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Design Principles for Learning Management Systems in Higher Education

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Authors: Ekaterina Bessonova
Maheshi Kavihari Ihala Gamage

Supervisor: Gemza Ademaj

Grading Teachers: Odd Steen
Niki Chatzipanagiotou

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AUTHORS: Ekaterina Bessonova and Maheshi Kavihari Ihala Gamage

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ABSTRACT (MAX. 200 WORDS):
Despite the widespread adoption and advanced capabilities of existing learning management systems (LMS), critical usability and functionality issues persist, hindering user experience and educational outcomes. Our research addresses these challenges by developing a comprehensive set of design principles designed to enhance LMS by following the design science research methodology. Through extensive literature review we identified LMS shortcomings and conceptualised actionable design principles to address them. Afterwards, we instantiated the principles in an LMS prototype (IT artefact), which subsequently was evaluated through user observations and semi-structured interviews with students from a large university in Sweden. Based on the gathered feedback, revisions to the prototype and design principles were made, resulting in an improved prototype and more holistic and user-centric set of principles. Our research bridges the gap in existing literature by providing a framework for developing intuitive, engaging, and useful LMS, with significant implications for educational institutions and LMS providers. These findings contribute to the broader discourse on educational technologies within information systems field and beyond, ensuring LMS better meet the pedagogical needs in higher education environments.

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1 Introduction

The landscape of education has been substantially impacted by the rapid evolution of digital technology, notably through the development and integration of learning management systems (LMS) in higher education institutions (Lucas, 2014; Huang *et al.*, 2021). These systems, often cloud-based, integrate administrative tools, instructional content, and learning activities into a cohesive online environment that supports various educational modalities including traditional classroom settings, blended learning, and fully online courses (Kakasevski *et al.*, 2008; Freire, Arezes and Campos, 2012; Nakamura, De Oliveira and Conte, 2017).

The inception of LMS dates back to the late 20th century and has since seen a significant transformation, evolving from simple content management platforms to complex ecosystems supporting interactive learning, analytics, and personalised educational experiences (Freire, Arezes and Campos, 2012; Duin and Tham, 2020; Al-Dhief *et al.*, 2024). As these systems mature, they continually incorporate features that extend beyond traditional learning boundaries, supporting improved accessibility to learning materials, enhanced communication between educators and learners, and data-driven instructional strategies (Söllner *et al.*, 2018; Maslov, Nikou and Hansen, 2021). Recent research underscores their positive impacts, with technological advancements linked to improved educational outcomes (Gupta and Bostrom, 2013; Nguyen *et al.*, 2021; Matook *et al.*, 2024).

1.1 Background

The ongoing evolution of LMS underscores their significant role in shaping pedagogical frameworks and operational practices of educational institutions through technology, highlighting a significant area of study within the information systems (IS) field (Leidner and Jarvenpaa, 1995). Similar to how IS has revolutionised sectors like business and healthcare (e.g., Yang, Su and Yuan, 2012), LMS leverage IS capabilities to streamline educational processes, enhance learning outcomes, and facilitate administrative tasks (Leidner and Jarvenpaa, 1995; Goldstein and Katz, 2005). As LMS continue to evolve, they present a fertile ground for IS research to explore innovative ways to enhance system design, user interface (UI), interactivity, and learner engagement. By addressing the specific needs and challenges within educational systems, IS research can significantly contribute to the development of more robust, intuitive, and accessible learning platforms (Huang *et al.*, 2021). Enhancing LMS through IS research could involve refining user experience design, integrating advanced analytics for personalised learning paths, and developing better communication tools within these platforms. Each of these improvements has the potential to significantly impact educational outcomes, making IS an important reference field for research and development within education and other adjacent fields (Baskerville and Myers, 2002, 2017). Through such endeavours, the field of IS not only extends its relevance but also reinforces its role in advancing educational technologies.

Previous IS research has broadly focused on three principal domains: enhancing student engagement with technology, improving learning outcomes, and understanding the factors influencing technology acceptance. Numerous studies have addressed student *engagement with technology*, highlighting diverse approaches like the emotional inference from human-computer interactions (Reinecke and Bernstein, 2013; Hibbeln *et al.*, 2017), the effects of peer information in competitive academic settings (Zhang, 2017; Li, Wang and Wang, 2021), and the usage of calls to action in online courses (Huang *et al.*, 2021). Notably, gamification has

been a recurrent theme, investigated for its capacity to sustain user engagement and cope with engagement challenges in both educational and workplace settings (Suh *et al.*, 2017; Leung *et al.*, 2023; Tseng *et al.*, 2023).

Regarding *improving learning outcomes*, Sharda *et al.* (2004) focused on collaborative learning requiring immersive presence, while Wan, Compeau and Haggerty (2012) and Piccoli *et al.* (2020) examined the role of self-regulated learning processes and scalable feedback mechanisms. Nguyen *et al.* (2021) developed foundational design principles for learning analytics systems aimed at enhancing educational practices in higher education. Matook *et al.* (2024) investigated the development of metacognitive skills in low-code application development within a work-integrated learning context.

Research on *technology acceptance* has delved into motivational factors and user satisfaction. Studies by Lee, Cheung and Chen (2005) and Chiu, Chiu and Chang (2007) emphasised the importance of both intrinsic and extrinsic motivations and the integrated impact of fairness and quality on learners' continuance intentions. Petter, DeLone and McLean (2008) provided a comprehensive review of IS success models, providing a consolidated view of factors that influence the acceptance and effectiveness of technology.

Despite the integral role of LMS in educational settings, studies like those by Lee, Cheung and Chen (2005), Huang *et al.* (2021) and Leung *et al.* (2023) are among the few that examine the optimisation of LMS features to enhance educational outcomes within IS field. This sparsity of focused research on LMS stands in contrast to the otherwise comprehensive exploration of technology acceptance and user engagement in educational contexts. The limited focus on LMS is particularly visible given the findings of Huang *et al.* (2021) and Leung *et al.* (2023), which suggest significant potential for LMS to impact educational practices positively. Therefore, there remains a noted gap in research, which suggests a potential area for future work, particularly in understanding how these systems can be better tailored to meet the evolving needs of learners and educators in a digital age.

Research on LMS beyond IS field has largely concentrated on evaluating user experience and user interface across different contexts. Various methodologies, such as usability evaluations, heuristic evaluations, user experience questionnaires, and mixed-method approaches, have been employed to assess the satisfaction, acceptance, and preferences of users towards e-learning platforms (Freire, Arezes and Campos, 2012; Paz *et al.*, 2015; Harrati *et al.*, 2016; Santoso *et al.*, 2016; Nakamura, De Oliveira and Conte, 2017; Sahid *et al.*, 2017; Paramitha, Dantes and Indrawan, 2018; Mtebe, 2020; Maslov, Nikou and Hansen, 2021; Saleh *et al.*, 2022). These studies highlight a range of user experiences, pinpointing the importance of usability, reliability, and the educational effectiveness of LMS platforms. Notably, while many studies underscore the significance of improving user interaction and interface design, others like Hijon-Neira *et al.* (2015), Duin and Tham (2020) and Romsi, Widodo and Slamet (2024) divert their focus towards direct learning outcomes and student engagement, suggesting an opportunity for deeper exploration into different ways of how LMS can enhanced to improve educational achievements and engagement levels. While there is an extensive focus on LMS in this literature, it still fails to provide a comprehensive and broad picture on systems' shortcomings and solutions associated with them.

