en goedgekeurd door de Sociaal-Maatschappelijke Ethische Commissie (SMEC) van KU Leuven (dossiernummer: G-2022-5775).

Informatiebrochure Think-Aloud Studie
Masterproef Lara Roosens

KU LEUVEN

Turning learning data into meaningful learning analytics dashboards

Bedankt voor uw interesse om deel te nemen aan een think-aloud studie voor de masterproef van Lara Roosens. Hieronder vindt u kort overzicht omtrent het onderzoek.

Doel van de studie

Deze masterproef heeft als doel een learning analytics dashboard te ontwerpen voor leerkrachten van het middelbaar onderwijs, dat informatie biedt over de klas en individuele studenten. Dit dashboard zal hopelijk bruikbaar zijn in de dagelijkse activiteiten van leerkrachten en als resultaat de zware werkdruk verlichten. In deze think-aloud studie zal het dashboard nagekeken worden op gebruiksvriendelijkheid en nuttigheid .

Hoe verloopt het onderzoek?

U zal als deelnemer enkele taken moeten verrichten op een prototype van het dashboard, met als doel de gebruiksvriendelijkheid van het dashboard te testen. Hierna zal u een vragenlijst moeten invullen waar opnieuw naar gebruiksvriendelijkheid en ook bruikbaarheid wordt gepeild. Praktische regelingen worden doorgestuurd na akkoord van deelname.

Wat gebeurt er met mijn gegevens?

Alle gegevens worden veilig en discreet behandeld door de hoofdonderzoek. De think-aloud sessie zal worden opgenomen (enkel audio). Deze opname zal worden vernietigd als alle data schriftelijk verwerkt zijn. Buiten uw e-mailadres en het aantal jaren tewerkstelling in het onderwijs, worden er geen andere persoonlijke gegevens van u bewaard. De resultaten van de focusgroep worden enkel gebruikt in het kader van wetenschappelijk onderzoek en zullen gepubliceerd worden.

Hoe kan ik deelnemen?

Indien u bovenstaande informatie begrijpt en hiermee akkoord gaat, mag u mij per mail een bevestigingsmail sturen. U krijgt dan alle praktische informatie doorgestuurd.

Nog vragen? Aarzel niet om mij te contacteren lara.roosens@student.kuleuven.be

Deze studie werd beoordeeld en goedgekeurd door de Sociaal-Maatschappelijke Ethische Commissie (SMEC) van KU Leuven (dossiernummer: G-2022-6099).

Appendix B

Script: in-depth interviews with think-aloud of proof-of-concept

This appedix contains the complete protocol of study conducted for the proof-of-concept in the ideate phase. First, a think-aloud study will be conducted in which the user is given certain instructions (see Table B.1) to examine various elements of the dashboard. The participants will next engage in an oral in-depth interview to discuss the dashboard's strengths, weaknesses, opportunities, and threats. The presentation find in this appendix was used to guide these conversations.

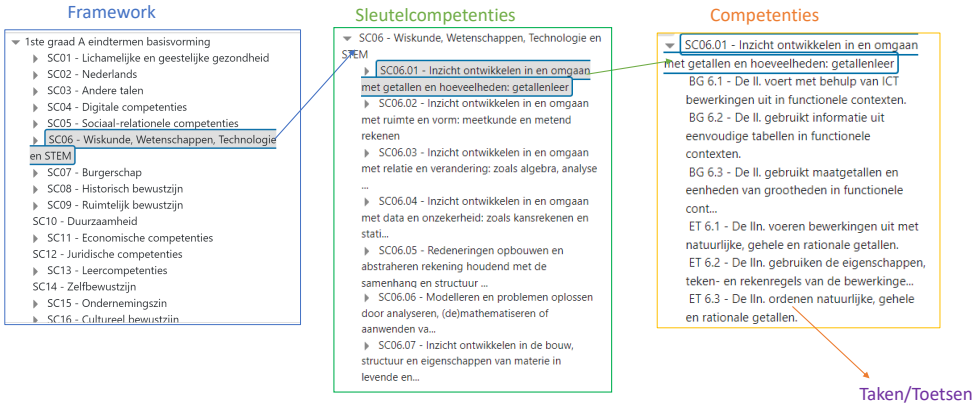
Table B.1: Instruction participants where asked during the think-aloud study

