Institute of Software Engineering
Software Quality and Architecture

University of Stuttgart
Universitätsstraße 38
D–70569 Stuttgart

Bachelorarbeit

Evaluation of the Impact of Progress Visualization on Motivation

Sangaran Ramesch

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Examiner:	Prof. Dr.-Ing. Steffen Becker
Supervisor:	Nadine Koch, M.Sc. Niklas Meißner, M.Sc.
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Abstract

Context. Digital learning platforms have become increasingly important in higher education. Within these platforms, progress visualizations are frequently used to support students in monitoring their learning progress and are often assumed to consequently enhance student motivation.

Problem. However, the current state of research regarding the motivational effects of progress visualizations remains limited and yields inconsistent results. While some studies indicate that progress visualizations can significantly increase student motivation, others fail to confirm this effect.

Objective. The objective of this thesis is to examine the factors that enable progress visualizations to foster student motivation. This examination is intended to provide a deeper understanding of motivational effects and to establish design guidance for effective motivating progress visualizations.

Method. Therefore, a requirements engineering process based on a literature review was conducted to derive requirements for motivating progress visualizations. Based on these requirements, a concept was designed, implemented and evaluated through a questionnaire-based user study.

Result. The results provide insights into the perceived motivational impact of different progress visualization mechanisms and highlight relevant design aspects. Mechanisms that clearly communicate achievements and guide towards meaningful next steps were perceived as particularly motivating. However, the small sample size requires cautious interpretation.

Conclusion. Overall, the findings contribute to a better understanding of how progress visualization mechanisms can influence student motivation. They provide initial design guidance for implementing motivating progress visualizations. Further research is necessary to validate the findings in larger, more diverse samples and to investigate long-term effects in real learning contexts.

Kurzfassung

Kontext. Digitale Lernplattformen haben in der Hochschulbildung zunehmend an Bedeutung gewonnen. Innerhalb dieser Plattformen werden Fortschrittsvisualisierungen häufig eingesetzt, um Studierende bei der Nachverfolgung ihres Lernfortschritts zu unterstützen und es wird oft angenommen, dass sie dadurch die Motivation der Studierenden steigern.

Problem. Der aktuelle Forschungsstand zu den motivierenden Effekten von Fortschrittsvisualisierungen ist jedoch limitiert und liefert widersprüchliche Ergebnisse. Während einige Studien darauf hinweisen, dass Fortschrittsvisualisierungen die Motivation signifikant steigern können, können andere diesen Effekt nicht bestätigen.

Ziel. Das Ziel dieser Arbeit ist es, die Faktoren zu untersuchen, die es Fortschrittsvisualisierungen ermöglichen, die Motivation von Studierenden zu fördern. Dies soll zu einem besseren Verständnis der motivierenden Effekte beitragen und Gestaltungsrichtlinien für effektive, motivierende Fortschrittsvisualisierungen ableiten.

Methode. Zur Erreichung dieses Ziels wurde ein Anforderungsanalyseprozess auf Basis einer Literaturrecherche durchgeführt, um Anforderungen an motivierende Fortschrittsvisualisierungen abzuleiten. Auf Grundlage dieser Anforderungen wurde ein Konzept entwickelt, implementiert und anschließend im Rahmen einer fragebogenbasierten Nutzerstudie evaluiert.

Ergebnis. Die Ergebnisse liefern Einblicke in die wahrgenommene, motivierende Wirkung verschiedener Mechanismen der Fortschrittsvisualisierung und heben relevante Gestaltungsaspekte hervor. Insbesondere Mechanismen, die erreichte Fortschritte klar kommunizieren und Studierenden Orientierung für sinnvolle nächste Schritte geben, wurden als besonders motivierend wahrgenommen. Aufgrund der geringen Stichprobengröße sind die Ergebnisse jedoch mit Vorsicht zu interpretieren.

Schlussfolgerung. Insgesamt tragen die Ergebnisse zu einem besseren Verständnis darüber bei, wie Mechanismen der Fortschrittsvisualisierung die Motivation von Studierenden beeinflussen können. Sie liefern erste Gestaltungsansätze für die Umsetzung motivierender Fortschrittsvisualisierungen und heben Aspekte hervor, die bei der Gestaltung solcher Mechanismen berücksichtigt werden sollten. Weitere Forschung ist erforderlich, um die Ergebnisse an größeren und vielfältigeren Stichproben zu validieren und langfristige Effekte in realen Lernkontexten zu untersuchen.

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MUI Material UI. 37

RE requirements engineering. 2

SD standard deviation. 21

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1 Introduction

In modern education, digital learning platforms have become increasingly important [Joh22]. In higher education, universities widely employ digital learning platforms that allow students to adapt their learning to their individual pace and needs. Platforms such as Moodle [Dia] and Ilias [eV] provide online access to structured course materials, including lecture slides, videos and worksheets. In addition, platforms aim to enhance the learning process through interactive features such as online assignments with automatic feedback and discussion forums, which enable students to connect with one another and engage in discussions about course content. However, in most cases, digital learning platforms are primarily used as a supplement to face-to-face teaching and as a supportive learning tool outside the classroom.

Student motivation is essential for successful learning and has a significant influence on learning outcomes [Gua22]. Despite the mentioned benefits of digital learning platforms, maintaining student motivation remains a persistent challenge [SK01]. One particularly prominent issue in digital learning environments is the lack of social motivation compared to conventional in-person learning. In an educational context, social motivation refers to the desire to learn through direct interaction with fellow students and instructors [BS23]. At the initial stage, this lack of social motivation may not be immediately apparent, as learners' engagement can be temporarily increased by the novelty of digital learning platforms [SK01]. This novelty effect can mask underlying motivational deficits. However, as the novelty fades over time, the absence of motivation becomes increasingly evident. Consequently, insufficient motivation may emerge as a critical factor that negatively affects students' learning success.

In order to assist students in overcoming motivational problems, literature recommends e-learning platforms to provide motivational elements [KBN23]. Therefore many e-learning platforms use gamification. Gamification is defined as "the process of adding games or gamelike elements to something (such as a task) so as to encourage participation" [Mer]. A prominent e-learning platform that utilizes a gamification approach is Duolingo [Duo24]. Duolingo is a platform for language learning and it employs gamelike elements, such as progress bars, rewards, rankings and other features. The intelligent tutoring system MEITREX [Mei24] is another example of a system that employs a gamification approach. MEITREX provides students with a variety of gamification components as well, including a level overview, a scoreboard, progress bar systems and other such features. Gamification includes various concepts and approaches, including motivation through progress visualization. Awareness of one's own progress can serve as a motivating factor for learners [Neh10]. This includes motivation through the setting and understanding of clear goals [NTRV13], through the self-monitoring of the progress towards these goals [Zim02] and through the satisfaction of achieving such goals.

Nevertheless, the current state of research in this field remains limited, particularly with regard to understanding in which way progress visualization can be an effective motivational tool and in which way it may not be effective or even demotivating. Further research is required to ascertain which specific mechanisms of progress visualization contribute to student motivation and which attributes are not or are even counterproductive. Accordingly, the main research questions to be addressed in this bachelor's thesis are as follows:

> **RQ1** Which progress visualization mechanisms impact students' motivation?
>
> **RQ2** How should identified progress visualization mechanisms be realized in order to motivate students?

Therefore, this thesis focuses on evaluating the impact of progress visualization on student motivation within e-learning systems. The goal is to understand how different types of progress representations influence learners' engagement and to identify which visualization mechanisms contribute positively or negatively to their motivation. To achieve this, the research will proceed in four main stages. First, a comprehensive literature review will be conducted to establish the theoretical foundation and identify existing approaches to progress visualization in digital learning. Second, based on these insights, a requirements engineering (RE) phase will gather user-centered requirements through a survey to determine what learners expect from motivational progress indicators. Following this, the collected requirements will serve as a foundation for the implementation phase, in which a newly designed progress visualization will be integrated into the intelligent tutoring system MEITREX. Finally, the developed progress visualization will be evaluated in terms of its impact on student motivation and learning experience.

The main contribution of this thesis is the development of design principles that define what kind of progress visualization enhances motivation and what factors may lead to demotivation. By understanding these dynamics, this work aims to support the creation of more engaging and effective e-learning environments that foster long-term student motivation and success.

Thesis Structure

This thesis is structured in the following manner:

Chapter 2 – Foundations: This chapter summarizes the foundations that are relevant to this thesis, including gamification and motivation. Furthermore, the MEITREX platform is introduced.

Chapter 3 – Related Work: This chapter reviews related work relevant to this thesis, focusing on research in the areas of gamification and progress visualization.

Chapter 4 – Requirements Engineering: This chapter presents the methodology and results of the RE.

Chapter 5 – Concept and Design: This chapter presents the conceptual design of the progress visualization based on the previously defined requirements.

Chapter 6 – Implementation: This chapter describes the implementation of the progress visualization prototype based on the proposed concept.

Chapter 7 – Evaluation: This chapter presents the evaluation of the implemented progress visualization, focusing on its impact on student motivation.

Chapter 8 – Conclusion: This chapter summarizes the findings of this thesis and discusses limitations as well as directions for future work.

2 Foundations

This section covers the foundations of the thesis. It introduces theoretical foundations to important concepts of this thesis such as motivation and gamification. Additionally, it presents the test environment MEITREX and provides overall necessary background to understand this thesis.

2.1 Literature Research Methodology

The literature research was mainly conducted through the search engine Google Scholar [Goo]. Also unconventional methods, such as using ChatGPT [Ope25] and Elicit [25] were used to find suitable papers for this thesis. Due to the recognized inaccuracies and errors associated with artificial intelligence, it was utilized exclusively for the discovery of relevant papers, with no information being derived from the artificial intelligence's own contributions, such as summaries. Instead, information was obtained directly from the proposed papers themselves. However, the majority of the literature research was conducted using Google Scholar, with artificial intelligence being used only as supplementary research tools. The following terms were used in many variations to identify relevant sources:

- progress visualization
- motivation
- gamification
- framework
- design
- monitoring
- game mechanics

Besides the named search terms many other terms were searched, but proved to be less relevant for this thesis and the most relevant papers were found through combinations of these search terms. Many relevant sources were also found through backwards snowballing from summaries from literature reviews such as those by Khaldi [KBN23] and Krath [KSV21]. Especially in the early stages of this literature research, they provided a valuable insight into the state-of-the-art. Additionally, related work was found through forward snowballing from papers of frameworks such as the Octalysis Framework from Yu-kai Chou [Cho19]. In this way the master thesis of Høylandskjær [Høy24] was found about designing motivational learning experience through progress tracking. The literature research was limited only by the availability of papers through the university network and by language, as only english and german papers were considered. The relevance of the papers for this thesis was quickly determined based on the title, abstract and final conclusion of the paper.

2.2 Motivation

Ryan and Deci [RD00] describe motivation as the psychological state of being moved, energized or activated towards a goal. In contrast, being uninspired to act is characterized as unmotivated. In the context of education, motivation has been identified as a critical factor in students' academic success [DDAA15]. Therefore, this thesis focuses on the fostering of motivation through progress visualization, particularly in the context of remote learning on digital platforms.

In order to foster motivation, it is necessary to establish a theoretical foundation for motivation. The most fundamental distinction of motivation is between *intrinsic* motivation and *extrinsic* motivation [RD00]. Intrinsic motivation is defined as the motivation to perform a task in itself. A person feels a sense of enjoyment, satisfaction or other positive emotions and takes pleasure in the task itself, without concerns about external factors. In contrast, extrinsic motivation can be defined as the motivation to attain a desired outcome through the performance of a given task. The task itself is not necessarily enjoyable and can even be exhausting, unpleasant or cause other negative feelings. However, the external outcome of the task still motivates individuals to perform the tasks regardless.

The distinction between intrinsic and extrinsic motivation is a well-established concept that is incorporated into numerous theories and frameworks. For instance, in the well-known Self-Determination Theory (SDT) [RD20a], intrinsic and extrinsic motivation are integrated into the theory itself. In a similar manner, although the Octalysis Framework [Cho19] itself does not incorporate intrinsic and extrinsic motivation, the book that presents the framework categorizes the defined types of motivation as intrinsic and extrinsic.

The following section will present the aforementioned SDT as theoretical foundation of motivation. Furthermore, the aforementioned Octalysis Framework [Cho19], a gamification design framework that differentiates types of motivation in the context of gamification elements, will be examined in the gamification section.

2.2.1 The Self-Determination Theory

The SDT proposes that motivation is dependent on the satisfaction of three basic psychological needs: *autonomy*, *competence* and *relatedness*. According to the SDT, these psychological needs apply universally to every human being [Gua22]. Autonomy can be defined as the need to feel in control and to act in accordance with one's own will and interests. Competence can be defined as the need to feel competent, effective and a sense of success and growth. Relatedness is described as the need to feel emotionally connected to others and to feel like a part of a group. All these basic needs are essential for motivation and neglect of any of these needs is considered detrimental to motivation [RD20a].

Motivation itself in SDT is differentiated into autonomous types of motivation and controlled types of motivation [RD20b]. Autonomous in this context is described as acting with full will and choice, while controlled is described as pressured or forced through external factors. In the context of intrinsic and extrinsic motivation, intrinsic motivation is defined as being solely autonomous. However, the SDT taxonomy now distinguishes between different types of extrinsic motivation [RD20a]. The four sub-types are *external regulation*, *introjected regulation*, *identified regulation* and *integrated regulation*. External regulation is characterized as the least autonomous sub-type of extrinsic motivation. This motivation is characterized by the drive to act in response to simple external rewards or punishments and is perceived as completely controlled and not autonomous. The most autonomous sub-type is integrated regulation and it is the form of motivation in which the value of the activity is recognized and in line with other core interests and values of a person. An example for integrated regulation would be for someone to study medicine to be able to save lives in the future, which is in line with the persons core interests and values [NR09]. Autonomous extrinsic motivation and intrinsic motivation both possess the capacity to manifest strong wills, yet are distinguished by the fact that only intrinsic motivation is rooted in the interest and enjoyment of the activity itself.