1.2 Research Problem, Purpose, Aim and Objectives

So far, despite the advanced features LMS offer and their extensive adoption, several of the mentioned studies have highlighted critical usability and functional shortcomings. Issues such as confusing content layout, inconsistent interface designs, and limited interaction capabilities hinder user experience and learning outcomes (Freire, Arezes and Campos, 2012; Duin and Tham, 2020). The complexity of LMS architecture can overwhelm users, obscuring valuable functionalities and impeding efficient navigation (Kakasevski *et al.*, 2008; Mtebe, 2020). Additionally, ethical concerns related to data privacy and the proper use of learning analytics need careful consideration to protect student information and ensure equitable treatment (Duin and Tham, 2020; Nguyen *et al.*, 2021).

These design flaws are not merely inconveniences but serious impediments that can result in a disconnect between the capabilities of LMS platforms and the actual requirements of educational environments (Strang, 2016). Given these issues, there is a critical need for clear design principles that address these deficiencies. Developing such principles would not only enhance the functionality and user experience of LMS platforms but also ensure they are better tailored to meet the pedagogical needs of higher education institutions (Nguyen *et al.*, 2021). Therefore, in this paper, we respond to the scholarly calls for in-depth analysis on how information systems can be optimally designed to support the full spectrum of educational activities, including administration, teaching/learning, and research (Pucciarelli and Kaplan, 2016; Becker *et al.*, 2017; Henderson, Selwyn and Aston, 2017; Lacity, Scheepers and Willcocks, 2018). We aim to develop design principles specifically focusing on learning management systems as a unique category of information systems that plays a vital role in higher education. Therefore, our research question reads as follows: *how to design learning management systems that provide comprehensive support for educational practices in higher education?* Through analysing and synthesising existing literature and gathering feedback from a broad range of users, we aim to develop a set of detailed design principles for LMS providers, which serve to improve the functionality and quality of the systems.

To address this question, we adopted the design principle schema and design science research (DSR) approach. The development of the principles was anchored in the design principle schema by Gregor, Chandra Kruse and Seidel (2020), which systematically outlines the development of design principles through a structured framework. This framework ensures that each principle is not only theoretically sound but also empirically justified, fostering a comprehensive understanding and practical application across technological and management domains (Gregor, Chandra Kruse and Seidel, 2020).

Our process followed the iterative and staged methodology proposed by Peffers *et al.* (2007), beginning with an in-depth analysis of the existing LMS capabilities versus the needs of educational institutions, drawn from academic literature and industry insights. The subsequent stages involved conceptualising a set of actionable design principles grounded in the technological and pedagogical requirements of higher education, as discussed by Jones and Gregor (2007). These principles were then instantiated into an artefact, which underwent thorough evaluation in real-world testing and stakeholder feedback within a university setting, thereby providing valuable insights used for refining the design principles.

Our study bridges the gap identified in previous research, which often either focuses extensively on user interface and engagement or overlooks comprehensive design aspects critical for enhancing educational outcomes. We synthesise existing literature with empirical data gathered

from LMS users to propose actionable design principles that enhance the quality, functionality and usability of the systems. Our research not only addresses pressing concerns such as usability flaws and ethical considerations related to data privacy but also contributes to the broader discourse on how IS can optimally support educational environments. By focusing on these aspects, this study aligns with and extends the current IS research body, providing a foundation for future studies aimed at refining educational technologies and improving learning experiences in higher education.

1.3 Delimitations

We focus our research on the application and enhancement of LMS within the context of higher education, concentrating solely on students as the primary user group. The empirical data for this study is collected from the students of a large university in Sweden, thereby situating the research within a specific educational and geographical context.

Our focus on higher education excludes other educational levels such as primary and secondary education. This restriction is due to the unique requirements and challenges faced by higher education institutions that differ significantly from those in other educational settings. The complexities of university-level course management, advanced pedagogical methods, and diverse student engagement strategies necessitate a specialised approach that is distinct from the broader educational spectrum.

By targeting students exclusively, this study aims to delve deeply into their specific experiences, needs, challenges, and preferences in using LMS for their academic activities. Importantly, students are the primary users of LMS, whose engagement and satisfaction are vital for the success of any educational technology. They interact with these systems on a daily basis to access course materials, submit assignments, participate in discussions, and track their academic progress. Therefore, their frequent and diverse interactions with LMS make them a critical group for understanding how these systems can be improved. By examining students' perspectives, the study can identify specific usability issues, design flaws, and areas for enhancement. More than that, students in higher education represent a diverse group with varying technological proficiencies, learning styles, and accessibility needs. Understanding these diverse requirements is essential for developing LMS features that are inclusive and supportive of all learners.

The selection of a single large university in Sweden as the site for data collection means that the findings may reflect specific institutional policies and cultural factors unique to this setting. While the insights gained may offer valuable contributions to the broader discourse on LMS design and functionality, caution should be exercised in generalising the results to different contexts, such as smaller institutions or other countries.

1.4 Outline of the Thesis

The further chapters provide a detailed literature review that both overviews LMS functionalities and focuses on their use in higher education. Then we explain the design science research approach adopted for the study, and conceptualise LMS design principles. In the "Conceptualisation of Design Principles" chapter, we discuss the adopted kernel theories and prior related research in greater depth than in the "Literature Review" chapter. This approach enhances the coherence of the thesis, as due to the specific nature of the design science research

approach it is crucial for readers to grasp the research structure before delving into a detailed exploration. An evaluation chapter assesses these principles, and is followed by a discussion that interprets the findings. The paper concludes by summarising the research, outlining practical implications, and suggesting directions for future research.

2 Literature Review

2.1 Learning Management Systems Overview

Learning Management Systems are comprehensive cloud-based platforms designed to facilitate and enhance the delivery, management, and assessment of educational courses and training programs (Nakamura, De Oliveira and Conte, 2017; Al-Dhief *et al.*, 2024). They serve as a foundational tool in ordinary education and e-learning, providing a structured environment where instructional content, learning activities, and administrative tools are integrated into a single, accessible online space (Kakasevski *et al.*, 2008; Freire, Arezes and Campos, 2012; Hijon-Neira *et al.*, 2015).

The genesis of LMS can be traced back to the late 20th century, with systems primarily focused on content management and delivery (Duin and Tham, 2020; Al-Dhief *et al.*, 2024). Initially conceived to digitise traditional learning materials, LMS platforms have evolved into complex ecosystems that support a wide range of teaching and learning activities. Over the years, as educational needs and technology advanced, LMS platforms have incorporated more sophisticated features like interactive learning, analytics, and personalised education experiences, transforming the landscape of education in higher education institutions (Freire, Arezes and Campos, 2012).