question	Which students in your class have failed your course but are making significant progress?
motive	Verify that the meaning of the four groups into which students are divided, is clear.
question	When looking at the first chart "Results students by competency" can you tell me which students score poorly on key competency 6? (Do this for options A, B, and C)
motive	Option A: See if the user understands that the scatter plot represents learners and can work with it / Option B: This question is not/difficult to answer with this graph. / Option C: Is it clear that a lighter colour represents a worse score?
question	You now want to explore key competency 6 in more depth and wonder which competencies lie behind it. How do you proceed?
motive	Check if the user understands to click on the name of the competence when he/she wants to view a level deeper.
question	Can you tell me Emma Davis' results for each key competency? (Do this for options A, B, and C)
motive	See if the interaction between the graphs is clear.
question	On which SC does the class score worst? (Do this for options A, B, and C)
motive	Examine whether the teacher finds a clear overview of the entire class.
question	Indeed, you correctly saw that SC06.06 did not score very high and now you wonder how many tasks or tests you have done for this competency. (Do this for options A and B)
motive	See if the graph "Competencies" (visualising the number of tasks) can be quickly understood.
question	You can see that for SC06.01 you have already done 3 tests/tasks, you investigate this further and wonder which tests were done for SC06.01.
motive	Check if the user understands to click on the name of the competence when he/she wants to view a level deeper, after already doing it in question 3. Check if there is a fast learning curve.
question	Can you give me the median, best and worst scores for assignment X (if they have no idea what a boxplot is: explain boxplot first, then ask the question again)
motive	Check if the user understands boxplots. If not, does the user understand boxplots after a short explanation?

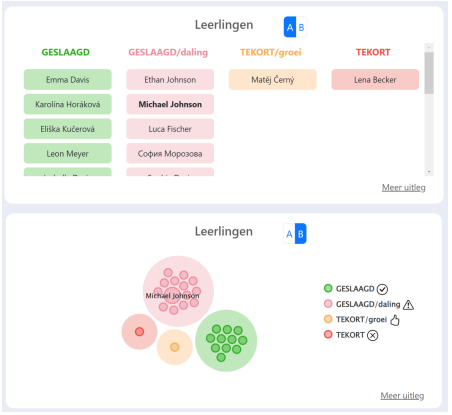
Think-aloud studie

GITO Overijse

Overzicht competentie framework



Leerlingen



Vragen

- "Bij welke leerlingen is er een groei/daling in de punten? "
- "Welke leerlingen lopen achter?"

4 Categorieën

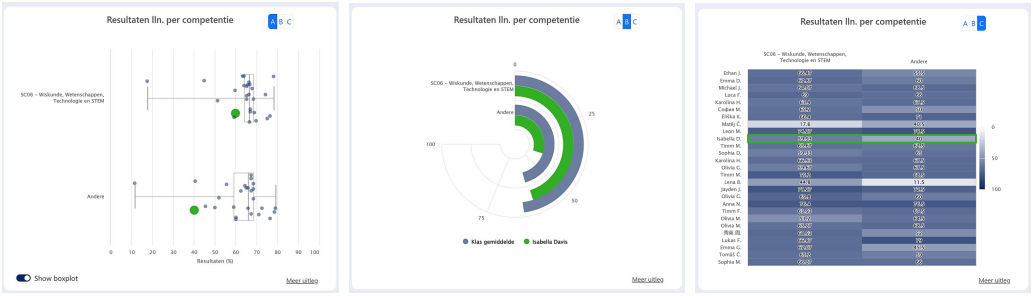
	GESLAAGD	TEKORT
Groei in de punten	Groen	Geel
Gevaar, daling!	Roos	Rood

Competenties

Vragen

- “Hoeveel toetsen/taken zijn er afgenomen voor een bepaalde competentie?“
- “Scoort de klas slechter op competenties die nog niet veel ondervraagd zijn?”

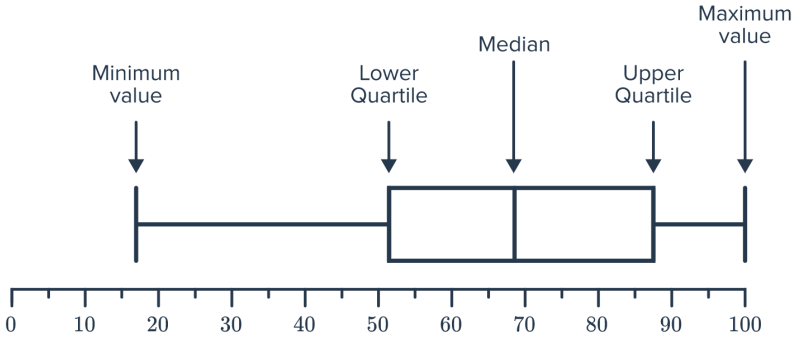
Resultaten lln. per competentie



Vragen

- "Hoeveel behaalde een leerling/de klas op een bepaalde competentie?“
- "Waar moet de klas nog meer op oefenen?"