SDT has been applied in various contexts like education, work, sport, video games and health care among others [RD20b]. In the context of education evidence was found that autonomous motivation, so intrinsic motivation and autonomous types of extrinsic motivation, has a positive impact on academic outcomes [NR09].

2.3 Gamification

Gamification in general is defined as the usage of gaming elements in a non-gaming environment [HHMS21]. The fundamental premise behind gamification was to imitate video game environments in other non-gaming contexts, with the objective of evoking a similar level of excitement and motivation [SRV13]. Gamification is already being used in various fields, including education, marketing, health and fitness [NTRV13]. According to the findings of numerous studies, a variety of gamification approaches applied in educational contexts, have been found to significantly increase student motivation and engagement [JBCC24]. In the literature review of Nah et al. [NZT+14] eight game design elements were identified, that are used extensively in the educational and learning context:

- *Points*: A point system used to measure the learners' success, for example experience points, which are well known from video games.
- *Levels/Stages*: A progression system in which early levels are easy and later levels become more difficult.
- *Badges*: Visual tokens awarded for achievements, often displayed on a student's profile.
- *Leaderboards*: Rankings that foster competition, usually highlighting top performers.
- *Prizes and Rewards*: Virtual rewards granted for accomplishments, such as unlocking new character outfits or similar virtual items.
- *Progress Bars*: Visual indicator that display advancement toward a goal.
- *Storyline*: Guides students through assignments by embedding tasks within a narrative, making learning more engaging and providing real-life context for theoretical content and problem solving.
- *Feedback*: Clear and immediate feedback that helps keep students engaged and supports their learning process.

In the context of progress visualization, especially relevant are progress bars, levels/stages, narrative/story, feedback and badges, which were defined in 280 articles with terms like progress or progression [HAK+23]. In practice many elements are incorporated combined [KBN23]. For instance, points and levels are often visualized together, as experience points are commonly represented by an experience points progress bar, where the achievement of the next level is indicated by the completion of the bar.

2.3.1 The Octalysis Framework

Yu-kai Chou [Cho19] emphasizes that effective gamification design requires consideration of the feelings intended to be evoked in users and selection of appropriate game elements that foster these feelings. In order to systematize this combination of game elements with motivational core drives, the gamification design framework called the Octalysis Framework was created. The Octalysis Framework defines 8 core drives, which are represented in an octagonal shape, with each side of the octagon representing one of the core drives (see Figure 2.1).

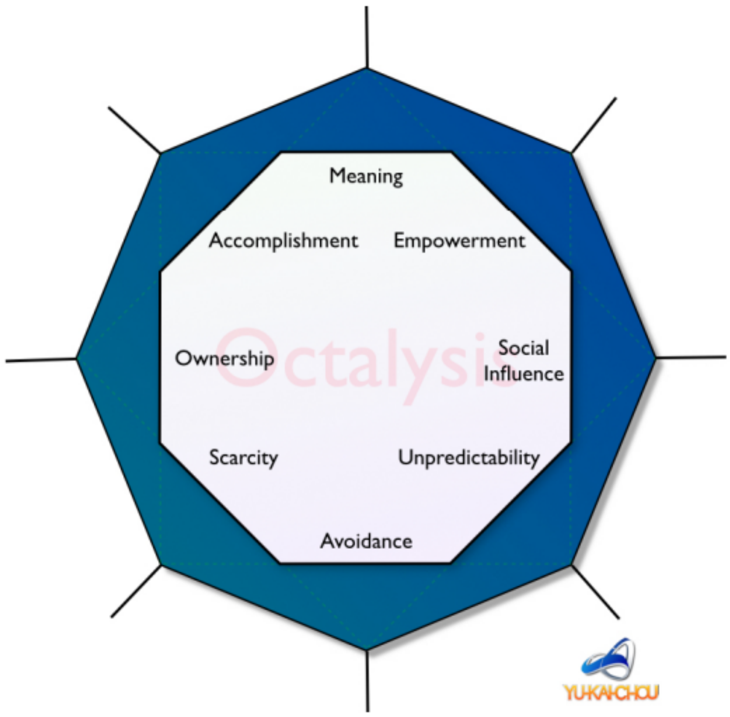

Figure 2.1: Octalysis Framework

The 8 core drives are:

- *Epic Meaning & Calling* refers to the feeling of contributing to a greater cause or being special due to a unique talent or circumstance, such as when individuals contribute to Wikipedia despite receiving no personal reward.

- *Development & Accomplishment* describes the internal motivation to make progress, achieve goals and overcome challenges.
- *Empowerment of Creativity & Feedback* represents the drive to express creativity and receive feedback on one's actions, for example when people enjoy building with LEGO or creating art.
- *Ownership & Possession* refers to motivation that arises from owning or controlling something, such as responsibility for a project, organization, or a personalized profile or avatar.
- *Social Influence & Relatedness* encompasses social motivations such as companionship, competition and nostalgia, where individuals are drawn to experiences that remind them of meaningful past moments, such as childhood memories.
- *Scarcity & Impatience* describes the motivation to desire something because it is rare, exclusive or not immediately obtainable.
- *Unpredictability & Curiosity* refers to the drive to engage with uncertain or unexpected outcomes, which can be observed in activities such as watching movies, reading books or gambling.
- *Loss & Avoidance* describes the motivation to prevent negative outcomes or missed opportunities, such as the fear of losing a job or missing a limited-time offer.

The author Yu-kai Chou [Cho19] further emphasizes that in the absence of an underlying core drive, no motivation is triggered. Accordingly, each game element that motivates in the context of gamification has an underlying core drive that is triggered by the game element. The second core drive Development & Accomplishment is of particular relevance to this thesis. The description of the internal drive for making progress, achieving goals and overcoming challenges matches exactly the motivation through progress visualization examined in this thesis. Yu-kai Chou [Cho19] stated that elements such as progress bars and levels primarily trigger the core drive of Development & Accomplishment. These elements are a common method of encouraging a sense of accomplishment. However, it is essential to highlight that the success of these methods is dependent on the presence of a challenging assignment that the user can successfully overcome. Achieving success too easily could result in boredom, which could in turn reduce motivation. Furthermore, there are game elements that have been identified as suitable for multiple core drives by Yu-kai Chou [Cho19]. Such elements include points, rewards and badges, which have the capacity to trigger not only the core drive of Development & Accomplishment, but also the core drive of Ownership & Possession and in certain instances even the core drive of Loss & Avoidance.

2.3.2 Player Types

Personalized gamification systems have been found to be more effective than one-size-fits-all approaches [TWD+16]. Therefore, Marczewski [Mar15] developed the Gamification User Types Hexad Framework (see Figure 2.2) to differentiate users by personality traits, in order to facilitate the development of personalized gamification systems. The framework is predicated on findings regarding human motivation, player types and practical design experiences. The concept of motivation within the framework is thereby grounded in the theoretical foundation of SDT, which was introduced earlier in this thesis.

Figure 2.2: Gamification User Types Hexad

The framework has established six distinct user types, which are defined as follows:

- *Philanthropists* are motivated by purpose. They are altruistic and willing to give without expecting a reward.
- *Socialisers* are motivated by relatedness. They want to interact with others and create social connections.
- *Free Spirits* are motivated by autonomy, meaning freedom to express themselves and act without external control. They like to create and explore within a system
- *Achievers* are motivated by competence. They seek to progress within a system by completing tasks, or prove themselves by tackling difficult challenges.
- *Players* are motivated by extrinsic rewards. They will do whatever to earn a reward within a system, independently of the type of the activity.
- *Disruptors* are motivated by the triggering of change. They tend to disrupt the system either directly or through others to force negative or positive changes. They like to test the system's boundaries and try to push further.

The Hexad Framework complements the Octalysis Framework [Cho19] since the Octalysis Framework differentiates between motivations and the Hexad Framework differentiates between player types that are more responsive to certain types of motivation. These concepts are therefore well-aligned, as one describes a specific type of motivation, while the other identifies a player type that is particularly responsive to this exact form of motivation. Socialisers from the Hexad Framework, who are motivated by relatedness and the desire to establish social connections, are more likely to be motivated by triggering the core drive of Social Influence & Relatedness from the Octalysis Framework, which incorporates all the social elements that motivate people. Furthermore, Philanthropists and the core drive Epic Meaning & Calling and Free Spirits and the core drive

Empowerment of Creativity & Feedback appear to be compatible, according to the definitions of each concept. Note that even though some player types and core drive seems to fit perfectly not every player type and core drive have a match.

The core drive Development & Accomplishment, which was previously identified as particularly relevant to this thesis, seems to motivate especially the two player types Achievers and Players. Therefore, the utilization of progress visualization is likely to be particularly impactful in motivating users who fall into the categories of Players and Achievers.

2.4 MEITREX

MEITREX [Mei24] is an intelligent tutoring system that has been implemented as a web application. MEITREX has been designed to encourage students to learn. Therefore, it enables students to engage with course content provided by lecturers and based on their performance, receive an overview of their individual learning progress. The goal of MEITREX is to individually assist students, to motivate them and to improve the learning experience of especially software engineering topics. This is achieved by the use of learner analytic techniques, gamification elements and personalized feedback.

MEITREX consists of several key components. On the top level, there are courses that a lecturer can create and students can enroll in. Within a course, there are several chapters that bundle content into thematic units. This content is provided by the lecturer and contains assessments for the students. These assessments are in the form of quizzes, flashcards and code assignments. The results of these assessments are used to measure the learning success of the students. The data that is gained from the students' learning progress is used to understand and adapt to the students' learning style and to increase motivation with gamification elements. There are a number of gamification elements in MEITREX, including a level map, a scoreboard and a progress bar system. The progress bar system, the so-called *skill progress bar system* (see Figure 2.3), is employed to display progress in various areas. The following section will introduce the assessment system. The skill progress bar system serves as the test subject in this thesis. Depending on the results of this thesis RE, the skill progress bar system will be reworked or even completely replaced by a newly designed progress visualization.

MEITREX is being developed at the University of Stuttgart and is still an ongoing project. The current state of development can be found on GitHub [Mei25].

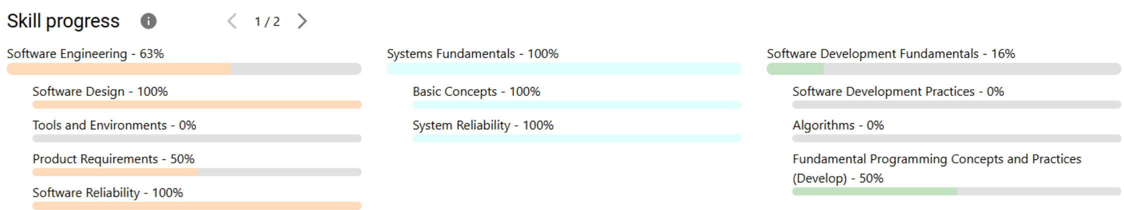

Figure 2.3: MEITREX Skill Progress Bar

2.4.1 MEITREX Competency Model

The aforementioned skill progress bar system is based on a competency model. The competency model was released by the latest version of the computer science curricular guidelines, the so-called CS2023 curricular guidelines [KRA+24]. The CS2023 curricular guideline define the fundamental knowledge and skills that students should acquire in a computer science study through that competency model, particularly on a bachelor's degree level. In the introduction of the CS2023 curriculum it is stated that "Since 2013 the focus of curricular design has moved from what is taught (a knowledge model) to what is learned (a competency model)" [KRA+24, p. 25]. This statement indicates that it is not far-fetched to use the model as an assessment standard for students. That's exactly what MEITREX is doing in a simplified way. In this thesis, the simplified version of the competency model will henceforth be referred to as the MEITREX competency model.

The original competency model is structured as a set of competency specifications. A competency specification consists of a task, a competency statement, knowledge, skills and dispositions. MEITREX simplifies the competences by only representing them with the attributes knowledge and skills for each task. The competency statement and the dispositions were left out to avoid further complexity in the assessment system for the students. Knowledge is described through a knowledge model, that is structured as a set of knowledge areas. Theses 17 knowledge areas (see Table 2.1) consist of related knowledge units. For example, the knowledge area Algorithmic Foundations is divided into the knowledge units Foundational Data Structures and Algorithms, Algorithmic Strategies, Complexity Analysis, Computational Models and Formal Languages, and Society, Ethics and the Profession. Skills are meant to describe the difficulty of topics. CS2023 introduced new skill levels: Explain, Apply, Evaluate and Develop. Those are based on the revised Bloom's taxonomy [AK01]. MEITREX still uses these revised Bloom's taxonomy containing: Remember, Understand, Apply, Analyze, Evaluate and Create. It is important to note that in MEITREX, knowledge units are called skills and the skills according to CS2023 are directly referred to as Bloom's Taxonomy in MEITREX.

The calculation of skill values in MEITREX is based on the Multivariate Elo-based Learner Model (M-Elo) proposed by Abdi et al. [AKSG19]. This model extends the classical Elo rating system by estimating a student's knowledge on the level of individual skills and updating these values after each completed assessment. According to the student's responses, adjustments are made to both skill values and assessment difficulties, resulting in an updated estimation of the student's current knowledge progress. The integration and implementation of M-Elo into MEITREX were carried out by Keller [Kel24]. Further insights into the model selection and integration process can be found in her work.

In conclusion, the skill progress bar system, which displays progress based on the MEITREX competency model, provides a visualization of learner progress at both the level of each overarching knowledge area and at the level of the individual knowledge units contained within them (see Figure 2.3).

• Artificial Intelligence (AI) • Algorithmic Foundations (AL) • Architecture and Organization (AR) • Data Management (DM) • Foundations of Programming Languages (FPL) • Graphics and Interactive Techniques (GIT) • Human-Computer Interaction (HCI) • Mathematical and Statistical Foundations (MSF)	• Networking and Communication (NC) • Operating Systems (OS) • Parallel and Distributed Computing (PDC) • Software Development Fundamentals (SDF) • Software Engineering (SE) • Security (SEC) • Society, Ethics, and the Profession (SEP) • Systems Fundamentals (SF) • Specialized Platform Development (SPD)

Table 2.1: Knowledge Areas

3 Related Work

Following the theoretical groundwork established in the foundation chapter, this chapter examines related empirical research on gamification and progress visualization. It analyzes how previous work has investigated the motivational impact of visual progress indicators and gamified elements in digital learning contexts. The differences in study design, visualization approaches and evaluation methods are highlighted to contextualize the contribution of this thesis and to identify existing research gaps.