LMS platforms play a crucial role in facilitating the educational process, offering a range of functionalities that can be categorised in several groups such as learning support, assessment and feedback, communication and collaboration, and productivity (Al-Dhief *et al.*, 2024). These groups are described in greater detail in Table 2.1. They support a variety of teaching and learning methods, including blended learning, flipped classrooms, and fully online courses (Söllner *et al.*, 2018). The impact of LMS on education goes beyond the traditional boundaries and includes improved accessibility to learning materials, enhanced communication between teachers and students and collaborative learning, and the ability to monitor and analyse student performance (Maslov, Nikou and Hansen, 2021; Nguyen *et al.*, 2021).

Table 2.1: Main Functionalities of LMS. Based on the work of Al-Dhief et al. (2024)

Group	Module	Description
Learning Support	*Courses*	Essential for organising and presenting learning materials and activities in different formats (text, video, audio), creating modules or lessons and providing controlled access to students.
	Online Presentations	Allows for the uploading and sharing of presentations, including integration with external video platforms like YouTube, enhancing the diversity of learning resources.
Assessment and Feedback	*Tests / Quizzes*	Supports the creation and management of quizzes, providing a database for questions, a marking scheme, and tools to analyse student performance, thereby enabling formative assessments.
	Assignments	Facilitates the uploading of assignments by educators and submission by students.

	Feedback	Enables providing feedback, which can range from automated quiz feedback to personalised comments on assignments.
Communication and Collaboration	*Announcements*	Used widely for disseminating course-related information, upcoming activities, and other pertinent news to all students.
	Discussion Forums	Provides a space for posting, reading, and responding to messages, facilitating vibrant academic discussions and collaborative learning.
	Groups	Facilitates students group work and timely coordination within the group.
	Emails	Provides an opportunity for the exchange of private emails.
Productivity	*Calendar*	Helps in organising schedules, deadlines, and important dates, ensuring that both students and educators are aware of upcoming events and obligations.
	File Management	Enables the uploading and downloading of files, making resources readily accessible to all users.
	Surveys	Gathers feedback on the courses and the system.
	Reports	Generates reports on student performance and system usage, providing valuable insights for continuous improvement.

Looking at a broader picture, the LMS market has steadily grown since its inception. The first known LMS, FirstClass, was introduced in 1990, marking the beginning of a new era in digital learning. This was followed by other systems like Blackboard in 1997, Moodle in 2001, Desire2Learn in 1999, and Canvas in 2008 (Al-Dhief *et al.*, 2024). These systems evolved from basic client-server software to sophisticated platforms offering a wide array of features. The evolution and core functionalities of LMS platforms reflect a shift towards more interactive, personalised, and accessible learning experiences in higher education. As institutions continue to adopt and integrate LMS into their teaching and learning strategies, the focus remains on enhancing user experience, engagement, and educational outcomes (Maslov, Nikou and Hansen, 2021; Saleh *et al.*, 2022; Leung *et al.*, 2023; Romsi, Widodo and Slamet, 2024).

2.2 Learning Management Systems in Higher Education

Learning management systems have become integral to higher education, facilitating not just administrative functions but significantly enhancing educational delivery. Studies, such as those by Dahlstrom *et al.* (2014) and Leidner and Jarvenpaa (1995), have underscored the positive impacts of educational information systems on the dynamics of teaching and learning. By providing essential infrastructure, LMS can support innovative educational strategies, facilitate content delivery, skill development, and foster collaborative work among students (Gupta and Bostrom, 2013; Matook *et al.*, 2024). Building on this foundation, Nguyen *et al.* (2021) have further emphasised the continuous advancements in this domain, suggesting that technological innovations in education significantly bolster learning outcomes. The utility of LMS extends beyond routine educational activities; they generate substantial data that can be

leveraged to refine teaching methods and shape institutional policies. This data-driven approach can lead to more informed decisions that directly enhance student performance and satisfaction (Nguyen *et al.*, 2021).

However, despite these benefits, LMS platforms are not devoid of issues. A notable one is the manner in which content is presented. Freire, Arezes and Campos (2012) have pointed out that the design and structure of content within LMS can often be confusing, lacking clarity in the sequence and relationship of tasks, which could hinder student understanding and progress. Interface issues such as inconsistent visual and pictorial language can create cognitive overload and confusion (Freire, Arezes and Campos, 2012). Growing from this, browsing problems and the discomfort of mobile interfaces also detract from the user experience (Maslov, Nikou and Hansen, 2021).

The architectural complexity of LMS can also be a barrier. As highlighted by Kakasevski *et al.* (2008), the inclusion of multiple modules intended to address various educational needs can overwhelm users, causing confusion about their appropriate use. Mtebe (2020) notes that this leads to many students remaining unaware of all the functionalities available within such systems.

The interaction capabilities within LMS, even though existent, are limited, affecting user motivation and the potential for knowledge exchange. Ensuring systems facilitate and encourage communication and collaboration through all available means is crucial for fostering an effective e-learning environment (Freire, Arezes and Campos, 2012).

One more significant concern is the ethical implications of data collection and analysis through LMS, which must be carefully considered to ensure privacy and equity. The responsible use of learning analytics can inform more personalised and effective educational strategies but requires thorough oversight to prevent misuse and protect student data (Duin and Tham, 2020).

Described complexity and issues can make it difficult for both students and educators to navigate the system efficiently, potentially stalling the learning process instead of facilitating it. Thus, despite all the supporting features LMS may have, there is still a reported disconnect between LMS activity and actual academic performance (Strang, 2016; Duin and Tham, 2020), suggesting that the mere presence of advanced technological tools does not automatically translate to better learning outcomes.

The success of an LMS heavily depends on the active engagement of instructors and the awareness among students of available features. Productive use of an LMS requires that a system is intuitive, educators are well-trained and that students are adequately supported through training and documentation (Mtebe, 2020). Without these, the potential benefits of an LMS may not be fully realised, underscoring the need for ongoing support and improvement in LMS implementation in higher education settings.

Thus, there is a clear demand for enhancements in user interface design, content interactivity, and overall visual appeal to make learning more engaging and accessible. These enhancements could involve more intuitive navigation, appealing user interface, richer multimedia content, more responsive design elements, personalised gamification and performance feedback tailored

to individual learning traits that cater to a diverse student body (Maslov, Nikou and Hansen, 2021; Leung *et al.*, 2023). Possible enhancements are discussed in detail later in the paper.

As a result, the research highlights a notable deficiency in the availability of specific functionalities within LMS that are deemed essential for fostering an effective learning environment. Furthermore, there has been a noticeable lack of comprehensive guidance for LMS providers on how to construct an LMS that meets the complex needs of higher education. This shortfall indicates a disconnect between the capabilities of current LMS platforms and the actual requirements of educational environments. Therefore, drawing conclusions from the literature, we can say that despite the extensive discussion on diverse LMS functions and their impacts, there remains a critical gap in existing research regarding a comprehensive list of specific features and qualities that these systems should embody to truly support educational processes.

To address this problem, our research aims to bridge this gap by proposing a set of detailed design principles. These principles are developed through a synthesis of extensive previous research and feedback from a diverse range of LMS users. By compiling a comprehensive list of design principles, the research seeks to provide a clear, actionable framework that can guide the systems providers in creating better and suitable platforms for higher education settings. This approach not only aims to enhance the functional capabilities of LMS but also ensures that these systems are more aligned with the pedagogical needs of institutions and their stakeholders, ultimately leading to improved educational outcomes.