Uitleg boxplot



SWOT analyse

Sterktes Wat maakt het dashboard sterk? Wat onderscheidt het van de methodes die u nu gebruikt?	**Zwaktes** Wat zijn de zwaktes van het dashboard?
Kansen Hoe kan het dashboard zich nog verbeteren of groeien? Wat zou ik er nog aan willen toevoegen?	**Bedreigingen** Zijn er bedreigingen die de groei van het dashboard in de weg kunnen zitten? Wat zou u tegenhouden om het dashboard te gebruiken?

Appendix C

Paper

The contributions of this thesis will be made available in a paper, with the goal of submitting this paper to the LAK conference of 2024.

Turning Competency Data into Actionable Insights for Teachers

LARA ROOSENS, KU Leuven, Belgium
ROBIN DE CROON, KU Leuven, Belgium
JAN VELGHE, GITO Overijse, Belgium
JAD NAJJAR, Eummena, Belgium
KATRIEN VERBERT, KU Leuven, Belgium

The rise of digitalisation in schools has generated large amounts of data. However, teachers often lack the necessary tools to use and interpret this data, while also facing high administrative burdens. This paper presents a Competency Dashboard, a learning analyics dashboard that supports teachers with continuous updates on students' progress and performance to lower their workload. This was done using an iterative and user-centered design process. The result of these evaluations indicates that the dashboard provides teachers with helpful insights and actionable content for understanding their students' grades and progress. The dashboard's design allows for easy understanding and for accessible visualisations of learning data.

CCS Concepts: • **Information systems** → *Data analytics*; • **Human-centered computing** → *Information visualization*; • **Applied computing** → *Education*.

Additional Key Words and Phrases: Learning analytics dashboards, actionable insights, secondary school teachers

ACM Reference Format:
Lara Roosens, Robin De Croon, Jan Velghe, Jad Najjar, and Katrien Verbert. 2023. Turning Competency Data into Actionable Insights for Teachers. In *LAK '24: International Conference on Learning Analytics and Knowlegde Conference, March 18–22, 2024, Kyoto, Japan.* ACM, New York, NY, USA, 10 pages. https://doi.org/XXXXXXX.XXXXXXX

1 INTRODUCTION

Learning analytics (LA) is a commonly used word in the field of education. It refers to the collection and analysis of educational data with the goal to improve learning and teaching [2, 19]. The growing interest in LA can largely be explained by the increase of digitalisation in schools [12]. This resulted in the generation and collection of large amounts of data through the use of learning management systems like Moodle and Smartschool. However, despite the availability of this data, teachers frequently miss the necessary tools to use and interpret this data. Moreover, teachers face a high administrative burden further highlighting the need for a solution that can reduce their workload [3]. Therefore, there is an important need to develop a tool for teachers that can provide continuous updates on the learning progress and performance of their students.

As a result, this research will focus on designing, developing and evaluating a learning analytics plugin for Moodle. This study focuses on secondary school teachers as end users, addressing the underexposure of learning analytics research in primary and secondary education, which has mainly focused on higher education [18]. By developing this

Manuscript submitted to ACM

plugin, we try to help secondary school teachers by giving them the essential information to achieve a better overview of their students, make more informed decisions, and reduce the time they spend on administrative tasks.

Although there is a growing interest in LA, there still remain some more noteworthy research gaps. Therefore, this paper aims to address these gaps and provide valuable insights into the design and development of a learning analytics dashboard specifically tailored for secondary school teachers. Taking these factors into consideration, the research questions (RQ) were defined:

(1) RQ1: What analytic insights does a teacher need, to have a more comprehensive view of the students current results and evolution, to support their pedagogical actions? (Goal: Useful and actionable content)
(2) RQ2: How should learning data be visualised such that all teachers, regardless of educational background or IT knowledge, can easily understand and use the dashboard? (Goal: Usable design)

2 RELATED WORK

This section will highlight the research gaps concerning learning analytic dashboards that were discovered in previous studies. A research gap in this context is something that many academics overlook when conducting their research on learning analytic dashboards.

Gap 1: Input from stakeholders. In several studies, it is acknowledged that the end user wasn't consulted enough [6, 14] or not even at all [8]. It is important to ask the end user what they want before you begin designing and to actively include them in the process of evaluating your design [15, 23]. According to Tavares et al. [21], creating a dashboard is an iterative process in which effective communication with the end user (in this case, teachers) is crucial.