3.1 Gamification

Jaramillo-Mediavilla et al. [JBCC24] conducted a systematic literature review on gamification and found that gamification significantly influences student motivation. From an initial pool of 50 collected articles, a screening phase was conducted to assess their relevance. During this process, the articles were filtered according to the inclusion criteria previously defined. In consequence, a selection of nine systematic literature review articles were selected and considered for further analysis. From the nine articles, five concluded that the integration of gamification fosters greater engagement, participation and motivation among students. However, the limited number of supportive studies in the review indicates that the overall evidence remains inconclusive. A similar conclusion was drawn in the meta-analysis of Sailer et al. [SH20], which found a significant, small effect of gamification on motivational learning outcomes, but described the observed effects as unstable across contexts. Therefore, Sailer et al. [SH20] emphasize that it remains unclear which factors contribute to successful gamification, which is a research question of this thesis.

Furthermore, literature reviews conducted by Khaldi et al. [KBN23] and Nah et al. [NZT+14] focus more on the game elements. The findings suggest that the incorporation of commonly used game elements, such as points, levels, leaderboards and progress bars, into educational settings can enhance student motivation. Nevertheless, Khaldi et al. [KBN23] emphasize that it remains unclear which underlying mechanisms cause individual game design elements to impact student motivation. Toda et al. [TOK+19] addressed this lack of formal definitions of concepts behind individual game elements by creating a taxonomy of game elements based on the opinions of 19 experts. The aforementioned experts were mostly composed of researchers and teachers. The final taxonomy consisted of 21 game concepts, including progression.

3.2 Progression

Toda et al. [TOK+19] emphasize that the absence of objectives and a sense of progression has been shown to decrease student motivation. Within this context, they find it noteworthy that most of the researchers examined in their study classified objectives, levels and progression as crucial gamification concepts. The primary focus of this thesis is the visualization of progress. In addition to the concept of progression itself, relevant concepts include acknowledgments, level, objectives and points. The concept of acknowledgment is defined as a form of feedback that praises the user, with examples including badges, medals and trophies. Consequently, the regular reception of feedback can contribute to a sense of progress. Similarly, the concept of levels contributes to learners' sense of progress by structuring the learning process into clearly defined stages. Objectives and points are inherently important concepts for defining progress, as learners require clear objectives to experience a sense of advancement toward specific goals, while points serve as a unit for measuring that progress.

In another study, Alonso et al. [AJA] explored the use of a visualization tool to increase students' awareness of their own progress and consequently increase their motivation. The impact of the visualization was mainly measured through the participation of students in optional activities. The visualization tool was updated on a weekly basis and it was found that 75% of the students accessed the tool even more frequently than it was updated. In addition, excluding the holiday season, more than 50% of students accessed their progress at least once per week. In comparison to the control group, which did not have access to the visualization tool, participation increased for all topics from the smallest increment of 30% to the most significant increases of over 90%. Despite the fact that the highest rates of participation were observed in both groups during the weeks of deadlines, only the experimental group demonstrated a significant participation rate in the weeks before the deadline. This finding suggests that students in the control group are motivated solely by the deadline, while those in the experimental group are consistently motivated throughout the entire period. Alonso et al. [AJA] further recommend conducting a questionnaire among students in the future to gain deeper insight into the utilization and perception of progress visualization.

Furthermore, Høylandskjær [Høy24] explored the use of progress tracking as a motivational tool. Therefore, she integrated progress tracking elements into a digital learning platform by focusing on the core motivational drivers from the aforementioned Octalysis Framework from Yu-Kai Chou [Cho19]. The methodological approach adopted was a iterative user-centered design process, whereby the design was repeatedly refined based on user feedback. The user feedback was collected through qualitative data gathering methods, in contrast to the aforementioned studies which relied mostly on quantitative elicitation and evaluation methods. The findings indicated that a perceived lack of progression was a recurring factor contributing to a decline in motivation. Accordingly, the final design incorporated the principles of Development and Accomplishment [Cho19]. The study concluded that focusing on core motivational drivers and integrating them can offer the users a more meaningful and motivational learning experience. However, the author emphasizes that the participants are not a general representation of all user needs and that the user needs and requirements should be further explored.

Hallifax et al. [HAK+23] found that, among 280 analyzed articles, 82% defined the game element *bar* with the term progress. No other game element was associated with the terms progress or progression as frequently. Consequently, as one of the game elements most closely related to progress visualization, studies investigating progress bars and their impact on student motivation are examined in the following.

O'Donovan [ODo12], for instance, investigated the potential of gamification to enhance student motivation. The study was conducted with 90 college students who participated in two surveys. The results of the study revealed that progress bars were the most popular game element. Participants rated how motivating each game element would be on a scale from 1 (very motivated) to 5 (very unmotivated). The progress bars received an average rating of 1.46, with 60% of students rating them as very motivating and more than 35% as moderately motivating.

Finally, Mazarakis et al. [MB23] conducted a field experiment using a between-group design to investigate how individual game design elements and their combinations impact motivation. In this experiment, each participant was assigned to a group featuring different game design elements. The study comprised a total of seven groups, including a control group. A total of 505 participants were evenly distributed across these groups and motivation was measured based on the number of questions answered in a quiz consisting of 190 questions. Participants were free to stop the quiz at any time. In comparison with the control group, all experimental groups demonstrated higher mean numbers of answered questions and higher completion rates of the quiz overall. Among the conditions in which only a single game design element was implemented, the progress bar group achieved the second-highest average number of answered questions, with a mean of 101.21 out of 190 questions. Furthermore, the highest completion rate for the quiz was observed in the group that incorporated a progress bar combined with feedback (50%) and the third-highest overall, but highest among the groups that only incorporated a single game design element, was the group that featured solely a progress bar (39.33%).

4 Requirements Engineering

This chapter presents the RE process, including the methodology and results. The results are the basis for the planned progress visualization design, which will be implemented in the further course of this thesis. In the context of this thesis, the RE process was conducted with the students as the only relevant stakeholders.

4.1 Research Questions

The main objective of this thesis was the development of design principles that define what kind of progress visualization enhances motivation and what factors may lead to demotivation. In order to establish these design principles, requirements for motivational progress visualization will first be gathered. These requirements will be integrated in a progress visualization and evaluated based on the students' perceptions of them in practice. Following the conclusion of the final evaluation, the design principles will finally be established.

In this RE phase, the initial requirements will be gathered for a motivational design for progress visualization. In addition to the requirements concerning the motivational aspect of progress visualization, general progress visualization requirements, such as expected functions and level of detail, and platform-specific requirements in the context of MEITREX will be gathered to develop the progress visualization. The platform-specific requirements are thereby important to build progress visualization that is fitting to the type of progress that should be visualized in MEITREX.

This thesis will conduct a RE process consisting of four stages: requirements elicitation, requirements analysis, requirements specification and requirements validation [WO24]. The following research questions will guide this process to achieve the aforementioned objectives:

> RQ1 **General Requirements:** What general requirements do students have for progress visualizations in digital learning environments?
>
> RQ2 **Motivational Requirements:** How do different characteristics of progress visualizations affect students' motivation and which specific features are perceived as motivating or demotivating?
>
> RQ3 **MEITREX Competency Model:** What requirements do students have for progress visualizations within the specific context of the MEITREX competency model?
>
> RQ4 **Priorities:** Which identified requirements should be prioritized for the effective design of progress visualizations?

4.2 Method

In order to answer the research questions, the requirements elicitation was conducted through an online questionnaire. The reason behind the utilization of an online questionnaire as a requirements elicitation technique was primarily to gather the opinions of a large variety of students while requiring minimal effort from participants, given the limitations of this bachelor thesis. The elicitation of the opinions of many students is important, because the intention is to introduce motivational design principles, that can be applied generally. Therefore, it was also unnecessary to engage in an in-depth investigation of the preferences of individual students, for instance by conducting the elicitation in interview formats.

The requirements were derived from the results of the requirements elicitation process. The resulting requirements were then prioritized. The MoSCoW [KBS22] analysis technique was utilized in order to determine the priority of each requirement. Consequently, a concept for the new progress visualization was developed, based on these requirements.

4.2.1 Questionnaire

The questionnaire consisted of three parts. The questionnaire opened with questions regarding participants' demographic data. Participants were asked about their gender, age, course of study and year of study. Then questions regarding general progress visualization and motivation through progress visualization followed. After that, the MEITREX competence model was explained briefly and the questionnaire concluded with questions regarding progress visualization and motivation in this particular context. The content of the questions was based on the previously conducted literature review. Accordingly, the participants were asked about the game elements that were found to be commonly used in the literature review. Regarding motivation in the context of progress visualization, students were asked about scenarios intended to elicit their opinions on the concepts behind the game elements described by Toda et al. [TOK+19]. For example, students were asked to rate scenarios such as “Seeing how I am achieving my milestones and goals” or “Seeing how my progress increases visually after completing tasks”, targeting the concepts of objectives and progression.

The questionnaire contains a number of question types, including single-choice, multiple-choice, Likert scale and open-ended questions. In the case of both single-choice and multiple-choice questions, respondents were often permitted to enter their own answers instead of those provided. In this way, despite the limited emphasis on students' in-depth preferences, students were given the opportunity to elaborate further on their views through open-ended questions and options for additional comments.

The complete questionnaire is available as part of the research dataset of this thesis [Ram26].

4.2.2 Participants

The questionnaire was started by 49 participants, but only 33 completed it. In order to ensure the validity of the responses, only the 33 correctly completed questionnaires were included in the analysis.

The questionnaire was distributed within Telegram and Discord groups to students at the University of Stuttgart. This distribution occurred predominantly within groups consisting of students majoring in fields related to computer science. This may explain why all respondents are enrolled in a computer science-related field of study (see Table 4.1).

From the in total 33 considered participants, about 76% identified themselves as male, 21% as female and 3% preferred not to specify the gender they identified with. The mean age of the participants was 22.96 years, with a standard deviation (SD) of 3.16. More details about the student demographics are shown in Table 4.1.

Gender		**Age**		**Course of Study**	
Male	75.76%	Average	22.96 yrs	Computer Science	54.84%
Female	21.21%	Maximum	35	Software Engineering	25.81%
Prefer not to answer	3.03%	Minimum	18[1]	Data Science	9.68%
		SD	3.16	Media Computer Science	9.68%

Table 4.1: Student Demographics

4.3 Results

In this section, the results of the questionnaire will be presented and discussed. The questions included in the questionnaire, along with the percentage distribution of responses from participants, are given to provide an empirical basis for the derivation of requirements presented in the subsequent section. All questionnaire responses are available in the research dataset of this thesis [Ram26].

4.3.1 General Progress Visualization

The first question following the demographic questions initiated the aforementioned section regarding general progress visualization and motivation in the questionnaire. The multiple-choice question asked participants to state their general expectations of progress visualization and provided them with a number of possible answers. Participants were permitted to select multiple answers and submit their own answers in addition to those provided.

The result was summarized in Figure 4.1. All 33 participants answered the question and the majority of them expect progress visualization to fulfill their main purpose to provide clear tracking of progress (90%). The second most chosen answer was that the participants expect progress visualization to highlight areas/topics that require attention (70%). Other answers that were chosen were that progress visualization should provide a clear overview of all areas/topics (64%), provide progress towards goals and milestones (64%) and that it should encourage making more progress (58%). Also frequently selected was that progress visualization should enhance the feeling of control over the learning progress (45%) and that it should present achievement in a rewarding matter (33%).

[1] One participant entered 0 as age, which is clearly a mistake and so was not considered.

The “Other” option was selected by the participants to provide two additional responses. The first participant stated that they expected progress visualization to be gamified and to include challenges, while the second response expressed a preference for minimal information on progress visualization and a simple and easily understandable representation.

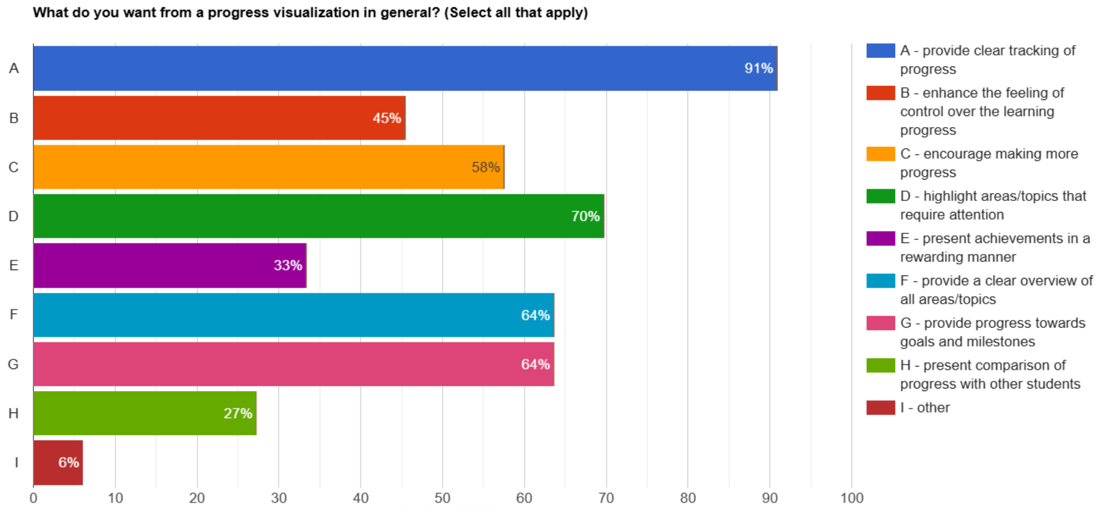

Figure 4.1: What do Students want from Progress Visualization in General?