3 Research Methodology

3.1 Research Philosophy

Hassan and Mingers (2018) argue for the importance of philosophical awareness in research, emphasising that a robust philosophical foundation enhances the depth of research outcomes. That is why our research is grounded in critical realism, which serves as an effective philosophical underpinning for information systems research. Critical realism, as advocated by Mingers (2004), acknowledges the complexity of social phenomena by differentiating between the empirical (what we experience), the actual (what happens), and the real (the underlying mechanisms). This philosophical stance allows us to not only describe observable interactions with the LMS but also to understand the deeper, often hidden structures and mechanisms that influence these interactions (Mingers, 2004).

3.2 Research Approach and Design

For our research we followed a staged, iterative process inspired by the design science research methodology proposed by Peffers *et al.* (2007), which systematically integrates continuous refinement of both design principles and IT artefacts (Figure 3.1). Initially, we *identified and articulated the problem*: existing learning management systems lack specific qualities and functionalities deemed essential for educational support, particularly in higher education contexts. This gap was recognised through a detailed analysis of academic literature and industry insights, highlighting a significant disconnect between existing LMS capabilities and the needs of educational institutions (e.g., Kakasevski *et al.*, 2008; Mtebe, 2020; Maslov, Nikou and Hansen, 2021).

To address these shortcomings, we set out to *develop a comprehensive set of design principles*. This stage involved an extensive review of academic literature on current technological states and the pedagogical requirements of higher education (Jones and Gregor, 2007). Our objective was to establish a set of actionable guidelines that could direct the development of better LMS taking into account arguments and opinions of renowned scholars and users from higher education establishments worldwide.

With these principles clearly defined, we proceeded to the artefact *design and development phase*. As articulated by Offermann *et al.* (2010), IT artefacts in design science research can vary in fidelity from simple sketches to sophisticated interactive software. For our LMS prototype, we opted for a medium-fidelity approach. Thus, the process began by translating the abstract principles into concrete features and structures within the LMS prototype. To achieve this, Figma, a robust design tool known for its prototyping capabilities, is utilised to create a visual and interactive representation of the LMS. The design of the artefact was informed by theoretical knowledge relevant to learning management systems (Peffers *et al.*, 2007; Sein *et al.*, 2011), ensuring that the artefact's architecture and functionalities were closely aligned with our defined design principles. This approach ensures that the design is not only theoretically sound but also practically viable, providing a platform for evaluation in higher education settings and further development.

Throughout the *demonstration and evaluation phase*, we conducted real-world demonstrations and collected stakeholder feedback through observations and semi-structured interviews. We

evaluated the artefact alignment with the users' needs and expectations. The feedback provided crucial insights into how well the artefact addressed the identified in the literature drawbacks, allowing for refinement of the conceptualised design principles and the artefact based on the gathered input. This approach ensured that both the design principles and the developed artefact were not only grounded in theoretical knowledge but also rigorously tested and refined through empirical evidence and user feedback, thus ensuring relevance and efficacy in real-world educational settings (Jones and Gregor, 2007).

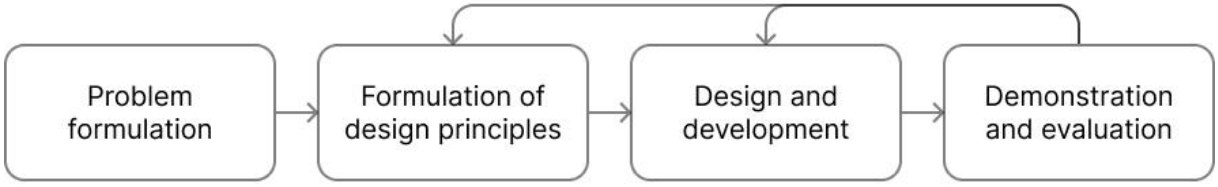

Figure 3.1: High-level overview of the research approach

3.3 Design Principles Formulation Approach

In our research, we used a systematic approach to construct design principles for learning management systems. These principles are scientifically formulated directives aimed at guiding the development of learning management systems, which belong to a specific class of IT artefacts. According to Iivari (2015), a design principle serves as a meta-artefact, providing a generalised framework that can be adapted to create specific IT artefacts within the same class. Sein *et al.* (2011) further elucidate that design principles encapsulate the knowledge necessary for creating additional instances of artefacts, thereby standardising practices and fostering consistency across different implementations.

The formulation of our design principles is grounded in the methodology outlined by Gregor, Chandra Kruse and Seidel (2020), which proposes a structured schema for their development. This schema is composed of several components: *implementers*, who are tasked with instantiating abstract principles into tangible designs[1]; *users*, whose needs and objectives the system aims to meet; *context*, the environment or setting in which the LMS operates; *mechanisms*, which are the processes or features that facilitate the achievement of the users' aims with the aid of *enactors*, systems or entities that execute the mechanisms[2]; and *rationale*, which provides the underlying justification for the belief that the mechanisms employed will effectively achieve the intended outcomes (Gregor, Chandra Kruse and Seidel, 2020).

This schema not only specifies the elements of a design principle but also emphasises the importance of a rationale for each principle, ensuring that each is backed by a logical and empirically supported explanation. The inclusion of multiple mechanisms and their respective enactors highlights the multifaceted nature of technology implementation, where different components work synergistically to fulfil user requirements. Moreover, the schema suggests employing decomposition to detail each principle further, enhancing clarity and utility for both implementers and enactors (Gregor, Chandra Kruse and Seidel, 2020). By adopting this structured approach, we aim to develop robust, empirically grounded design principles that are communicable and actionable for both technology- and management-oriented audiences, aligning with the objectives of design science research as outlined by (Hevner *et al.*, 2004).

[1] In our case *implementers* are LMS providers (implied in the principles).
[2] In our case *enactor* is an LMS itself (implied in the principles).

3.4 Data Collection

Our research was conducted within the context of a large university in Sweden, Lund University, which has an enrolment of over 45,000 students. The primary LMS in use at this institution is Canvas. It serves as a comprehensive platform facilitating various educational processes, including collaboration, communication, and course administration. Despite its extensive capabilities, both faculty and students have criticised the system. Faculty concerns primarily revolve around the LMS's user interface, which is perceived as confusing and not intuitive, complicating the organisation and management of courses and assignments. Students, on the other hand, report frustrations with the system's inconsistencies and technical glitches, which adversely affect their ability to access course materials, submit assignments, and engage in meaningful interactions with peers and instructors.

3.4.1 Data Collection Methods

For exploring complex phenomena like this one in depth, qualitative research is well-suited (Patton, 2015). It offers rich, detailed insights into participants' experiences and perceptions. This approach is particularly valuable for us in understanding how users interact with the LMS and the specific challenges they encounter.

In accordance with the guidelines provided by Weiss (1994) for performing qualitative research, our study employed observations and semi-structured interviews to gather empirical data. Observations were conducted to capture the natural behaviours and interactions of participants with the prototype, allowing us to note unspoken elements of the context that might influence responses—details that might be missed through more structured research methods (Boudreau, Gefen and Straub, 2001; Tremblay, Hevner and Berndt, 2010). Semi-structured interviews were chosen because of their flexibility, which enabled us to probe deeper into the personal experiences and perceptions of participants while maintaining focus on our primary research question. This method facilitates a conversational style that encourages participants to share detailed and personal narratives, offering us nuanced understandings of their perspectives (Patton, 2015).