Gap 2: Misinterpretation of visualisations. The term "misinterpretation of visualisations" refers to research that failed to take into account the influence that end users have on how data is visualised and how people interpret designs. Different genders or ages may interpret a visual in a different way [23]. Many other dashboards neglected simplicity, making it too complex and time-consuming for the teachers [21]. According to Tavers et al., LA dashboard should be simple to "read, manipulate, and interpret" for teachers.

Gap 3: Lack of impact. Verbert et al. [22] specify a process model of learning analytics. This model illustrates the various steps users take when using a dashboard. The different stages of this model are: awareness, reflection, sensemaking, and impact. The same study also notes that the majority of LA dashboards can be categorised using the first three steps. Few, however, discuss the last step of impact.

This research aims to address these gaps and provide valuable insights into the design and development of a learning analytics dashboard specifically tailored for secondary school teachers. The first goal is to add visuals to the dashboard based on teachers' needs and wishes (Gap 1) and to ensure the visuals have an impact on students (Gap 3). This addresses the first research question of the thesis. The second goal (addressing the second research question) is to create a user-friendly dashboard that effectively represents complex data to avoid visual misinterpretations (Gap 2). To achieve this, it is again important to involve end users in evaluating different prototypes (Gap 1).

3 CONTEXT

3.1 Moodle

This research will develop a learning analytics dashboard. To collect data and make this a functional dashboard, the dashboard is build on the learning platform Moodle. Since Moodle is open-source, free, and the most widely used

learning management system (LMS) in the world [25], it was chosen as the LMS. Moodle is a learning management system that gives teachers the ability to create online courses and distribute them to students [25]. All of that data is stored in a relational database and can be accessed, so working with a school that already uses Moodle is a must.

3.2 Competency framework

There are quality standards in the form of end-terms imposed by the government, which a teacher is obligated to achieve and document. End-terms are minimum goals that the Flemish government considers necessary and reachable for that population of pupils [1]. These end-terms are structured in a curriculum or a so called 'competency framework' and contains different levels. Key competencies, the highest level, are "groups of content-related skills that students must learn to operate in society and grow as individuals" [24]. To ensure consistency, each key competence has a set of defined building blocks. Then each building block is composed of end-terms. Finally, teachers must link these end-terms to their assignments. Because school regulations varies by country, this study focuses foremost on secondary schools in Flanders.

To obtain this data, teachers would have to link their assignments to end-terms. This feature exists in Moodle, but is barely used by teachers of the cooperating school 'GITO Overijse'. As the user studies will be done mostly in collaboration with this school, the hesitancy to add data to Moodle poses a significant challenge, making the research more complicated. The creation of a dashboard requires a lot of data, which is currently unavailable. Resolving this issue entails giving the teachers something in return for their afford. However this creates a somewhat paradoxical situation, as we need data to create the dashboard but also need the dashboard to motivate data collection. One potential solution is to use test data instead of real-time data, although this compromises the accuracy of the studies. Nevertheless, it is a necessary measure.

4 FUNCTIONALITY OF DASHBOARD

A competency dashboard has been developed to present students' performance for each competency through visual representations. Figure 1 shows the final design. The dashboard is partitioned into three white frames, each of which is labelled with a purple tag. These tags were included solely for the purpose of providing easy referencing, but they are not part to the design of the dashboard. Other components of the dashboard are enclosed in blue and labelled with Roman numbers for convenient referencing.

Frame 1: students. In the first frame, the teacher can find information about their class. This section addresses the questions of 'student data' in Table 1. To answer these questions, the class is divided into four groups. First, the class is divided into students who have passed the subject and those who have not. Next, an analysis is made to look for students who have an improvement or decline in their grades.

In the top right corner (component III), the user can find the option to select a different visualisation. Option A (as seen in Figure 1) presents a list of all the students in the class, while option B (Figure 2a) gives a more anonymous view of the class and provides a high-level view of the size of each group.

Frame 2: competencies. In Frame 2, one can address the questions of 'competency data' seen in Table 1. The bar chart on the left shows the number of completed assignments for each competency. On the right, the bar chart presents the class average for each competency, on a 100% scale. The red dotted line indicates the 50% threshold.