4.3.2 Motivation in the Context of Progress Visualization

Thereafter, the next question aimed to investigate the impact on student motivation through several progress visualization mechanics. Therefore the students were requested to rate several progress visualization mechanics and features on a 5-point Likert scale. The participants could rate them by categorizing their level of motivation as either strongly demotivating, demotivating, neutral, motivating or strongly motivating. The participants indicated that being close to achieving a goal was the most motivating mechanic (61% strongly motivated, 36% motivated, 0% neutral, 3% demotivating). Conversely, seeing that no progress had been made yet was rated as the most demotivating mechanic (24% strongly demotivating, 52% demotivating, 18% neutral, 3% motivating, 3% strongly motivating). Further results of the categorization of the students are summarized in Figure 4.2 and will be addressed again in the Section 4.4 “Requirements”.

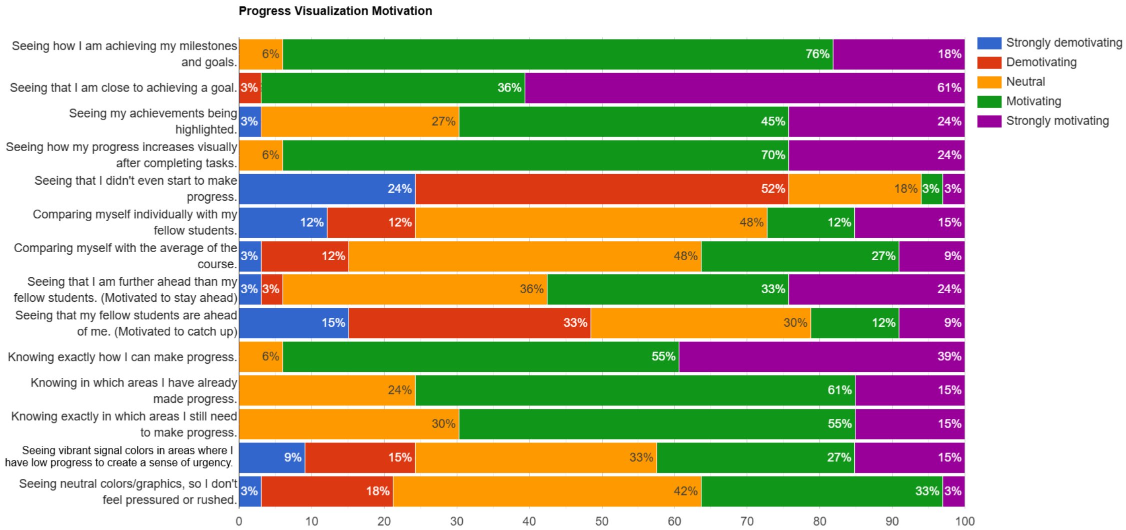

Figure 4.2: Progress Visualization Motivation

In order to enable a meaningful interpretation of the participants' responses, the Likert-scale categories were converted into numerical values ranging from -2 (strongly demotivating) to 2 (strongly motivating). The mean values were then grouped into intervals of 0.8 in order to classify their motivational impact (see Table 4.2). For instance, scores ranging from 1.2 to 2 were interpreted as strongly motivating.

Statement	Score	Category
Seeing how I am achieving my milestones and goals	1.12	Motivating
Seeing that I am close to achieving a goal	1.55	Strongly Motivating
Seeing my achievements being highlighted	0.88	Motivating
Seeing how my progress increases visually after completing tasks	1.18	Motivating
Seeing that I didn't even start to make progress	-0.91	Demotivating
Comparing myself individually with my fellow students	0.06	Neutral
Comparing myself with the average of the course	0.27	Neutral
Seeing that I am further ahead than my fellow students (motivated to stay ahead)	0.73	Motivating
Seeing that my fellow students are ahead of me (motivated to catch up)	-0.33	Neutral
Knowing exactly how I can make progress	1.33	Strongly Motivating
Knowing in which areas I have already made progress	0.91	Motivating
Knowing exactly in which areas I still need to make progress	0.85	Motivating
Seeing vibrant signal colors in areas where I have low progress to create a sense of urgency	0.24	Neutral
Seeing neutral colors/graphics, so I don't feel pressured or rushed	0.15	Neutral

Table 4.2: Likert-Scale Scores and Classification

4.3.3 Progress Visualization of the MEITREX Competency Model

Then the context of the MEITREX competency model was briefly explained. The explanation was kept simple so that participants could quickly understand what kind of progress should be visualized. The explanation was supported by a few examples and an illustration.

Having established this foundation, the participants were then invited to select the most helpful and motivating type of progress visualization for the given context. The selection was provided in a multiple-choice format, covering the most common known types of progress visualization. The participants were permitted to select multiple answers, if they found multiple suitable ones. Furthermore, they were permitted to submit a customized response that introduced a new progress visualization type.

The option to submit a customized response was utilized in this study to comment on another option, but did not recommend a new progress visualization type. The results demonstrated that for the participants, progress bars were identified as the most suitable and motivating type of progress visualization, with 85% of respondents selecting this option. Levels/ranks were the second most popular choice, with 70% of respondents indicating their approval of this option. The complete results for this selection can be found in Figure 4.3.

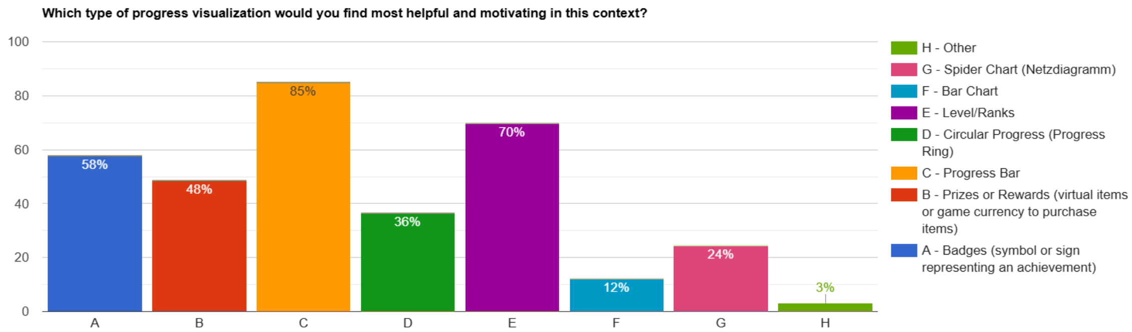

Figure 4.3: Progress Visualization for MEITREX

Thereafter, students were asked to specify their preferred level of detail in the progress visualization. Most respondents expressed a preference for hiding the detailed competency progress at first glance in order to create a cleaner, more compact view (41%). The second most common response among the participants was a preference for always displaying all underlying competencies (34%). The remaining respondents expressed either the opinion that the overall progress of each knowledge area was sufficient and that the progress of each competency was not necessary (16%), or that they did not have a preference at all (9%). This balanced distribution indicates that no single option clearly dominates and that the level of detail is an individual preference for each student.

In the next question, students were asked whether they would like to see the completion percentage as text, in addition to the progress visualization. It was found that 73% of the students expressed a preference for a text label indicating the completion percentage, while 21% indicated that they had no preference and only the remaining 6% objected. In conclusion, the explicit display of the completion as text is widely desired, in addition to the progress visualization. Furthermore, it appears to disturb almost no people.

4.3.4 Open-ended Questions

Concluding the questionnaire, participants were asked to respond to two open-ended questions. The purpose of these questions was to gather any additional information regarding motivating and demotivating factors that had not been addressed by the questionnaire thus far. The first question was thereby answered by 12% of the participants.

> **Question:** "Are there more features that would encourage you from a progress visualization?"
> **Answers**:
>
> - "The progress should also visualize the order in which the topics should be learned, giving an overview of the whole learning progress and showing where I am in that process. Maybe also visualizing where the average student is to get a sense of whether I am doing well or falling behind."
> - "You are 80% ready for the exam or some other information that reminds you of the exam." [2]
> - "Comparing myself to how I was some time ago."
> - "Time estimation until completion of a task package or milestone."

The second question was answered by 6% of the participants.

> **Question:** "Are there more features that would discourage you from a progress visualization?"
> **Answers**:
>
> - "If there is only one global progress bar and completing one small task does not influence the global progress (or only by a small amount)."
> - "Sometimes less is more. I would not want to check my progress if I had to click through five menus to do so."[2]

These answers for the open-ended questions and custom answers or comments to the questions before will be concerned in the concept for the implementation. The custom answers often include suggestions how to realize certain features and this only becomes relevant for the conceptualization.

4.4 Requirements

4.4.1 Functional Requirements

In this section, the requirements are clearly formulated and prioritized. The MoSCoW [KBS22] analysis technique is utilized in order to determine the priorities. This technique employs a categorization of requirements into four priorities: *Must Have, Should Have, Could Have* and *Won't Have*. *Must Have* requirements are considered to be fundamental and must be met to ensure the project's success. *Should Have* requirements are considered high-priority and should be fulfilled if

[2]Translated quotation, because it was originally written in German.

possible, while *Could Have* requirements are regarded as desirable but not essential. Finally, the *Won't Have* requirements, which will not be fulfilled in the implementation. The categorization of the requirements into the four aforementioned priorities proceeds as follows:

Condition	**Calculated Priority**
Participant Agreement ≥ 75% Or Strongly Motivating Or Prevents Strongly Demotivating	Must Have
Participant Agreement ≥ 50% Or Motivating Or Prevents Demotivating	Should Have
Participant Agreement ≥ 25% Or Neutral	Could Have
Participant Agreement < 25%	Won't Have

Table 4.3: Conditions for the calculated Priority of a Requirement

The participants' agreement is derived from the results of the questionnaire's single-choice and multiple-choice questions, while the motivation level is measured using the Likert scale interpretation (see Table 4.2). The motivational conditions specified that, for instance, a *Must Have* requirement must be either strongly motivating or must prevent strongly demotivating effects.

In the following, the requirements that have been gathered will be listed, with a description explaining each requirement and an evidence providing the results on which it is based. Furthermore, the algorithmic priority, as determined by the aforementioned scheme (see Table 4.3), will be stated. The algorithmic priority can be manually adjusted based on domain knowledge about MEITREX or in order to remain within the scope of this thesis. For each manually adjusted priority, a proper reasoning will be given.

R1 – Progress Bar System
Description: The progress visualization type should be a progress bar system.

Evidence:

- 85% of the respondents considered progress bars to be one of the most helpful and motivating types of progress visualization, in the context of MEITREX (see Figure 4.3)

Algorithmic Priority: Must Have

R2 – Clear Progress Tracking
Description: The progress visualization should be designed to clearly track and display progress. Besides the visual representation of progress, the progress visualization should also display the percentage of progress in textual form.

Evidence:

- 91% of the respondents expected a progress visualization to provide clear tracking of the progress (see Figure 4.1)
- 73% wanted to see a completion percentage text (see Section 4.3.3)
- 64% of the respondents expected a progress visualization to provide progress towards goals and milestones (see Figure 4.1)
- participants felt motivated by knowing in which areas they already made progress (see Table 4.2)
- participants felt motivated by knowing in which areas they still need to make progress (see Table 4.2)

Algorithmic Priority: Must Have

R3 – Highlight Achievements
Description: Achieved goals and milestones should be highlighted in the visualization, distinguishing them from unachieved ones.

Evidence:

- participants felt motivated by their achievements being highlighted (see Table 4.2)
- participants felt strongly motivated by seeing them close to achieving a goal, by highlighting the achievement of a goal, the visualization close to achieving a goal stands more out as well (see Table 4.2)

Algorithmic Priority: Must Have

R4 – Task Recommendation
Description: The progress visualization should recommend tasks to make progress in specific areas and competencies. The task recommendation is intended to enhance students' sense of control over their learning progress by providing them with specific insights into how they can improve in each area.

Evidence:

- participants felt strongly motivated about knowing how to exactly make progress (see Table 4.2)
- 58% expected encouragement to make more progress (see Figure 4.1)
- 45% expected enhancement of the feeling of control over the learning progress (see Figure 4.1)

Algorithmic Priority: Must Have

R5 – Clear Overview
Description: The progress visualization should be able to show an overview of the progress of each knowledge area and competency.

Evidence:

- 64% of the respondents expected a progress visualization to provide a clear overview over all areas (see Figure 4.1)
- 75% of respondents preferred having access to competencies, either with competencies hidden but accessible (41%) or always displayed (34%) (see Section 4.3.3)

Algorithmic Priority: Should Have

R6 – Animation
Description: The progress visualization should show the transition between two progress states.

Evidence:

- participants felt motivated by seeing their progress increase visually after completing tasks and them achieving goals (see Table 4.2)

Algorithmic Priority: Should Have

R7 – Highlight Areas for Improvement
Description: The progress visualization should highlight areas and competencies that require improvement.

Evidence:

- 70% expected highlighting of areas that require attention (see Figure 4.1)
- 58% expected encouragement to make more progress (see Figure 4.1)
- participants felt neutral about seeing vibrant signal colors for areas that need improvement (see Table 4.2)

Algorithmic Priority: Should Have

R8 – Hide Areas Pending Start
Description: The progress visualization should hide areas where no progress is possible yet, because tasks involving that area are not available to begin yet.

Evidence:

- participants felt demotivated seeing that they did not even start to make progress (see Table 4.2)

Algorithmic Priority: Should Have

R9 – Average Comparison
Description: The progress visualization should show the comparison of the students' progress with the average progress in the course.

Evidence:

- participants felt neutral about comparing themselves with the average progress of the course (see Table 4.2)
- participants felt motivated seeing themselves further ahead than fellow students (see Table 4.2)

- participants felt neutral seeing themselves behind fellow student (see Table 4.2)
- 27% expected comparison of the progress with other students (see Figure 4.1)

Algorithmic Priority: Could Have

R10 – Level/Rank System
Description: The progress visualization should include a level/rank system.

Evidence:

- 70% of the respondents considered level/ranks to be one of the most helpful and motivating types of progress visualization, in the context of MEITREX (see Figure 4.3)

Algorithmic Priority: Should Have

Adjusted Priority: Won't Have

Reasoning: Despite the fact that a progress bar system can be well combined with a level/rank system, MEITREX has already employed a level system that integrates the results of this progress visualization. Consequently, this suggests that the progress visualization is already integrated within the level system. The introduction of an additional level system for competencies would only cause confusion and be overwhelming for students.