To smooth the data collection, we developed an interview guide that listed key themes and questions (Appendix A), yet allowed for flexible, conversational engagement with participants. It helped ensure that while observations and interviews remained open to diversity, they were also systematically aligned with our research objectives (Weiss, 1994). Following the guide, to perform the observations we first asked participants to interact with the prototype, engaging in a variety of predefined tasks aimed at evaluating the system's functionality and usability. This phase lasted approximately 20 minutes for each participant and allowed for observation of their ability to navigate and utilise the LMS independently, noting tasks they could accomplish without assistance.

Subsequently, we conducted semi-structured interviews lasting approximately 40 minutes and consisting of 30 questions that probed deeper into the users' experiences with the prototype. Questions were designed to elicit detailed feedback on the intuitiveness of the design, personalisation capabilities, and the overall user experience, which were critical for assessing the LMS's ability to meet educational needs. Interview questions also explored the participants' satisfaction with the system's features and their comparative experiences with other LMS platforms they had used before.

3.4.2 Participants Selection

The selection of respondents was conducted through purposive sampling, targeting a diverse cohort of students from various faculties and programmes of the university (Etikan, 2016). The goal was to ensure that our sample included individuals with varying degrees of familiarity and satisfaction with the LMS they used before, so that we could capture a holistic view of the system's strengths and weaknesses. To recruit participants for our study, we utilised online channels including email invitations and social media posts, which allowed us to reach a wide range of students. This strategy aimed to engage a diverse group of users from the university, thereby ensuring that our findings and subsequent design improvements were informed by a broad spectrum of experiences and perspectives within the educational setting (Weiss, 1994). This setting, characterised by its large scale and the existing challenges with the Canvas LMS, provided a rich environment for examining the efficacy of our proposed design principles and the developed IT artefact in addressing real-world educational and technological challenges.

3.4.3 Ethical Considerations

The observations and interviews were conducted in a manner that emphasised building trust and cooperation, ensuring that participants felt comfortable sharing their honest and detailed experiences, thereby enriching the data's depth and reliability (Weiss, 1994). During the study we adhered to ethical guidelines outlined by Patton (2015), which emphasise the importance of informed consent, confidentiality, and respect for participants. Informed consent was obtained before data collection, ensuring participants were aware of the research scope and their role. Confidentiality was maintained by anonymising data and securely storing all information. Any identifying details were removed from the transcripts to protect participants' identities. Next, participants were fully informed about the study's purpose, procedures, voluntary and anonymous participation and their right to withdraw at any time without any repercussions. These assurances safeguarded their autonomy and comfort throughout the research process, which was crucial in establishing a secure environment that encouraged the free and open sharing of information (Patton, 2015).

Moreover, the study adhered to ethical principles specific to internet-based research, considering issues such as intrusiveness, respect for privacy, sensitivity to vulnerability, potential harm, and confidentiality (Patton, 2015). These considerations are particularly pertinent when conducting research in online communities, where participants may have varying expectations of privacy and vulnerability levels.

3.5 Data Analysis

Analysing the data collected from observations and interviews, we aligned with qualitative research principles as outlined by Weiss (1994). We first transcribed the audio recordings from the interviews verbatim to preserve the accuracy and richness of the data. Subsequently, thematic analysis was applied to both the interview transcripts and observation notes. This involved an iterative process of coding the data in several phases to identify patterns and themes related to the user experience with the prototype. Initially, open coding was performed where descriptive codes were assigned to the data chunks representing distinct ideas or concepts. This step facilitated the recognition of preliminary themes concerning common issues and satisfactions expressed by the users regarding the prototype interface and functionalities. Following this, axial coding helped in connecting these codes into broader categories, which

were more reflective of systemic issues and positive aspects within the user interaction with the prototype.

To ensure the reliability and validity of our analysis, coding was conducted independently by two researchers, followed by a consensus meeting to discuss and reconcile any discrepancies in the interpretation of the data. This collaborative approach minimised researcher bias and enhanced the depth of analytical insights. Moreover, quotes from participants were selectively included to substantiate the identified themes, providing concrete examples of user frustrations and satisfactions.

In the final stage of our analysis, the themes that emerged from both the observations and interview data were related to the existing literature in the IS field and beyond to frame our findings within broader theoretical contexts. It was done by mapping our themes onto established theories from relevant literature, thereby enriching our understanding and interpretation of the empirical data. This strategy highlighted specific usability issues and user satisfactions and provided a solid basis for proposing practical improvements to LMS.

3.6 Scientific Quality

The scientific quality of this study was ensured through rigorous methodological approaches and adherence to established qualitative research criteria. According to Patton (2015), several sets of criteria can judge qualitative studies' quality, including traditional scientific research criteria and constructivist criteria.

This study followed traditional scientific research criteria, emphasising credibility, transferability, dependability, and confirmability. Credibility was achieved through prolonged engagement with participants, persistent observation, and triangulation. Transferability was ensured by providing detailed descriptions of the research context and participants, allowing readers to assess the applicability of findings to other settings. Dependability was addressed by maintaining a comprehensive audit trail, documenting all research decisions, and methodological changes. Confirmability was ensured through reflexive practices, where we as researchers critically examined our biases and their influence on the research process. These measures align with Patton's (2015) recommendations for enhancing the trustworthiness of qualitative research.

4 Conceptualisation of Design Principles

Design principles distil insights from existing research and are intended to guide the creation of new LMS tools that belong to the same functional category (Piccoli *et al.*, 2020). Our formulation of these principles is deeply rooted in the extensive body of literature on LMS and technology-mediated learning environments. By synthesising the accumulated knowledge, we aim to provide a robust framework that not only aids in the construction of LMS solutions but also ensures these systems are adaptable and relevant in diverse educational contexts.

We divide all design principles into two distinct categories: quality design principles and functional design principles. *Quality design principles* in this context refer to the quality standards of a system that ensure that LMS are reliable and meet the needs of users within diverse educational environments. These principles are derived from insights into existing information systems and technology-mediated learning research, being pivotal in ensuring that LMS support continuous and productive use. *Functional design principles* guide the structural and operational aspects of LMS features, ensuring they facilitate a conducive learning experience, thus making them necessary for the development of technologically advanced and useful educational tools.

In our research, we incorporate both *Intervention Theory* and *Social Cognitive Theory* as kernel theories. Intervention theory is based on empirical research in organisational behaviour and change management (Nguyen *et al.*, 2021). This foundation helps ensure that the interventions designed within the LMS are grounded in proven principles that can lead to effective change. As described by Argyris (1970), intervention theory describes how intervenors facilitate enhancing skills in problem-solving, decision-making, and implementing decisions. This theory outlines three primary principles for creating effective interventions: valid and useful information, free and informed choice, and internal commitment. *Valid and useful information* is defined as information that enables influenced individuals to manage their own behaviours and results, while being verifiable and impactful for the targeted issues. *Free and informed choice* emphasises the influenced individuals' central role for both the design and implementation of interventions, which is crucial in contexts such as education where their engagement is essential for success. *Internal commitment* refers to the influenced individuals' sense of ownership and responsibility towards the intervention, driven by their alignment with the initiative's purpose and their belief in their ability to influence outcomes (Argyris, 1970).