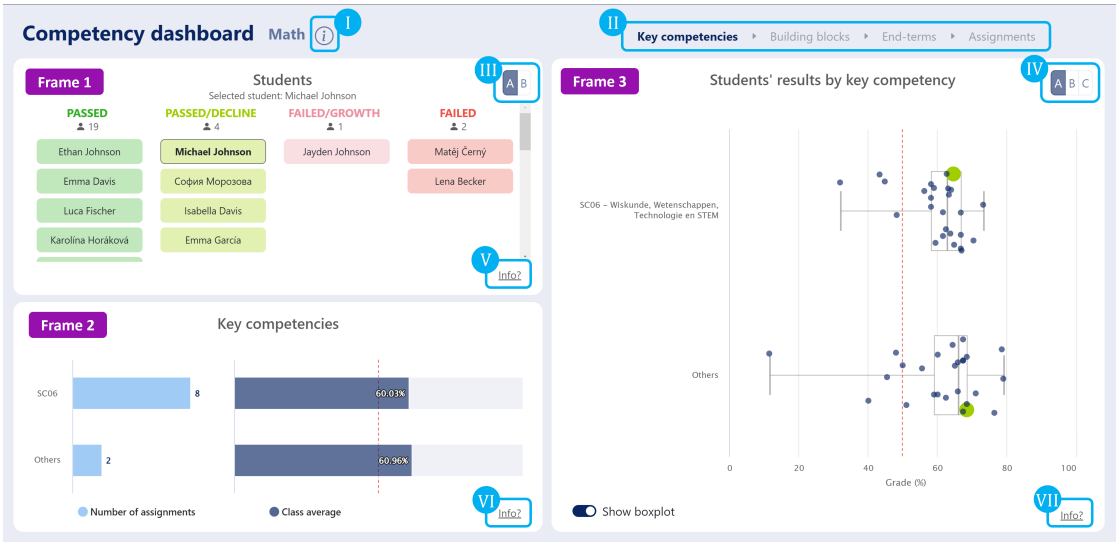
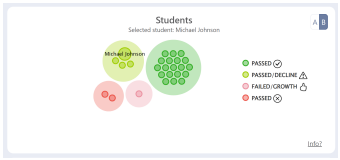


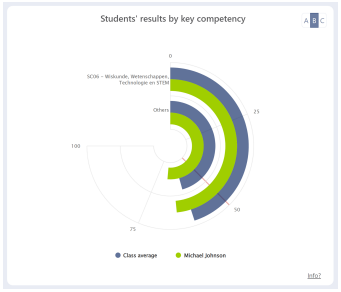
Fig. 1. Final design of the dashboard. I) info-button whole dashboard, II) breadcrumbs, III) option-button Frame 1, IV) option-button Frame 3, V) info-button Frame 1, VI) info-button Frame 2, VII) info-button Frame 3

Frame 3: students' results by competency. In Frame 3, the aim is to provide insights into the performance of individual students and the class as a whole regarding specific competencies. Three visualisations were selected. Option A (Figure 1) is a scatterplot with boxplot with each dot representing a student. Option B (Figure 2b) is a bar chart showing both the class average and individual student data. Option C (Figure 2c) is a table where darker shades represent lower grades. This last format resembles a gradebook, which looks closest to the method teachers currently use. The user can switch between these options using component IV.

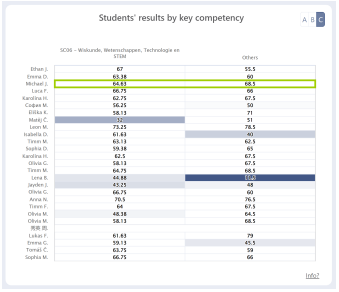
Other components. Component II consists of breadcrumbs that provide an indication of the current level the user is located on. These levels directly correspond to the levels defined in the competency framework. Four pop-ups (opens when clicked on components I, V, VI, VII) have been added with additional explanations, to assist teachers while using the dashboard.



(a) Frame 1 Option A: high-level overview



(b) Frame 3 Option B: bar chart



(c) Frame 3 Option C: table

Fig. 2. Other visualisations for Frame 1 and 3

5 METHODOLOGY: ITERATIVE AND USER-CENTERED DESIGN

The primary aim of this research is to develop a dashboard for secondary school teachers that provides useful and actionable content, with a user-friendly design that takes stakeholder feedback into account. In order to achieve these objectives, the decision was made to adopt an established design methodology: 'Design Activity Framework for Visualization Design' [13] This method suggests an iterative approach that consists of four activities: understand, ideate, make and deploy. Figure 3 provides an overview of each activity.