R11 – Individual Comparison
Description: The progress visualization should show the comparison between individual students.

Evidence:

- participants felt neutral about comparing themselves individually with fellow students (see Table 4.2)
- participants felt motivated seeing themselves further ahead than fellow students (see Table 4.2)
- participants felt neutral seeing themselves behind fellow student (see Table 4.2)
- 27% expected comparison of the progress with other students (see Figure 4.1)

Algorithmic Priority: Could Have

Adjusted Priority: Won't Have

Reasoning: MEITREX has already integrated a leaderboard system, enabling students to compare their individual performances. Furthermore, the implementation of an individual comparison of students within a progress bar system is considered impractical.

4.4.2 Non-Functional Requirements

The questionnaire was designed solely to gather functional requirements, as the progress visualization in development serves only as a test subject in this thesis for evaluating its motivational aspects. Nevertheless, as mentioned in an open-ended question (see Section 4.3.4), quick and convenient accessibility is important and without it, the progress visualization would probably not be used.

Furthermore, common non-functional requirements such as performance, reliability, responsiveness, scalability, usability, maintainability and accessibility must be fulfilled to ensure that the visualization operates efficiently for all students. These include low loading times for improved performance, fast interaction feedback for enhanced responsiveness, intuitive layout and mechanisms for improved usability, stable operation under high user load for scalability, consistent sytem behavior for reliability and modular implementation structures for maintainability. Regarding accessibility, numerical progress values will be displayed in addition to the visual progress bars to support users who may have difficulties perceiving color-based progress indicators. However, it should be noted that progress visualizations are inherently visual representations and can therefore only be made accessible to a limited extent.

5 Concept and Design

In this chapter, the conceptual foundation for the developed progress visualization will be presented. The objective of the progress visualization is essentially to enhance student motivation. The concept and design are, therefore, based on the previously conducted RE.

In order to convey the design and concept more efficiently, a mock-up of the progress visualization was sketched (see Figure 5.1). The mock-up visualization is intended to serve as an illustrative example to support reader understanding and should not be regarded as an exact replica of the final design.

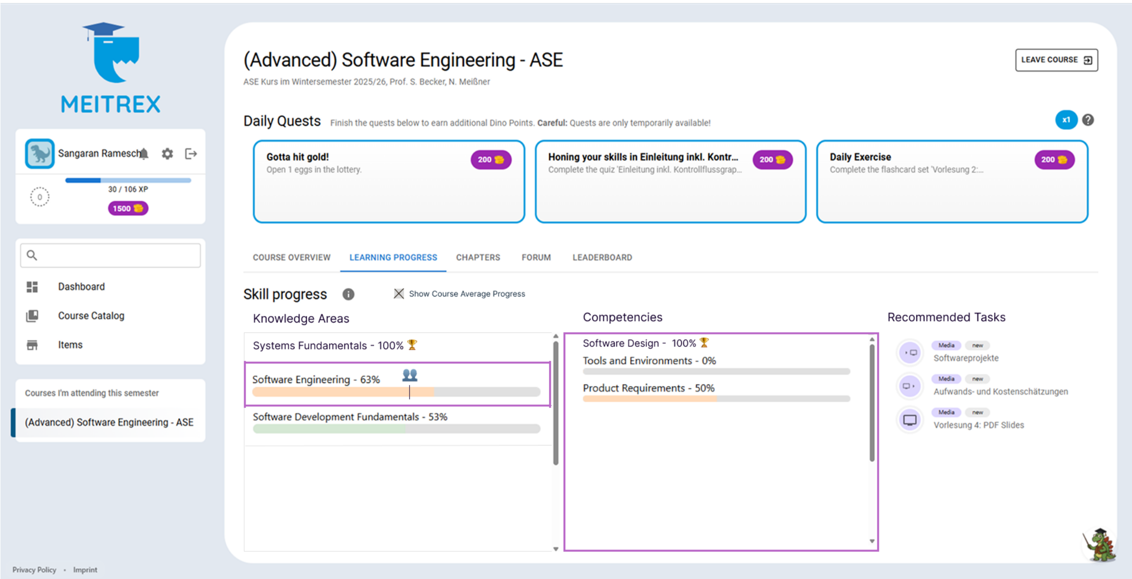

Figure 5.1: Progress Visualization Mock-Up Design

5.1 Structure

The progress bar system is structured in a three-column layout. The left column contains the knowledge areas, the middle column the competencies and the right column the recommended tasks. Only knowledge areas and competencies utilized in the course are included. The structure is hierarchical, with the knowledge area column providing an overview over the progress and serving as the navigation component. The competencies column provides progress information for each competency in a knowledge area, while the recommended tasks column offers action possibilities to improve. This structure, thereby, fulfills the previously described requirement **R5 – Clear Overview**.

5.2 Progress

The progress for each knowledge area and underlying competency is displayed through progress bars. This approach enables the illustration of progress in the required progress visualization type (**R1 – Progress Bars System**). It is planned to reutilize the same progress bar component that the MEITREX skill progress bar system (see Figure 2.3) employed. The progress bar component is characterized by a simple appearance that is intuitively comprehensible.

In addition to the visual representation of progress, the progress for each knowledge area and competency is also presented in written form using a percentage display. The design combines visual progress indicators and explicit percentage values in order to address the requirement **R2 – Clear Progress Tracking** by rendering learning progress transparent and easily comprehensible.

In the mock-up visualization (see Figure 5.1), the knowledge areas and competencies that have been 100% fulfilled no longer feature progress bars. These have been replaced by a small trophy icon that is positioned next to the percentage display. The objective of this approach is to highlight achievements and thereby attempt to fulfill the requirement **R3 – Highlight Achievements**. In conventional progress bar systems, nearly completed and fully completed states are often visually difficult to distinguish. The highlighting of achievements therefore also improves the differentiation between completed and nearly completed progress states, enabling users to immediately recognize which knowledge areas and competencies still require attention.

5.3 Functionality

The progress visualization is navigated through the selection of the knowledge area. Therefore, the progress of each knowledge area is constantly visible. The mock-up design illustrates how the selected knowledge area will be visually highlighted, so the user knows which knowledge area is selected currently. The competencies column displays all competencies from that knowledge area and the recommended task column displays the following tasks according to the course plan that covers skills from that knowledge area (**R4 – Task Recommendation**). The recommended tasks are based on knowledge areas rather than competencies, because a single task can cover multiple competencies. The recommendation of tasks according to competencies would result in a considerable number of competencies being assigned to identical tasks, thereby causing redundancy and reducing their overall usefulness. The task recommendation will be realized by utilizing the "Up next" component, which has previously been implemented in MEITREX. The task elements that are visible in the recommended task column of the mock-up visualization (see Figure 5.1) originate from the "Up next" component. The task elements are clickable and direct the user to the task itself. The "Up next" component selects tasks according to the course plan by picking the first unfinished tasks. This progress visualization is planned to reutilize the "Up next" component by filtering the recommended task by the knowledge areas.

The next feature is animation (**R6 – Animation**), a design element that cannot be directly represented within static mock-ups. It is intended that each progress value be saved each time the user visits the progress visualization. Consequently, upon revisiting the progress visualization following the completion of tasks, the user will be able to observe the progression from the previous state to the current state. One of the most rewarding scenarios through this feature would be students revisiting the progress visualization after completing several tasks and seeing their progress increase from their last viewed state to the current one.

Another planned feature is the required **R9 – Average Comparison**. Nevertheless, this feature will not be constantly active, as the previously conducted RE revealed that, alongside the positive impact, there were also outcomes that had a negative effect on the motivation of some students. Therefore, the progress visualization will include a check-box with which this feature can be disabled and enabled. The course average progress will be illustrated by a mark in the user's progress bars. The user is able to utilize the marker to compare their progress with the course average.

The last features are centered on the requirements **R7 – Highlight Areas for Improvement** and **R8 – Hide Areas Pending Start**. These features are realized in the same way utilizing the categorization from another MEITREX component. The component in question is the level chapter overview component that categorize chapter into the following categories "Done", "Catch Up", "In Focus", "Upcoming" and "Locked". In this progress visualization, competencies involved in a chapter categorized as "Catch Up" and their corresponding knowledge areas will be highlighted, indicating those in need of improvement. The highlighting will be realized through a simple red blinking of the border of the knowledge area or competency. Competencies that are solely present in chapters categorized as "Locked" will be rendered in gray to signify that no progress is currently possible in these competencies. This is also the case with knowledge areas, in which all their competencies are only involved in chapters that are currently categorized as "Locked".

5.4 Considered Options

Prior to the implementation of the currently planned progress visualization system, the MEITREX skill progress bar system (see Figure 2.3) incorporated a multi-page progress view. Across each page, three distinct knowledge areas are presented in a horizontal alignment, with their progress displayed through a progress bar. Beneath each knowledge area, the corresponding competencies were listed, accompanied by progress bars that were marginally smaller than the knowledge area progress bar. The decision was taken to abandon this structure, as the progress visualization did not provide a complete overview of all the knowledge areas utilized in the course. Instead, the content is divided across multiple pages, resulting in users navigating back and forth without any organization. This hinders the immediate comprehension of the full scope of the course and slows down the process of finding specific information. The new structure provides a complete overview through the constantly present knowledge areas, allowing users to efficiently access details specific to each knowledge area, such as the progress for the underlying competencies and recommended tasks.

6 Implementation

This chapter describes the implementation of the progress visualization prototype in MEITREX. Firstly, an overview of the MEITREX architecture is provided. In the following section, the progress visualization is presented, focusing on the implementation of the individual features defined in the concept. The code of the progress visualization and any other component in MEITREX is open-source and available on GitHub [Mei25].

6.1 MEITREX Architecture

The system architecture of MEITREX, a web application, follows a microservice architecture. The frontend has been implemented using React and TypeScript, with Tailwind CSS employed for styling. React Relay is utilized for the efficient retrieval and distribution of data across the component tree.

The backend employs the microservice architecture, in which individual services are responsible for specific tasks. The communication between the frontend and backend is provided through a GraphQL API. Since the backend consists of multiple microservices exposing their own APIs, the gateway provides a unified public API for frontend access.

The implemented progress visualization prototype requests data from the SkillLevel Service and Course Service. Furthermore, backend services communicate with each other via internal GraphQL endpoints. This enables skill values to remain up to date, as the Content Service informs the SkillLevel Service about completed tasks.

Further information regarding the architecture can be found in the MEITREX documentation.[Tea24].

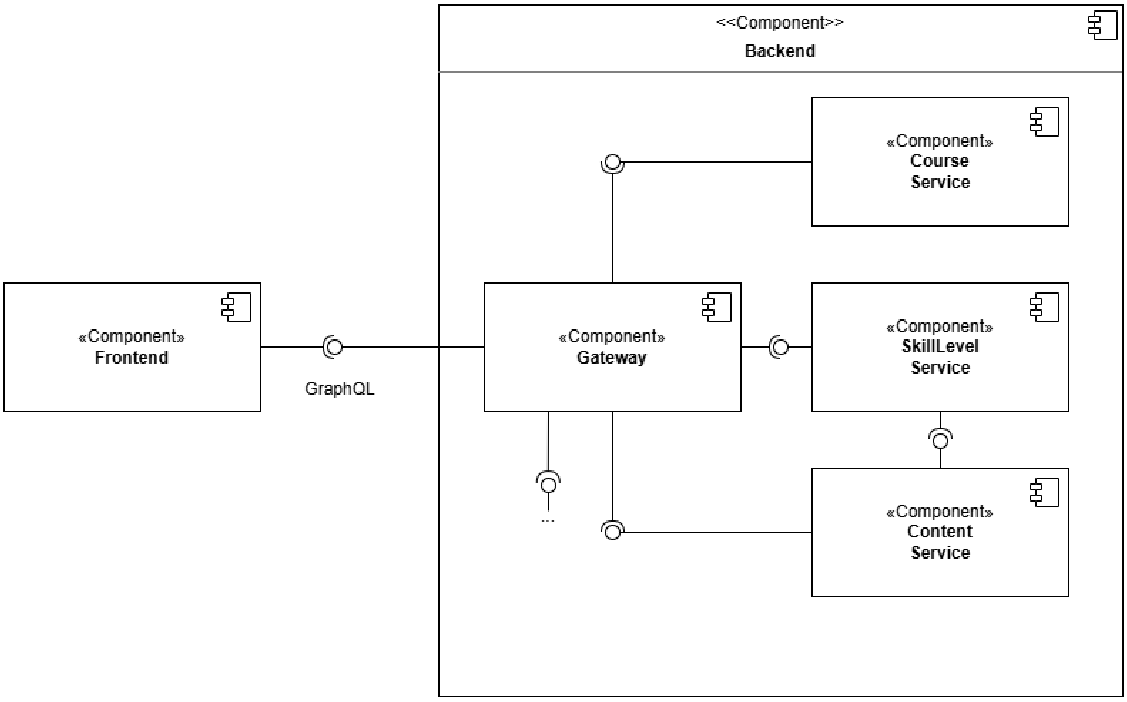

Figure 6.1: MEITREX Architecture Model, with only relevant Components showing

6.2 Realization of the Concept

During the RE phase, eleven requirements were identified. A total of nine of these were incorporated into the concept, while two (**R10**, **R11**) were excluded for the reasons discussed in the RE. In the case of **R10**, the feature was identified at an early stage as incompatible with other existing MEITREX features and was therefore excluded from the concept. More generally, such incompatibilities or technical limitations may only become apparent during the implementation phase if they are not detected earlier. Consequently, requirements defined during the conceptual design phase may not always be implemented exactly as specified or may not be implementable at all. However, in the present implementation, all nine requirements included in the concept could be successfully realized. An overview of the implemented progress visualization is presented in Figure 6.2.