The interdependence of these principles is vital. The presence of valid and useful information enables influenced individuals to make informed decisions, which in turn enriches the pool of valuable information and reinforces internal commitment if the decisions lead to positive results (Argyris, 1970). Therefore, we use these insights to inform the development of *quality design principles* for LMS, ensuring that they align with the needs of the users.

Social cognitive theory highlights the importance of self-regulation in learning processes. It emphasises that learning involves actively acquiring, enhancing, or modifying one's knowledge, skills, and values through a set of principles and practices that enable individuals to monitor their behaviours and adjust them in the process of achieving their personal goals (Leung *et al.*, 2023). As a result, self-regulated learning offers a robust explanation of the learning process and its ability to account for learning success across diverse contexts and educational stages. This makes it an important part of social cognitive theory, which is widely used in both IS and education fields (Leung *et al.*, 2023), and it plays a central role in its application within learning environments. Individuals engaged in self-regulated learning are

considered to be metacognitively, motivationally, and behaviourally active participants in their learning process, managing their learning through strategies that involve planning, monitoring, and adjusting their behaviours according to self-set goals (Wan, Compeau and Haggerty, 2012).

In the research written by Wan, Compeau and Haggerty (2012), self-regulated learning is analysed within e-learning contexts, distinguishing between personal and social self-regulated learning strategies. The study finds that personal self-regulated learning strategies are particularly effective in enhancing declarative knowledge acquisition, skill development, and learner satisfaction. Social self-regulated learning strategies, on the other hand, also contribute positively to learning outcomes, emphasising the importance of peer interaction and social resources in learning processes (Wan, Compeau and Haggerty, 2012).

Personal self-regulated learning strategies are primarily focused on the individual management of learning tasks and the personal organisation of the learning process. They include *self-evaluation*, where learners assess their own performance and understanding, and *organising and transforming*, which involves rearranging or modifying learning materials to make them more comprehensible. *Goal setting and planning* are crucial as they entail defining clear objectives and devising strategies to achieve them. *Seeking information* extends beyond the provided materials, encouraging learners to find additional resources. *Keeping records and monitoring* help learners track their progress and important insights, while *environmental structuring* focuses on creating a conducive physical and digital study environment. *Self-consequences* involve setting rewards or punishments based on one's performance to enhance motivation. Techniques such as *rehearsing and memorising* are employed to improve retention of information, and *reviewing* involves revisiting content to reinforce understanding and memory (Zimmerman and Martinez-Pons, 1988; Wan, Compeau and Haggerty, 2012).

Social self-regulated learning strategies, on the other hand, leverage the social context of learning, promoting interactions and communications that facilitate educational achievements. They include six subdimensions. *Seeking peer assistance* involves engaging fellow learners for help and exchanging information, which fosters a collaborative learning environment. Similarly, *seeking instructor assistance* allows learners to obtain guidance and clarification directly from educators. In organisational settings, *seeking manager assistance* can provide support for learning-related tasks, while *seeking IT-expert assistance* is vital for resolving technical issues related to e-learning tools. *Social comparison* enables learners to gauge their progress against that of their peers, can motivate and direct learning efforts. Lastly, *social interaction* is done through participation in group discussions and collaborative activities enhances learning by enabling knowledge sharing and collective problem-solving (Zimmerman and Martinez-Pons, 1988; Wan, Compeau and Haggerty, 2012).

Both groups of researchers, Wan, Compeau and Haggerty (2012) and Leung *et al.* (2023), state that educators can facilitate the use of these strategies by providing resources and environments that encourage both personal management of learning and social interaction. This includes access to technological tools, collaborative platforms, and a supportive learning culture that recognises the diverse needs of individual learners. This makes the theory an important underlying framework for the development of *functional design principles* for LMS.

4.1 Quality Design Principles

4.1.1 Quality Design Principle #1

According to Nguyen *et al.* (2021) and Baskerville, Kaul and Storey (2017), ensuring a system's availability and the continuity of its services is crucial, especially for systems like LMS, as consistent availability and error management preventing severe consequences ensures that the system remains operational and reliable for users at all times. For instance, the independence between services in a system's architecture minimises downtime, thereby maximising availability (Nguyen *et al.*, 2021). This design strategy prevents service interruptions, allowing students and educators to rely on the system for continuous educational activities. Furthermore, the observations by Ifenthaler, Gibson and Dobozy (2018) and Nguyen, Gardner and Sheridan (2017) highlight that systems like LMS need to remain accessible at all times since server shutdowns can deter users from engaging with the system and disrupt educational activities, negatively affecting their education process and overall experience.

Piccoli *et al.* (2020) stress the significance of a system's ability to manage a large user base efficiently. In short, their study illustrates how serverless architectures enable systems to handle hundreds of simultaneous users without performance degradation, even during peak usage times (Piccoli *et al.*, 2020). This capability is essential for LMS, particularly in institutions with large student populations or when used in widespread open online courses that experience variable and high demand.

A system's rapid response to user inputs is another important factor for user satisfaction and the maintenance of an engaging learning environment. Piccoli *et al.* (2020) state that the ability of a system to deliver (near) real-time responses to a vast number of users simultaneously is a testament to its robust design. This responsiveness not only improves user engagement but also facilitates immediate learning and feedback processes, which are essential for prompt educational advancements (Piccoli *et al.*, 2020). Accordingly, the easy maintainability and upgradability of such systems reduce system complexities, prevent prolonged downtimes, and ensure that the system evolves in alignment with technological advancements and educational needs.

As highlighted by Matook *et al.* (2024), the handling of sensitive data such as students' performance requires stringent measures to protect privacy. It is essential that data be only published publicly in aggregated form and that individual responses are not disclosed, ensuring that user anonymity is maintained and personal data is protected from unauthorised access, alterations, and losses (Nguyen *et al.*, 2021; Matook *et al.*, 2024). This approach not only safeguards the information but also builds trust among users, encouraging them to engage more freely and confidently with the LMS.

Based on the reviewed literature, we articulate the first quality design principle (QDP) for LMS, which consists of several components: availability, scalability, performance, reliability, and maintainability. Systems should be designed for robustness, ensuring high *availability* with minimal downtime so that users can consistently *rely* on the service. They must be *scalable*, capable of handling an increasing number of users and larger data volumes without *performance* degradation, even during peak loads. Additionally, the system should provide *rapid responses* to user inputs and be straightforward to *maintain* and update, thereby minimising frustrations and maximising user satisfaction, while *protecting* and *securing* user data. Incorporating the components, this principle aims to create a dependable, efficient, and

user-friendly environment that supports continuous productive use. As a result, according to the design principle schema, the principle reads as follows: for LMS providers to ensure a robust operation of the system for users[3] across environments[4], develop strategies and technologies that enhance availability, scalability, performance, reliability, privacy, security, and maintainability, as these combined efforts help meet users' expectations of a stable and efficient service while adapting to evolving demands and threats.