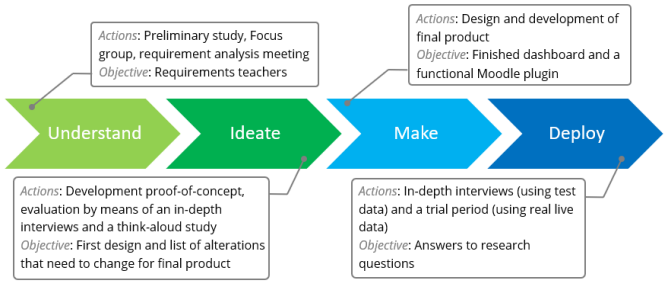


Fig. 3. Graphical overview of methodology

5.1 Understand

The "understand" activity involves gathering information to find the needs of the user. In this first step, a focus group and a requirement analysis meeting were organised to gain a thorough understanding of the problem. These activities led to the identification of the teachers' specific requirements, which were used to guide the design process for creating a solution that fulfills their needs. The focus group involved the participation of six secondary school teachers. This focus group session employs the "metaplan" [7] technique. In the requirement analysis meeting one school (GITO Overijse) was looked at specifically, as this research is done in collaboration with this school. The information was gathered through a one-on-one interview with the person responsible for blended learning, who also works closely with teachers.

Both studies look for teachers' needs and what information they would like to gather about their students. The teachers' data preferences include skills and competencies. However, some ideas required data that is not currently available in Moodle, such as mental well-being or home situations, and needed to be filtered out. Table 1 shows all the (filtered) ideas of the two studies. The ideas are categorised into three groups: those needing student data, competence data, or a combination of both. Each group corresponds to one frame of the final design. Important to note, these findings align with previous research that also identified questions about student difficulties, and skill mastery [11, 21].

5.2 Ideate

The "ideate" activity involves generating ideas and considering potential solutions. In this activity, multiple prototypes were developed and one proof-of-concept (POC) was evaluated through a user-study. The purpose of this study is the verification of usabilty and usefulness of the POC and updated requirement analysis. This study involves individual, in-person think-aloud sessions and in-depth interviews. Feedback was obtained from five teachers and two Human-computer interaction (HCI) experts. Multiple visualisations were considered for the three frames, considering different

design criteria. The resulting output was the initial design and a list of required alterations to enhance the design of the final product. This iterative approach helped in generating ideas and improving the design.

Table 1. Results of focus group and requirement analysis meeting (after filtering). Divided into three groups: those needing student data, competence data, or a combination of both. Requirements with higher priority have a star behind them.

Student data
• Which students' grades have increased/decreased? ⭐
• Which students are struggling?
Competence data
• How much time did I spend (in a course) on a certain competency?
• Do I see a return of my time in competencies where I put more effort in?
Combined data
• How advanced is a student on a specific competence? ⭐
• What is the performance of the whole class on a certain competency?
• What competencies should students focus on for extra practice? ⭐

5.3 Make

The "make" activity involves creating the prototype. Here, the first step involves redesigning the dashboard based on the feedback gathered from teachers and experts during the previous step. After this, the design can be transformed into a functional Moodle plugin. This research mainly focuses on the design of the various prototypes. However considerable effort was also devoted to the development of the dashboard itself. The dashboard has been implemented as a plugin for Moodle, allowing secondary schools to incorporate it into their system. It connects to the Moodle database to retrieve up-to-date data. The interactive charts of the dashboard are built with the Highcharts js-library.

5.4 Deploy

The "deploy" activity involves ensuring that the final solution meets the desired outcomes. Two qualitative user studies are conducted here: in-depth interviews (using test data) and a trial period (using real live data). The goal is to answer the research questions. Next section will go in to more detail about the set-up and results of these final user-studies.

6 FINAL EVALUATION

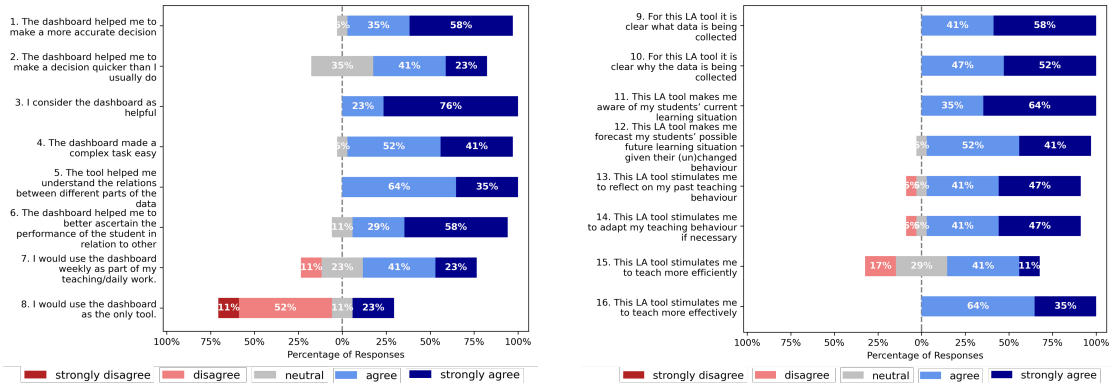
6.1 Participants and experimental design