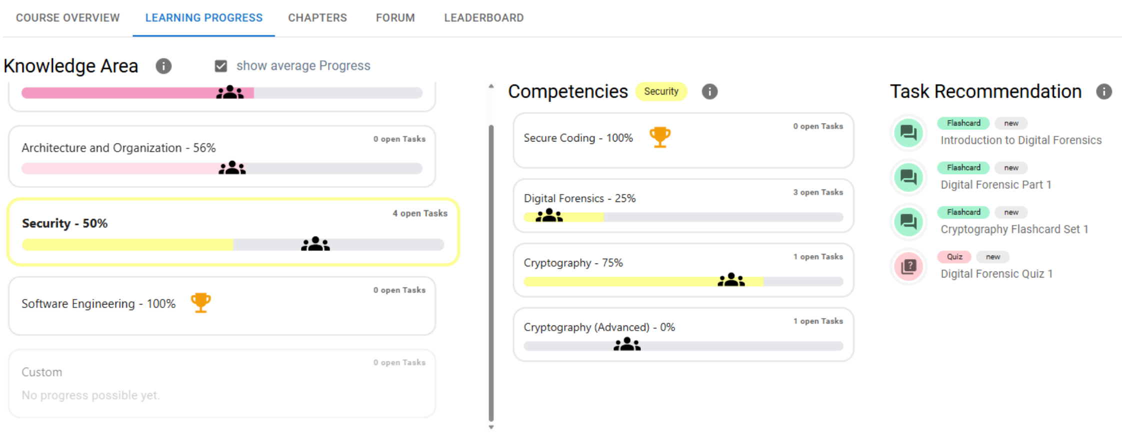

Figure 6.2: Progress Visualization

The MEITREX course view employs a tab-based navigation structure that organizes different system features. The progress visualization was implemented in the *Learning Progress* tab, replacing the previously existing skill progress bar system that was discussed in the foundations of this thesis (see Chapter 2). The progress visualization was implemented as a progress bar system based on the concept presented in the previous chapter. The representation of each knowledge area and competency is realized through a custom-developed component called *CompetencyProgressbar*. As MEITREX utilizes Material UI (MUI) for its core components, the CompetencyProgressbar component was developed using MUI elements to ensure stylistic consistency across the platform.

The CompetencyProgressbar provides a set of configurable input parameters that enable flexible reuse across different visualization contexts. Core parameters define the displayed knowledge area or competency name as well as the progress values, including the starting progress and updated progress used to animate progress changes.

The knowledge areas, competencies, corresponding progress values and related data are retrieved via GraphQL queries from the respective backend services responsible for handling the data. The animation was implemented so that the progress value transitions from the previous state to the updated state, while a textual indicator (e.g., 0% $\rightarrow$ 51%, see Figure 6.3) is displayed for the duration of the animation before returning to the normal visualization state.

While the updated progress value is retrieved from the database, the previous progress value is obtained from the *sessionStorage*. The sessionStorage is a browser-based web storage mechanism that temporarily stores data for the duration of a single browser session. Each time the user accesses the progress visualization, the current progress values are stored in the sessionStorage. Upon subsequent visits within the same session, these stored values are compared with the newly retrieved data, allowing the animation to be triggered only when progress changes are detected.

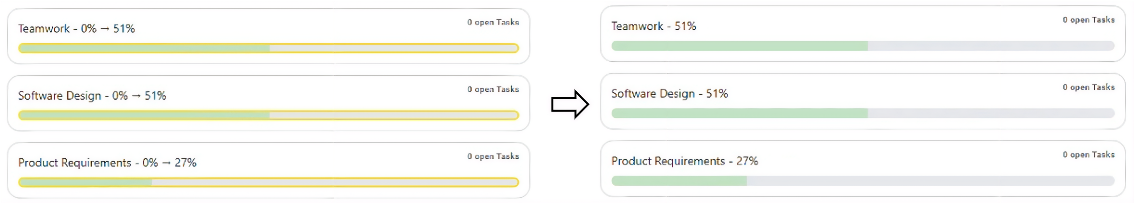

Figure 6.3: Animation

Additional parameters enable the display of progress-related information, such as average progress, participation data and the number of open tasks. The visualization of average progress values can be activated via a checkbox (see Figure 6.2). Average progress is represented by a group icon and hovering over the symbol reveals additional information (see Figure 6.4), including the exact average progress value and the number of students who have started working on the respective knowledge area or competency. This optionally accessible information aims to provide better contextualization of the average progress for students interested in it.

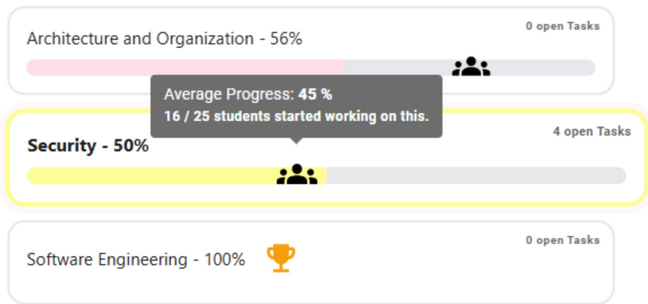

Figure 6.4: Average Progress

Furthermore, several configuration options control the visual appearance and interaction behavior of the component, including size variations to distinguish knowledge areas from competencies, color customization and multiple visual states such as selection, disabled status or urgency highlighting. The color system was predetermined, with MEITREX assigning individual colors to each knowledge area. The conditions under which a knowledge area enters the disabled or urgent state were defined in the concept chapter. The visualization of the disabled state can be observed in Figure 6.2, where the knowledge area *Custom* appears greyed out and does not contain a progress bar, instead displaying a message indicating that no progress is possible yet. The depiction of urgent states is achieved through the implementation of a subtle red pulsing animation of the progress bar borders, as described in the concept.

The implementation of the task recommendation feature was largely consistent with the version planned in the concept. However, during the implementation phase, it became apparent that, in cases where knowledge areas included a large number of open tasks, the task recommendation view could become overwhelming. A notable challenge was the identification of specific tasks associated with each competency. In cases where competencies were marked as urgent, the identification of the task that had triggered the urgency was particularly challenging. Consequently, the task recommendation was expanded to include a feature that enabled filtering of tasks according to competencies (see Figure 6.5). The selection of a competency resulted in the display of tasks exclusively involving that competency, with them then being separated into urgent tasks and other tasks.

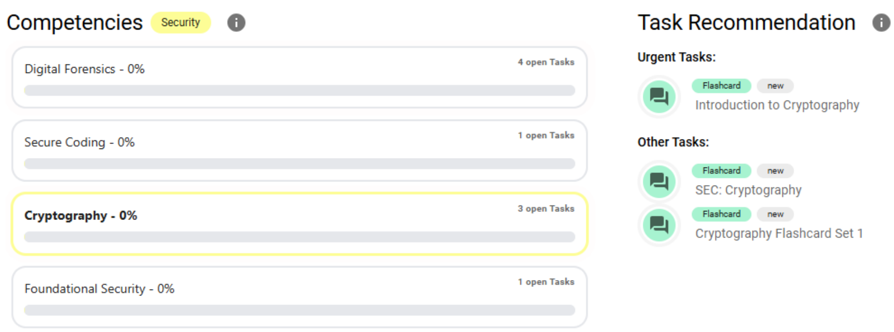

Figure 6.5: Task Recommendation

The implementation described in this chapter represents the final version of the progress visualization prototype. This version serves as the basis for the evaluation conducted in the following chapter, which investigates the impact of the progress visualization on student motivation.

7 Evaluation

The present chapter provides the evaluation of the implemented progress visualization with regard to its impact on student motivation. The chapter is structured into four sections. Firstly, the study design is described, followed by the presentation of the results. The findings are then discussed in relation to the research objectives and finally, the threats to validity of the evaluation are addressed.

7.1 Study Design

The evaluation was conducted as an online survey study using a structured online questionnaire. The questionnaire will be presented in the following section.

The decision to employ a questionnaire-based survey design instead of a user study, in which participants actively work through a course and test the progress visualization, was made for several reasons. As O'Donovan [ODo12] previously emphasized, learners may lose interest when tasks do not provide an appropriate level of difficulty. Similarly, Yu-kai Chou [Cho19] highlighted that achievements, that are too easily obtained can lead to boredom and consequently reduce motivation. At the same time, it is vital that tasks remain achievable in order to foster a sense of progress and accomplishment. Consequently, the design of a course environment that offers an adequate difficulty level for students from different study programs and semesters would have been highly challenging in the scope of this thesis. In order to address this issue, the evaluation process relied on the participants' imagination. Participants were presented with scenarios intended to activate their prior experiences and memories of learning situations, and were then asked to assess the progress visualization mechanisms based on these experiences.

Furthermore, the utilization of a questionnaire-based approach reduced the effort for participants, thereby lowering barriers to participation and potentially increasing the number of respondents.

7.1.1 Questionnaire

The questionnaire was structured into three main parts. As already done in the RE questionnaire, this questionnaire first collected demographic information, in order to characterize the sample.

In the second part, the progress visualization mechanisms, previously examined during the RE phase, were evaluated using a five-point Likert scale ranging from strongly demotivating to strongly motivating (**Q1-I**). However, this time only those mechanisms that were actually implemented in the prototype were included. Afterwards, participants were invited to arrange the mechanisms from most to least important in terms of their impact on student motivation (**Q2-I**). For this entire part, participants were instructed to base their ratings on how they would personally imagine an ideal implementation of each mechanism.

This segment of the questionnaire functioned as a baseline for comparison and as a control condition. The capture of students' general idealized expectations allowed for a later comparison with the students' evaluations of the mechanisms concretely implemented in MEITREX.

In the final part of the questionnaire, participants were asked to evaluate the same mechanisms as in the previous section again on the same five-point Likert scale (**Q1-M**). However, this time each mechanism was accompanied by a picture or short video illustrating its specific implementation within the progress visualization prototype in MEITREX. Alongside providing their ratings, participants were invited to provide a reasoning for their assessment, for instance to explain potential differences compared to their earlier evaluations based on an idealized imagination. Subsequently, participants were again invited to arrange the mechanisms in order of importance, this time explicitly considering the specific implementation of the mechanisms in MEITREX (**Q2-M**). The questionnaire was then concluded with an open-ended question that invited participants to share further comments, criticisms, or suggestions for improving the progress visualization implemented.

The complete questionnaire is available as part of the research dataset of this thesis [Ram26].

7.1.2 Participants

Following the same distribution approach as in the RE phase, the questionnaire was shared with the same student groups on Telegram and Discord at the University of Stuttgart.

The questionnaire was completed by 14 participants. Among the participants, about 71% identified themselves as male and 29% as female. The mean age of the participants was 24.64 years, with a SD of 4.43. More details about the student demographics are shown in Table 7.1.

Gender		Age		Course of Study	
Male	71.43%	Average	24.64 yrs	Computer Science	57.14%
Female	28.57%	Maximum	35	Software Engineering	28.57%
Prefer not	0%	Minimum	19	Media Computer Science	14.29%
to answer		SD	4.43	Data Science	0%

Table 7.1: Student Demographics

7.2 Results

This section presents the findings of the evaluation study. The results are presented in three parts. Firstly, the evaluation of the progress visualization mechanisms based on participants' general idealized expectations is described. Following this, the evaluations of the mechanisms implemented in MEITREX are presented. Finally, the two sets of results are systematically compared to identify similarities, differences and potential shifts in perceived motivational impact. Interpretations of these findings are addressed in the subsequent discussion section. The complete evaluation data are available in the research dataset of this thesis [Ram26].

7.2.1 Idealized Progress Visualization

The questions in this section, as previously described, served as a baseline for comparison. In accordance with the findings of the preceding RE analyzes, the participants indicated that being close to achieving a goal was the most motivating mechanism (71% strongly motivated and 29% motivated). Furthermore, the results indicated again that the perception of no progress being made was the most demotivating mechanism (21% strongly demotivating, 36% demotivating, 36% neutral and 7% motivating). The remaining results are summarized in Figure 7.1 and will be revisited in the comparison with the students' evaluation of the implemented progress visualization.

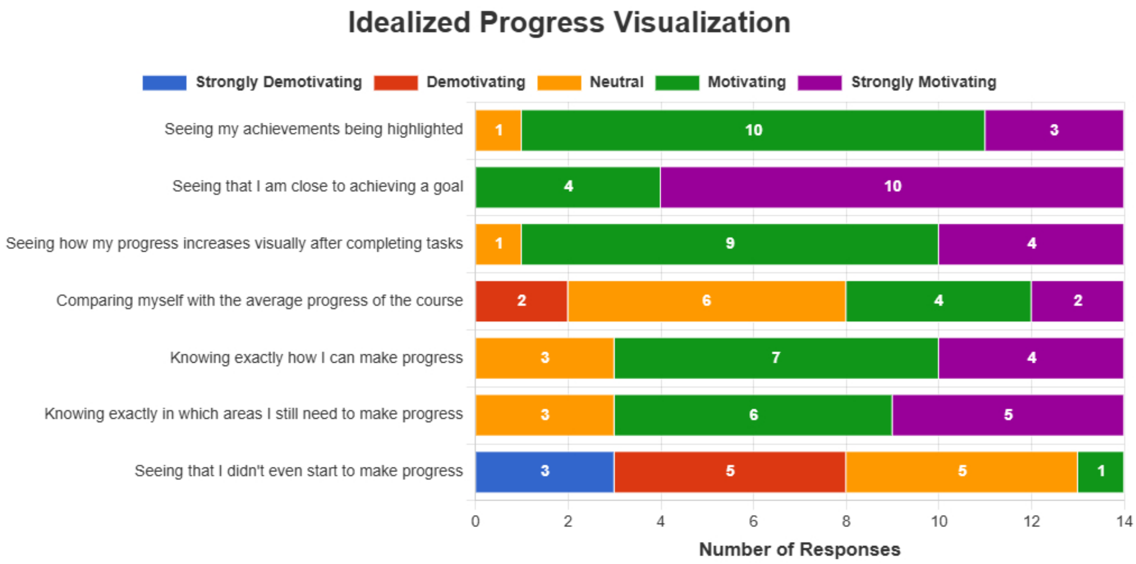

Figure 7.1: Idealized Progress Visualization Motivation (**Q1-I**)

Another question in this section invited participants to arrange ten aspects of progress visualization according to their perceived impact on student motivation (**Q2-I**). The aspects were ranked from 1 to 10, with lower ranks indicating higher importance. The results indicated that the most crucial aspect was considered to be clear progress tracking (mean rank: 2.64), followed by a clear progress overview (mean rank: 3.36) and the type of progress visualization (mean rank: 3.57). Among the specific progress visualization mechanisms, task recommendation was ranked as the most important (mean rank: 5.07). Conversely, hiding areas where no improvement is currently possible was perceived as the least important aspect (mean rank: 8.79). Further details of the ranking results are summarized in Table 7.2.