> **QDP1.** *Robust system design*: develop strategies and technologies that enhance availability, scalability, performance, reliability, privacy, security, and maintainability

By ensuring the LMS is highly available, scalable, and performs well, this principle supports the components of intervention theory. In a system embodying this principle, users are able to receive reliable information for effective decision-making through a robust infrastructure of the system. The provided reliability fosters a strong sense of trust and commitment among users, aligning their needs with the system's capabilities.

4.1.2 Quality Design Principle #2

LMS should be able to deliver specific, relevant, and actionable information that enables users—students, educators, and administration—to effectively influence their behaviours in a positive way and guide decisions in learning and teaching activities. This is supported by various studies in the field of learning analytics, which emphasise the need for providing information that is valid, useful, and facilitates direct, practical action (Dawson, Gašević and Siemens, 2015; Nguyen *et al.*, 2021). For instance, if an LMS reports that a student is struggling in a specific area, teachers can respond with targeted instructional changes or additional resources, thus directly influencing learning outcomes. The granularity of the information provided—specific to the needs and contexts of individual users—ensures its applicability across various levels of decision-making, from classroom management to curriculum adjustments (Ifenthaler, Gibson and Dobozy, 2018; Nguyen *et al.*, 2021). However, it is important to note that the LMS developers do not provide educational information, rather, they are supposed to create an environment that gathers educational data and information from the users, processes it, and supplies actionable insights. As a result, according to the design principle schema, the principle reads as follows: for LMS providers to enable optimal educational outcomes and support informed decision-making for users in diverse informational contexts and across environments, develop adaptive technologies that deliver valid, specific to and useful for the user information as they enable extending user's decision-making capabilities and positively influence behaviour.

Literature underscores the importance of timing in the delivery of educational content and feedback. Ifenthaler, Gibson and Dobozy (2018) stress the necessity of up-to-date information in dynamic educational settings, where data and student needs evolve rapidly. This calls for adaptive learning technologies that not only provide real-time feedback but also support adjusting the educational content according to the individual learner's progress and needs (Wan, Compeau and Haggerty, 2012). Butler *et al.* (2007) and Shimada *et al.* (2018) highlight that the timing of information can significantly influence its effectiveness, where tactically delayed feedback can enhance learning outcomes compared to immediate feedback. This is because

[3] Students, learners, and similar.
[4] Web, mobile, etc.

delayed feedback may allow learners to reflect on their answers and develop problem-solving skills before receiving feedback, which aligns with the principles of self-regulated learning and metacognition (Butler *et al.*, 2007; Wan, Compeau and Haggerty, 2012). As a result, LMS should be able to provide information and feedback right at the time when it is needed and in a form that is easily comprehended by the users, thereby enhancing learners' comprehension and management of their own learning processes, ultimately fostering a deeper internal commitment to learning. Therefore, according to design principle schema, the principle reads as follows: for LMS developers to enable optimal educational outcomes and support informed decision-making for users in diverse informational contexts and across environments, develop technologies for providing information and feedback on demand and in a comprehensive form and format as it enhances learning by allowing for better reflection and adjustment of educational strategies.

Higher education institutions encounter frequent challenges with the integration of disparate data systems. They typically maintain multiple, non-integrated systems that store a wide array of educational data such as learning and teaching resources, student profiles, etc. (Nguyen *et al.*, 2021). Chatti *et al.* (2014) and Siemens (2013) highlight the importance of continuous data integration, which allows for the assimilation of data with varying schemas from multiple sources, thereby facilitating a continuous and smooth flow of data across different platforms and modules of the same system. Such integration supports the reflection of an accurate picture of the learners and their learning processes. As a result, according to the design principle schema, the principle reads as follows: for LMS providers to provide comprehensive educational support for users across environments, develop data integration and interoperability mechanisms ensuring seamless data flow across different platforms and within the system's various modules as it supports learning processes, providing a cohesive and integrated educational experience.

> **QDP2a.** *Actionable information*: develop adaptive technologies that deliver valid, specific to and useful for the user information
>
> **QDP2b.** *Impactful information delivery*: develop technologies for providing information and feedback on demand and in a comprehensive form and format
>
> **QDP2c.** *Interoperability*: develop data integration and interoperability mechanisms ensuring seamless data flow across different platforms and within the system's various modules

These principles ensure that an LMS has the appropriate architecture for delivering specific, relevant, and timely data tailored to users' needs, enabling informed decision-making and positively influencing behaviours, thereby closely aligning with the tenet of intervention theory "valid and useful information". By promoting real-time feedback and adaptive learning technologies, the LMS ensures that information remains pertinent and understandable. Continuous data integration guarantees accuracy and comprehensiveness, aligning with the theory's requirements for verifiable and targeted information. This approach not only supports good educational outcomes but also fosters users' internal commitment to their learning and teaching processes.

4.1.3 Quality Design Principle #3

Human computer interaction research has consistently highlighted how aesthetic and consistent design elements, as well as dynamic interactive features, significantly influence users' emotional responses (Tractinsky *et al.*, 2006; Sheng and Joginapelly, 2012). Positive emotional responses are crucial as they directly enhance acceptance and interaction with technology (Hibbeln *et al.*, 2017), while negative emotions can impede user engagement and technology adoption (Venkatesh and Davis, 2000; Beaudry and Pinsonneault, 2010).

The aesthetic experience, according to Suh *et al.* (2017), not only predicts the continuance intention to use a system but also fosters meaningful engagement that transcends mere hedonic enjoyment. This notion is supported by findings that aesthetic experience in information systems can catalyse psychological and behavioural responses favourable to sustained interaction with technological artefacts, which, in turn, facilitates users' needs for meaning, self-expansion, and active discovery (Suh *et al.*, 2017). Because this aesthetic engagement is linked to greater continuance intention, it encourages users to persist with an LMS that offers an engaging visual and interactive experience. This aligns with observations from Jiang *et al.* (2016), who noted that users' perceived aesthetics of a website can positively influence their perception of its utility, showcasing a spillover effect where aesthetics enhance functional appreciation.

Furthermore, incorporating design elements that enhance the aesthetic experience, such as performance tracking tools, visualisation of progress, and competitive charts, can significantly boost user engagement (Suh *et al.*, 2017; Romsi, Widodo and Slamet, 2024). The integration of gamification, as explored by Romsi, Widodo and Slamet (2024), offers a strategic enhancement to learner engagement, particularly for those who may require additional motivation. The use of game-like elements such as badges and leaderboards can transform the learning process into a more dynamic and appealing experience, which not only attracts but also retains learner attention and participation.

As mentioned before, LMS should be designed with a clear understanding of user needs and educational goals, preferences, and challenges, while providing an appealing and engaging user interface (Wan, Compeau and Haggerty, 2012). Thus, we can construct another principle, which is underpinned by another construct of intervention theory, "internal commitment", meeting the immediate educational needs of users and fostering a deeper sense of commitment, thereby enhancing the likelihood of successful educational outcomes. As a result, according to the design principle schema, the principle reads as follows: for LMS providers to enhance user acceptance and sustained interaction with the system of users across environments, implement user-centred design that includes aesthetics, functionality, and interactive features as it generates positive emotional responses, improves user perceptions and fosters a sense of internal commitment to educational goals.