Two studies will evaluate the final high-fidelity prototype. The first study employs in-depth interviews where the teachers will interact with the dashboard using test data. It consist of three parts: a tutorial, an in-depth interview, and questionnaires. The questionnaire includes four parts: demographic information, assessment of user-friendliness using the SUS questionnaire [4], evaluation of dashboard usefulness using the LADA questionnaire [10], and measurement of the impact of LA tools for teachers using the EFLA questionnaire [16]. Nineteen teachers from three different secondary schools participated in this study. In the second study, a one-week trail period was held, where teachers use the dashboard with there own class data. Google Analytics was to see how often the teachers used the dashboard, and

afterwards feedback was asked about the impact on their teaching practices. Only two teachers participated in this second study as they were the only ones linking end-terms to assignments.

6.2 Results

A thematic analysis was conducted on the collected data and was made with the notes and recordings of the nineteen in-depth interviews. Moreover, certain findings are strengthened by the inclusion of quantitative data (Figure 4). Below the six most prominent lessons learned are summarised and linked with previous research.



(a) Quantitative results (LADA)

(b) Quantitative results (EFLA)

Fig. 4. Responses of two questionnaires

6.2.1 ***Lesson learned 1 (usability):*** The SUS score gives a good initial picture about the usability of the dashboard. The result on the SUS questionnaire is 85.7, this result falls within the 'excellent' group [4]. Teachers indicated that the dashboard offered a quick overview (10/19) and a high degree of simplicity and time efficiency (10/19). They indicated that these elements are also a must in order for teachers to adopt a new tool. One teacher said: *"The KISS [Keep it simple, stupid!] principle is extremely applicable here for my colleagues"*. The dashboard's design took this into account and provided a user-friendly interface, ensuring a smooth on-boarding experience for teachers. The inclusion of breadcrumbs, color-coded elements, an intuitive user flow, and a concise class overview (Frame 1) where mentioned as elements to fulfilling these requirements. Dashboard that are too complex or are time-consuming to retrieve insights from, was also mentioned by Tavers et al. [21] as a problem that lead to teachers not using the dashboard

6.2.2 ***Lesson learned 2 (helpful insight and actionable content):*** The competency dashboard provided helpful insights as well as actionable insights to the teachers. The helpful insights that teachers mentioned included problem identification and differentiation (8/19) , student monitoring (10/19), self-reflection (10/19), and lesson planning (6/19). These findings are consistent with prior research that highlights the importance of providing teachers with information regarding student progress, guide their interventions, lesson preparation, and student support [11, 21]. Furthermore, the dashboard provided actionable content that allowed teachers to take specific pedagogical actions. Examples of these actions included repeating lectures when necessary (4/19), adjusting the difficulty level for a high-performing class (2/19), informing students about how they are doing (5/19), providing encouragement (4/19), offering targeted remediation (9/19), focusing on high-achieving students (2/19), and enabling better assessment during deliberations

(4/19). Due to the underexposure of 'impact' and 'actionable content' in existing research [17, 22], the findings of this study make a valuable contribution to the field of HCI.

Out of these insights not only teachers, but also students benefit from the dashboard. as they will recieve more targeted remediation, more encouragement etc. Even high-performing students can now receive enhanced support, thanks to the increased time available to teachers, allowing them to better assist all students.

6.2.3 ***Lesson learned 3 (not only assessing on results):*** The dashboard provides a complete overview of student performance in the class based on results. However, teachers (5/19) have highlighted the importance of considering additional factors such as behavior and student monitoring systems to properly assess a student. This suggestion is confirmed by research, which indicates an important relationship between the affective state and student performance [5], and highlights the importance of teachers anticipating and responding to student emotions for successful learning outcomes [9]. These elements are currently missing in the data, limiting the dashboard's ability to provide a complete evaluation.

The significantly lower score response of question 16 (Figure 4b) of the quantitative data analysis can also be explained by this as teachers emphasised the importance of not only relying on grades.