Element	Mean rank	SD
Clear Progress Tracking	2.64	1.34
Clear Progress Overview	3.36	1.60
Type of Progress Visualization	3.57	3.01
Task Recommendation	5.07	2.87
Animation	5.50	1.91
Highlight Achievements	5.64	2.44
Highlight Areas for Improvement	6.50	2.50
Individual Comparison	6.93	2.13
Average Comparison	7.00	2.83
Hide Areas where no improvement is possible yet	8.79	1.89

Table 7.2: Student Ranking of Progress Visualization Aspects (**Q2-I**)

7.2.2 Progress Visualization in MEITREX

In this section, participants evaluated each feature implemented in the progress visualization prototype. The mechanisms that were perceived as most motivating were the highlighting of achievements through the replacement of completed progress bars with a trophy icon (36% strongly motivated and 64% motivated) and the task recommendation feature, which provides clear guidance on how to make further progress (43% strongly motivated; 50% motivated; 7% neutral). In contrast, the hiding of areas where no progress is currently possible, implemented by replacing the progress bar with a text label indicating this state, was perceived as having the lowest motivational impact. A detailed overview of the results is presented in Figure 7.2.

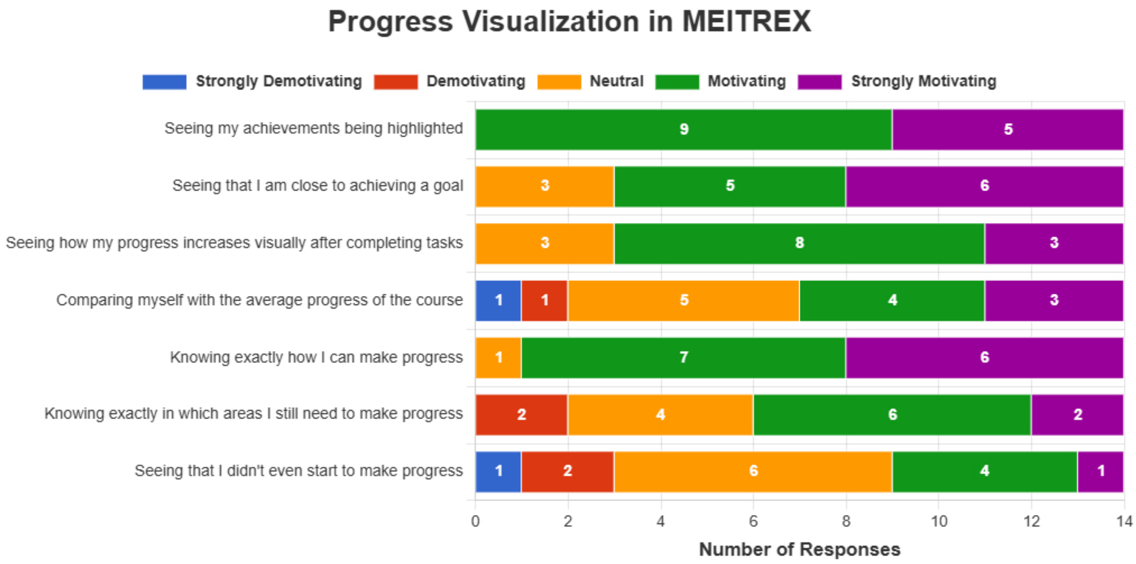

Figure 7.2: Progress Visualization Motivation in MEITREX (**Q1-M**)

Participants were then invited to once again arrange different aspects of progress visualization according to their perceived impact on student motivation (**Q2-M**). This time, they were instructed to base their judgments on the specific implementation of the progress visualization prototype in MEITREX. The findings indicated that clear progress tracking (mean rank: 2.71) and a clear progress overview (mean rank: 3.57) were perceived as the most crucial aspects. Highlighting achievements ranked third overall (mean rank: 4.00), making it the highest-ranked individual progress visualization mechanism. Hiding areas where no improvement is currently possible received the lowest importance rating in this ranking (mean rank: 9.29). Further details of the ranking results are summarized in Table 7.3.

Element	**Mean rank**	**SD**
Clear Progress Tracking	2.71	1.54
Clear Progress Overview	3.57	1.34
Highlight Achievements	4.00	2.77
Type of Progress Visualization	4.21	3.17
Animation	5.14	2.18
Task Recommendation	5.43	3.08
Highlight Areas for Improvement	6.64	2.65
Individual Comparison	6.79	1.42
Average Comparison	7.21	1.76
Hide Areas where no improvement is possible yet	9.29	1.44

Table 7.3: Student Ranking of Progress Visualization Aspects in MEITREX (**Q2-M**)

Finally, the questionnaire concluded with an open-ended question inviting participants to provide any additional comments, feedback or suggestions. One participant provided a comment that did not relate directly to the progress visualization itself, but instead emphasized the motivational benefits of group work. The participant proposed that MEITREX could incorporate a functionality that facilitates the formation of working groups among students within a given lecture, with the objective of presenting and discussing task solutions collaboratively. Another participant expressed positive feedback, stating that the system appears to be well-designed and fosters student motivation. A further participant suggested that, from the initial state, tasks within the task recommendation should be displayed in the recommended working order. However, this ordering has already been implemented in the progress visualization, as the task recommendations are displayed from top to bottom in the recommended working order.

7.2.3 Comparison of Idealized and Implemented Progress Visualization

This section provides a comparison between the evaluation of the idealized progress visualization mechanisms conceived by the participants and the evaluation of the implemented mechanisms in MEITREX. The objective of this comparison is to identify similarities, differences and potential shifts in perceived motivational impact. First, the motivational classifications based on the average Likert-scale scores of the idealized mechanisms (**Q1-I**) and the implemented mechanisms (**Q1-M**) are compared. In order to interpret the results, participants were invited to rate each mechanism on a Likert scale ranging from -2 (strongly demotivating) to +2 (strongly motivating). The mean scores obtained were then grouped into intervals of 0.8 to classify their motivational impact (see Table 7.4). For instance, scores ranging from 1.2 to 2 were interpreted as strongly motivating. Subsequently, the average ranking results of the idealized mechanisms (**Q2-I**) and the implemented mechanisms (**Q2-M**) are compared.

Analyzing the evaluations of the imagined idealized progress visualization mechanisms alongside the implemented mechanisms in MEITREX reveals that the largest numerical difference occurred for hiding areas where no progress is possible yet (Idealized: -0.71 → Implemented: 0.14). The perception shifted from demotivating, when observing areas where no progress was possible yet, to neutral once these areas were hidden. The majority of participants reported that this mechanism had no impact on their motivation and generally did not concern them. However, a few participants provided positive feedback, stating that the mechanism can reduce feelings of being overwhelmed, as the display of too many areas at once may appear intimidating. Furthermore, some participants noted that the mechanism helps them focus on content that is currently relevant and prevents them from working on tasks in an unintended order. In contrast, other participants expressed their dislike when no progress bar was visible, or emphasized that the presence of too many hidden progress areas could be frustrating.

Further mechanisms that demonstrated an increase in perceived motivational impact included the highlighting of achievements (Idealized: 1.14 → Implemented: 1.36), as well as knowing exactly how to make progress through task recommendations (Idealized: 1.07 → Implemented: 1.36). Both mechanisms shifted from motivating to strongly motivating.

For the highlighting of achievements, several participants explicitly commented on the trophy icon. The icon was described as motivating and perceived as a visual reward, an earned achievement or a prize in a competition. Other comments referred to the highlighting of achievements more generally as fulfilling.

For the task recommendation mechanism, several participants highlighted that it facilitated the decision of what task to work on next. They stated that having clear recommendations reduced the effort required to choose between tasks. Some participants noted that the mechanism removed the burden of deciding independently what to do next, allowing them to focus more directly on learning. In contrast, not knowing what task to choose was described as potentially overwhelming or demotivating. Overall, the guidance provided by the system was perceived positively.

Conversely, a decrease was observed for the visual increase in progress implemented through animation, which was initially perceived as strongly motivating in the idealized evaluation but shifted to motivating in the evaluation of the implementation (Idealized: 1.21 → Implemented: 1.00). Nevertheless, participants' comments on the animation mechanism were overall positive. Several participants indicated that seeing the progress bar move created a sense of making progress and made the work completed so far more visible, which they perceived as motivating. One participant also described feeling encouraged to continue working in order to move the bar further. On the other hand, a few participants stated that the animation itself was not particularly important and that it would not be motivating before completing the work.

Despite maintaining the same classification, there was a notable decline in the scores for both perceiving being close to achieving a goal (Idealized: 1.71 → Implemented: 1.21) and highlighting areas for improvement (Idealized: 1.14 → Implemented: 0.57).

However, as the classification for being close to achieving a goal remained in the strongly motivated category, participants' comments were overall very positive. The mechanism was described as highly motivating, with participants noting that being close to completion encouraged them to finish the area, helped them push through and motivated them to reach an easily achievable goal. Only two participants mentioned that it was not important to them or that they would personally focus on less developed areas.

For the highlighting of areas for improvement, participants provided feedback similar to that given for the task recommendation. The mechanism was described as helpful for managing the learning process, keeping track of tasks to work on and saving time when selecting tasks. However, the implementation through blinking was described as too aggressive, overwhelming and annoying. One participant noted that the task recommendation alone was sufficient.

The SD values for the evaluation of the idealized mechanisms are low to moderate, with all values remaining below 1, indicating a relatively uniform assessment of the mechanisms. The highest SD values were observed for comparing with the course average (SD = 0.94) and seeing that no progress was made yet (SD = 0.91). In the evaluation of the implemented mechanisms, these same two mechanisms demonstrated the highest SD values and were the only ones greater than 1, indicating somewhat varying perceptions of these mechanisms in general.

However, the varying perceptions among participants were already apparent in the comments presented previously regarding hiding areas where no progress is currently possible yet. For the mechanism comparing progress with the course average, the varying perceptions among participants are similarly reflected in their comments. Participants described different reactions depending on the scenario. Some stated that being ahead of the course average could be demotivating to continue, while being behind could motivate them to catch up. Others reported the opposite effect, describing it as demotivating to be behind and rewarding to see themselves ahead of their peers. Additionally, some participants expressed a general dislike of such comparisons due to the pressure they create, whereas others indicated that they generally enjoy competition. Further details of the comparison are provided in Table 7.4.

	Idealized			**Implemented**		
Statement	**Score**	**SD**	**Category**	**Score**	**SD**	**Category**
Seeing my achievements being highlighted	1.14	0.53	Motivating	1.36	0.50	Strongly Motivating
Seeing that I am close to achieving a goal	1.71	0.47	Strongly Motivating	1.21	0.80	Strongly Motivating
Seeing how my progress increases visually after completing tasks	1.21	0.58	Strongly Motivating	1.00	0.68	Motivating
Comparing myself with the average progress of the course	0.43	0.94	Motivating	0.50	1.16	Motivating
Knowing exactly how I can make progress	1.07	0.73	Motivating	1.36	0.63	Strongly Motivating
Knowing exactly in which areas I still need to make progress	1.14	0.77	Motivating	0.57	0.94	Motivating
Seeing that I didn't even start to make progress	-0.71	0.91	Demotivating	0.14	1.03	Neutral

Table 7.4: Comparison of Likert-Scale Scores, Standard Deviation and Classification

The comparision in the rankings of progress visualization aspects (see Table 7.2 and Table 7.3), showed that in both instances clear progress tracking (mean rank: 2.64 and 2.71) and clear progress overview (mean rank: 3.36 and 3.57) were the most important aspects to progress visualization. Conversely, the participants ranked both times individual comparison (mean rank: 6.93 and 6.79), average comparison (mean rank: 7.00 and 7.21) and hide areas where no improvement is possible is yet (mean rank: 8.79 and 9.29) last. Especially for the two highest ranked aspects clear progress tracking and clear progress overview, as well as for the lowest ranked aspect hiding areas where no improvement is possible yet, are indicating in both rankings with low SD values (below 2) a relatively high level of agreement among participants.

7.3 Discussion

This section interprets the results presented in the previous section and discusses their implications in relation to the research objectives of this thesis. In particular, the findings are examined with regard to the research questions introduced in the beginning of this thesis:

> **RQ1** Which progress visualization mechanisms impact students' motivation?
>
> **RQ2** How should identified progress visualization mechanisms be realized in order to motivate students?

A first key insight from the evaluation is that, regardless of any specific progress visualization mechanisms, the fundamental functionality of a progress visualization is essential for student motivation. In particular, participants rated clear progress tracking and a clear progress overview as the most important aspects regarding their impact on student motivation. This could suggest that the motivational effects of individual progress visualization mechanisms may only unfold if the progress visualization first fulfils its fundamental functions of transparently tracking progress and providing a clear overview of that progress.

Seeing my achievements being highlighted:
Highlighting of achievements was classified as motivating in the imagined idealized version and as strongly motivating in the implemented version, in both cases with a high level of agreement among participants. Among the evaluated progress visualization mechanisms (excludes clear progress tracking, clear progress overview and type of progress visualization), it ranked third for the idealized version and first for the implemented version. In regard to the research question **RQ1**, this suggests that highlighting achievements provides a sense of accomplishment, which positively impacts student motivation. This interpretation aligns with the Octalysis Framework [Cho19] introduced in the theoretical foundations of this thesis, which identifies Development & Accomplishment as a core motivational drive related to the intrinsic desire to make progress and achieve goals.

Many participants emphasized the positive effect of the trophy icon, which implemented the highlighting of achievements. With regard to the research question **RQ2**, the results suggest that highlighting achievements should be realized through recognizable patterns and symbols that students already associate with success and achievements.

Seeing that I am close to achieving a goal:
Perceiving being close to achieving a goal was classified as strongly motivating for both the imagined idealized version and the implemented version, indicating that this mechanism successfully impacts student motivation (**RQ1**). Several participants emphasized that seeing themselves close to achieving a goal motivated them to complete it. This interpretation also aligns with the description of the core motivational drive Development & Accomplishment [Cho19], which describes the intrinsic desire to achieve goals.

In relation to research question **RQ2**, the results indicate that mechanisms enabling students to perceive being close to achieving a goal should be implemented in a way that makes near-completion clearly visible. In the prototype, this effect emerged as a side effect of the achievement highlighting mechanism, where completed progress bars were replaced by trophy icons. This visual distinction made nearly completed progress bars stand out more clearly, thereby strengthening the perception of being close to achieving a goal and encouraging students to complete the remaining tasks.

Seeing how my progress increases visually after completing tasks:
The visual increase in progress was classified as strongly motivating in the idealized version and as motivating in the implemented version. Additionally, among the evaluated mechanisms, it ranked second for both the imagined idealized version and the implemented version. Thereby, several participants indicated that the visual increase in progress created a sense of making progress, which was perceived motivating. This again aligns with the description of the core motivational drive of Development & Accomplishment [Cho19]. These findings therefore indicate that visually increasing progress after task completion is another mechanism that positively impacts student motivation (**RQ1**).

The realization should clearly highlight the increase in progress since the previous visit, as participants emphasized the importance of being able to see the work they had completed so far. This suggests that the process of animating the transition from any state to the current state may be less motivating than starting the animation from the progress state of the previous visit. Consequently, students are able to more accurately perceive the extent to which their progress has been enhanced by the tasks completed since the previous visit (**RQ2**).

Comparing myself with the average progress of the course The mechanism of comparing progress with the course average progress was classified as motivating in both evaluations. However, it also exhibited the highest SD values in both cases, indicating a relatively high variation in participants' perceptions of this mechanism. The qualitative feedback reflected these differences: while some participants expressed enjoyment of competition and found such comparisons motivating, others indicated a general dislike of comparisons with peers. These findings align with the Hexad Framework [TWD+16] introduced in the theoretical foundations of this thesis, which describes different user types characterized by distinct motivational preferences. In particular, this mechanism may be especially motivating for the user type Players, who are driven by competition and rewards, as well as for Socialisers, who are motivated by social interaction and relatedness. In relation to the research question **RQ1**, the results indicate that this mechanism can have a positive impact on student motivation as well as negative impact on student motivation.

As this mechanism has the potential to both motivate and demotivate students, it should not be enabled by default in one-size-fits-all designs. Instead, implementations should allow students to activate comparison features voluntarily, ensuring that learners who find such comparisons motivating can benefit from them without negatively affecting others (**RQ2**).

However, the comparison with the course average ranked second to last in importance regarding its impact on motivation for both the idealized and the implemented version. This suggests that the mechanism was generally considered less important compared to other progress visualization mechanisms. Therefore, the implementation of such a feature should be carefully weighed against the required development effort.

Knowing exactly how I can make progress:
This mechanism, implemented through the task recommendation feature, was evaluated as motivating for the imagined idealized version and as strongly motivating for the implemented version. Among the evaluated mechanisms, it ranked first for the idealized version and third for the implemented version. Participants explained this classification by emphasizing the reduced effort required to choose the next task. Removing this hindrance was perceived as motivating by several participants. With regard to the research question **RQ1**, the results therefore indicate that knowing exactly how to make progress is a mechanism that positively impacts student motivation.

Based on the evaluations and participants' comments, task recommendation mechanisms should clearly indicate in which areas progress can be achieved and explicitly suggest which tasks should be completed next (**RQ2**).

Knowing exactly in which areas I still need to make progress:
The highlighting of areas that need improvement was classified as motivating in both evaluations. Likewise, both the idealized version and the implemented version were ranked fourth among the evaluated progress visualization mechanisms. The positive feedback from participants was similar to the feedback provided for the task recommendation mechanism, while the negative feedback mainly criticized the way the mechanism was implemented. Regarding the research question **RQ1**, the findings indicate that this mechanism has the potential to enhance student motivation, although its implementation requires careful consideration.

Participants particularly emphasized that the red blinking used to highlight areas needing improvement was perceived as annoying, aggressive and overwhelming. Therefore, with regard to the research question **RQ2**, the results suggest that such highlighting should be implemented in a more subtle and less intrusive manner to avoid overwhelming users.

Seeing that I didn't even start to make progress:
The mechanism of seeing that no progress has been made yet was classified as demotivating in the imagined idealized version. This negative perception was addressed in the implemented design by hiding areas where no improvement is possible yet, which was classified as neutral. In the ranking of mechanisms based on their impact on motivation, this mechanism was rated last in both the idealized and the implemented version. Participants indicated that this feature can reduce feelings of being overwhelmed. With regard to the research question **RQ1**, hiding areas where no improvement is possible yet can therefore help prevent demotivation.

The implementation should be realized so that the existence of these areas, where no progress is possible yet, is still apparent, as participants indicated that maintaining an overall view of the course is important. Naturally, this feature should only be included if there exist areas that are not available for work and are continuously unlocked over time (**RQ2**).

7.4 Threats to Validity

The following section discusses potential threats to the validity of the study and their implications for the interpretation of the results.

7.4.1 Construct Validity

The evaluation was conducted through a questionnaire study instead of a user study in which participants could actively work on a course and test the progress visualization. This decision was based on the findings of O'Donovan [ODo12] and Yu-kai Chou [Cho19], who emphasized that tasks should have an appropriate level of difficulty while still remaining achievable in order to foster a sense of progress and achievement without reducing motivation. However, creating multiple courses tailored to different skill levels was not feasible within the scope of this thesis. Additionally, the expected sample size was limited and further filtering participants based on their skill level during the survey distribution was therefore avoided.

In an ideal setting, the evaluation would have been conducted across multiple courses with participants from early, mid and late semesters and from different fields of study who could actively use the progress visualization to reflect its real-world usage.

Another threat to construct validity is that only a single implementation of each progress visualization mechanism was evaluated. To determine how these mechanisms can best motivate students, multiple implementations would need to be compared to identify the most effective realization of each mechanism. However, due to the focus on multiple mechanisms in this study and workload limitations within the scope of this thesis, only one implementation per mechanism was evaluated.

7.4.2 Internal Validity

A potential threat to the internal validity of research on gamification and progress visualization is the novelty effect. Song [SK01] emphasized that the use of new technologies or unfamiliar features can increase motivation independently of the actual effectiveness of the implementation. To reduce this threat, participants were asked to justify their evaluations in their own words. This approach encouraged participants to reflect on the individual progress visualization mechanisms and explain why they perceived them as motivating or demotivating. Although this measure cannot fully eliminate the novelty effect, it was intended to encourage participants to evaluate the mechanisms themselves rather than relying solely on their initial impressions.

The most effective way to diminish the novelty effect would be to conduct a long-term study. However, this was not feasible within the scope of this thesis due to time constraints. The progress visualization was developed from scratch as part of this work, including the literature review, the RE, the conceptualization and the implementation, which limited the time available for the evaluation.

7.4.3 External Validity

The external validity of this study is particularly threatened by the small sample size. This limits the statistical power of the results and requires a cautious interpretation of the observed effects. Furthermore, all participants were enrolled in computer science-related fields and the sample was heavily male-dominated. Consequently, the findings may not be generalizable to students from other fields of study or groups with different gender distributions. The results of the study should therefore be regarded as preliminary indications to guide further research rather than definitive conclusions.

8 Conclusion

This chapter presents the conclusion of this thesis, including a summary, the identified benefits and limitations, lessons learned during the project and directions for future work.

8.1 Summary

This thesis explored the impact of progress visualization on student motivation, with the aim of supporting the design of motivating digital learning environments. In order to address this objective, two research questions were investigated. The first research question concerned which progress visualization mechanisms influence student motivation and the second research question addressed how these mechanisms should be designed to effectively motivate students. To examine these questions, a literature review was first conducted, followed by a RE process to derive requirements for motivating progress visualizations. Based on these requirements, a progress visualization concept was developed and implemented in the intelligent tutoring system MEITREX. The resulting prototype was then evaluated with regard to its potential impact on student motivation.

The literature review established the theoretical foundation of the thesis. Motivation was examined and defined based on SDT [RD20a] and its role within gamification was analyzed using the Octalysis Framework [Cho19] and the Hexad Framework [TWD+16]. Building on these insights, as well as findings from related work identified in the literature review, the RE process was conducted. The RE aimed to identify key expectations regarding progress visualization, including preferred types, important functions and specific motivational aspects considered relevant by students. The resulting requirements formed the foundation for the conceptual design of the progress visualization implemented in MEITREX.

The implemented progress visualization was subsequently evaluated through a questionnaire-based study. Participants first assessed the mechanisms based on their own idealized expectations and then evaluated the implemented mechanisms in MEITREX. This approach enabled a direct comparison between the imagined ideal designs and the actual implementations. The results provided insights into which mechanisms were perceived as motivating or demotivating, the underlying reasons for these perceptions and how such mechanisms should be designed to increase motivational impact. In particular, highlighting achievements and task recommendations were perceived as strongly motivating, as they clearly communicate accomplishments and guide students toward meaningful next steps. In contrast, comparative elements, such as course-average comparisons, showed more mixed effects.

Overall, the findings contribute to a deeper understanding of how progress visualization can influence student motivation and provide practical design considerations for the implementation of motivating progress visualizations in digital learning systems.

8.2 Benefits

The findings of this study provide promising insights into the design of motivating progress visualizations for digital learning environments. In particular, the results suggest that the integration of progress visualization mechanisms can support student motivation and offer practical guidance on how such mechanisms should be implemented.

These insights can benefit software designers and developers who aim to develop motivating digital learning systems. The study highlights the motivational impact of different progress visualization mechanisms and provides guidance on how they can be implemented to positively influence motivation, while also identifying design choices that may reduce their motivational effectiveness.

As a consequence, students may benefit from progress visualizations integrated into their digital learning environments. The progress visualization mechanisms can help students to better track their development and potentially increase their motivation to engage with course content, which may ultimately contribute to improved learning outcomes.

8.3 Limitations

Despite the insights gained from this study, several limitations must be considered when interpreting the results. Firstly, the evaluation was conducted with a small number of participants, which limits the statistical power of the results.

Furthermore, the majority of participants were enrolled in computer science-related fields and the sample was strongly male-dominated. Therefore, the findings may not be fully representative of students from other academic disciplines or more diverse populations.

A further limitation concerns the evaluation method itself. The study utilized a questionnaire in which participants evaluated both their own imagined idealized progress visualization mechanisms and the implemented mechanisms in MEITREX. This approach enabled a comparison between imagined ideal designs and the implementation, but the evaluation was primarily based on subjective perceptions from students of varying levels of experience with progress visualization. Furthermore, the participants were not able to test the progress visualization directly, as it was only presented through images and videos in the questionnaire. Consequently, the mechanisms were never utilized in a real course setting over an extended period of time eihter. As a result, potential long-term motivational effects and changes in perception during continuous interaction could not be examined.

Considering the aforementioned limitations, the findings should be interpreted as indicative tendencies rather than definitive conclusions and further studies are required to validate and extend the results.

8.4 Lessons Learned

During the implementation of the progress visualization, the importance of considering scalability became evident. The calculation of the course average progress initially worked correctly in the local development environment, where it was tested using a small number of simulated user profiles within a simplified course containing only a few tasks across a limited number of competencies. However, issues arose once the system was deployed. In the production environment, hundreds of students interacted with real courses containing many tasks distributed across numerous competencies and knowledge areas. As a result, the initially implementation of the average progress calculation proved to be inefficient under realistic conditions. This experience highlighted the importance of considering scalability and realistic usage scenarios during system design and testing, as implementations that perform well in simplified local tests may behave differently when exposed to real-world workloads.

Another lesson learned concerns the participation rates in online questionnaires. It became apparent that participation rates tend to decrease as the required effort for participants increases. Although the distribution method remained identical and the questionnaires were available for the same duration in both the RE and the evaluation, the number of completed responses decreased from 33 in the RE to 14 in the evaluation. Furthermore, the evaluation questionnaire demonstrated a higher dropout rate before completion. Given that the additional effort increased the completion time by a few minutes, a somewhat lower participation rate was expected. However, the decrease in completed responses was greater than anticipated. This experience highlights how changes in participant effort can considerably influence participation and completion rates in online studies.

8.5 Future Work

Future research could build upon the findings of this thesis to further investigate the impact of progress visualization on student motivation and to validate the proposed design approaches in broader contexts.

Therefore, future research should aim to address the limitations of this study. Firstly, the implemented progress visualization should be evaluated through real interaction with the system rather than through illustrations in the form of pictures and videos. In addition, subsequent studies should seek to include participants from a variety of academic disciplines as well as a more diverse population.

Additionally, a long-term study should be conducted to examine motivational effects over an extended period of time and to observe potential changes in perception during continuous interaction with the progress visualization. Given that motivational perceptions may be influenced by novelty effects and other situational factors, a single, momentary evaluation may not be sufficiently reliable for assessing motivation, which can vary depending on a person's daily state of mind.

Further research should also explore additional approaches to measuring motivation in order to obtain insights beyond subjective self-assessments by students. For instance, behavioral indicators such as time spent on the platform or the number of completed tasks could be analyzed to complement self-reported motivational measures.

Regarding the specific mechanisms, future research could focus on examining individual mechanisms in greater detail and compare different implementation approaches. This could provide deeper insights into how progress visualization mechanisms should be designed and implemented in order to maximize their motivational impact.

Overall, such future studies could contribute to a deeper understanding of how progress visualizations influence student motivation and support the development of more effective motivational progress visualization mechanisms in digital learning environments.

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I hereby declare that the work presented in this thesis is entirely my own and that I did not use any other sources and references than the listed ones. I have marked all direct or indirect statements from other sources contained therein as quotations. Neither this work nor significant parts of it were part of another examination procedure. I have not published this work in whole or in part before. The electronic copy is consistent with all submitted copies.

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