6.2.4 ***Lesson learned 4 (scatterplot with boxplot as favourite boxplot):*** The scatterplot emerged as the preferred visualisation among teachers (15/19). Teachers appreciated its ability to display both individual student performance and the distribution of the entire class, providing a comprehensive overview at a glance. Quotes from participants highlight their positive views:

- P7: "I find this one very clear because you can see where the class and the student are situated."
- P17: "I would use this one the most; everything is clear at a glance."

6.2.5 ***Lesson learned 5 (bar chart as least favourite visualisation):*** The bar chart emerged as the least preferred visualisation tool among teachers. Teachers (9/19) expressed that it required more effort to extract information compared to other visualisations. As bar charts are the most popular graph to visualise data in LA dashboards [17], this is a conflicting finding. However, the dislike of the bar chart is a result of two issues: the class average and the radiant shape. Teachers (10/19) felt that the class average could give a biased or distorted image of a student's performance. The radiant shape of the bar chart made it difficult to extract information and insights. Some quotes where:

- P6: "I don't find the circular format convenient, the 100% is laced strangely. The circle creates an extra difficulty."
- P17: "I find it very difficult to read, I have to think harder about it."
- P3: "The class average doesn't say much, I prefer Option A for the class distribution."

6.2.6 ***Lesson learned 6 (divided opinion about the table visualisation):*** Opinions on the table visualisation (option C) were divided. Some participants (10/19) found it overwhelming and lacking in added value compared to other visualisations. These comments are in line with prior research, stating that tables are time-consuming and do not have a clear benefit [20]. However, another group (6/19) favored the table as it was familiar and gave more trust. Since there is a clear dichotomy present, it is meaningful to examine the trends between these two groups. The two groups where compared on their responses to the demographic questionnaire filled out during the user study. Due to the small number of participants, strong conclusions cannot be drawn from the analysis. However, interesting trends can still be observed. STEM teachers generally disliked the visualisation, and more experienced teachers did not show a preference for the traditional table.

7 DISCUSSION

7.1 Answering research question 1

To address this research question, the study employed a user-centered design approach, emphasising the importance of gathering input from end users. This approach aligns with the understand phase of the methodology. Two studies, namely a focus group and a requirement analysis meeting, were conducted to ensure that teachers' perspectives and requirements were taken into consideration.

This research successfully answered the first research question by identifying the analytic insights required by teachers to gain a comprehensive view of their students' results and evolution. The objective of developing a learning analytic dashboard that offers useful insights and actionable content benefiting teachers (and even students), has been achieved. Nevertheless, future improvements could take into account the inclusion of additional factors, such as student behaviour, to enable a more complete evaluation of students.

7.2 Answering research question 2

To address this research question, the study applied an iterative design process, starting from the insights gathered during the understand phase. This research question was mainly addressed in the ideate phase and make phase. The aim was to visualise these insights in an understandable way.

The findings indicate that a usable design for the learning analytics dashboard was achieved, enabling teachers to easily understand and use the visualised learning data. The scatterplot emerged as the preferred visualisation, providing an overview of individual student performance and class distribution. Nevertheless, future developments should be cautious using radiant bar charts and class averages. Additionally, it is important to remember that although there is a specific target group of secondary school teachers, some of them prefer sticking to traditional approaches while others are open to new visualisations. However, this tendency towards traditional methods does not extend to the dashboard, as almost all teachers wanted the use the dashboard next school year.

7.3 Limitations and future work

It is crucial to acknowledge the limitations of this research as well as possible future work. **(1)** One limitation of this research was the lack of available data, which made the development of a dashboard more complicated. Test data was used instead of real-time data, compromising the accuracy of the studies. **(2)** Another limitation was the time constraint, with a one-week trial period and initial impressions captured through interviews. Further evaluations should be conducted over a longer period to explore the dashboard's use and impact in different contexts. **(3)** The importance of considering the affective state of students was highlighted, but limitations arose due to the unavailability of this data in Moodle. **(4)** During the user studies, teachers asked to extend the dashboard to an 'individual student' view. This view would show the same data for one student over multiple courses (as now the dashboards shows all students of one course). This extension would provide insights into whether a student is struggling in a specific subject or facing challenges across the board.

8 CONCLUSION

This research focused on designing, developing, and evaluating a competency dashboard, specifically targeting secondary school teachers. We addressed research gaps in the field of LA and tried to provide valuable insights into the design and development of a LA dashboard for secondary school teachers. To achieve these objectives, an iterative and user-centred

design process was followed. The result of this research is a working LA dashboard that provides teachers with helpful insights and actionable content for understanding their students' grades and progress. The dashboard's design allows for easy understanding and use of visualised learning data.

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