> **QDP3.** *Integrated user experience design*: implement user-centred design that includes aesthetics, functionality, and interactive features

4.1.4 Quality Design Principle #4

Studies, such as those by Huang *et al.* (2021), elucidate the challenges of student engagement in digital learning environments, highlighting how the lack of deep interaction can lead to disengagement, procrastination, and eventual withdrawal from the learning process. This

indicates a need for LMS designs that actively involve learners and provide continuous feedback mechanisms, thereby maintaining user engagement and mitigating the risks of dropout.

Research also underscores the significant impact of autonomy on student learning and engagement. For instance, Nguyen *et al.* (2021) argue that learning systems like LMS should enable learners to exert control over their educational data and derived interventions, thereby fostering a sense of ownership and responsibility towards their learning processes. Matook *et al.* (2024) illustrate that autonomy not only grants students the right to make their own learning decisions but also empowers them to set personal learning goals and pursue knowledge independently, even in the face of challenges. This autonomous engagement is critical for developing metacognitive skills, which are fundamental for self-regulated learning. Supporting this, the work by Wan, Compeau and Haggerty (2012) suggests that interactive content that demands active engagement can further facilitate goal setting, planning, and self-evaluation among learners.

Research by Leung *et al.* (2023) accentuates the importance of supporting self-regulated learning through system features that enable goal-setting, self-assessment, and reflection. Such functionalities empower learners to tailor their educational journeys via customisable learning paths, as suggested by Wan, Compeau and Haggerty (2012), thereby fostering a more personalised and engaging learning experience. This customisation aligns with the basic users' learning goals and enhances their internal commitment by demonstrating the system's support for their educational objectives.

Based on the reviewed literature, we conceptualise another principle, which posits that providing learners with the ability to control their interaction with the system and customise it according to their preferences is crucial for enhancing engagement and learning productivity. This principle is grounded in intervention theory, particularly the constructs of "free and informed choice" and "internal commitment," which are vital in educational settings, where engagement is directly correlated with success. Piccoli *et al.* (2020) provide a practical application of this principle, detailing a system redesign that enhances learner autonomy by allowing students to dictate the pace and order of their assignment submissions. Such options are vital, as they cater to diverse learning preferences and needs, increasing educational efficacy and student satisfaction. As a result, according to the design principle schema, the principle reads as follows: for LMS providers to foster user engagement and autonomy of users across environments, implement customisable interface and content settings that allow for personalisation of their educational experiences as they promote learners' sense of ownership and active participation.

> **QDP4.** *User control and customisation*: implement customisable interface and content settings that allow for personalisation of their educational experiences

Table 4.1 below organises the relationship between quality design principles and the components of intervention theory, illustrating how each principle aligns with specific theoretical aspects to enhance learning management systems. QDP1 is marked across all three components, indicating its comprehensive approach to ensuring system reliability, performance, and security. QDP2a, QDP2b and QDP2c focus on providing valid and useful information, with QDP2a also supporting free and informed choice. QDP3 is linked solely to internal commitment, highlighting its role in creating engaging and aesthetically pleasing user

interfaces. QDP4 ties into free and informed choice and internal commitment, reflecting its focus on empowering learners to customise their educational experience according to their preferences and goals.

Table 4.1: Quality Design Principles basis on Intervention Theory Components

Quality Design Principles	Intervention Theory Components		
	Valid and useful information	*Free and informed choice*	*Internal commitment*
QDP1. Robust system design	**X**	**X**	**X**
QDP2a. Actionable information	**X**	**X**	
QDP2b. Impactful information delivery	**X**		
QDP2c. Interoperability	**X**		
QDP3. Integrated user experience design			**X**
QDP4. User control and customisation		**X**	**X**

4.2 Functional Design Principles

4.2.1 Functional Design Principle #1

A primary consideration in LMS design is usability and user acceptance (Maslov, Nikou and Hansen, 2021). Research by Mtebe (2020) highlights the prevalence of outdated and inconsistently presented instructional materials and an underutilisation of available system tools, emphasising the need for LMS interfaces that are both intuitive and conducive to exploration by users with varying degrees of technological proficiency. This is supported by findings from Maslov, Nikou and Hansen (2021), who argue for the importance of user-friendly designs and the consistent organisation of courses and content, supporting the diverse capabilities of administration, students, and professors, suggesting that systems should be straightforward to navigate and manage. The system should minimise complexity and offer a clean interface that enhances rather than complicates the user's ability to find and utilise educational resources.

According to Hoehle and Venkatesh (2015), the relevance of content and the effectiveness of search mechanisms are also important for user satisfaction. The system should allow for the organisation of course materials in a manner that is easily navigable and searchable, enabling users to quickly locate relevant materials. This approach not only supports the learning experience but also enhances the educational outcomes by making learning resources more accessible.

The capability of LMS to harness the rich multimedia potential of the Internet significantly enriches the learning environment (Lee, Cheung and Chen, 2005). Incorporating images, sounds, and videos should be a fundamental aspect of the LMS design, providing a dynamic and engaging learning experience. Multimedia elements can help illustrate complex concepts, cater to different learning styles, and increase student engagement and retention.

Collectively, these studies in conjunction with self-regulated learning components (organising and transforming, seeking information, environmental structuring, rehearsing and memorising, and reviewing) inform a comprehensive principle for LMS design that prioritises ease of use, and strategic organisation of content, all aimed at optimising educational outcomes and user satisfaction. As a result, according to the design principle schema, the principle reads as follows: for LMS providers to enhance user satisfaction with the system and educational outcomes of users across environments, implement intuitive interfaces and streamlined navigation and access as it promotes usability and intuitive exploration, cater to varied technological proficiencies.

> **FDP1.** *Course and content management*: implement intuitive interfaces and streamlined navigation and access

4.2.2 Functional Design Principle #2

Research has consistently shown that effective use of LMS features, such as discussion forums, collaborative tools, and real-time communication platforms, is essential in fostering an engaging and interactive educational environment (Wan, Compeau and Haggerty, 2012; Mtebe, 2020). Effective communication and collaboration in an LMS should prioritise the integration of tools that enable both synchronous and asynchronous interactions among students and between students and instructors. Synchronous tools, including real-time chats and video calls, facilitate immediate feedback and mimic the dynamic interactions typical of traditional classrooms, thereby enhancing the social presence and connectedness within the learning environment (Wan, Compeau and Haggerty, 2012; Söllner *et al.*, 2018). Asynchronous tools like forums, message boards, and collaborative workspaces allow learners to engage at their own pace, providing flexibility and time to reflect on discussions, which can lead to deeper learning (Hoehle and Venkatesh, 2015).

Moreover, the pervasive underutilisation of these collaborative features often results from a lack of awareness or insufficient training on how to effectively employ them. To combat this, LMS developers should not only ensure these tools are seamlessly integrated but also actively promote their use through appealing interfaces and visible prompts (Mtebe, 2020). Additionally, system-generated notifications and prompts can play a significant role in guiding learners to use these collaborative tools effectively. Such notifications might include reminders to participate in discussion forums or to engage with peer-generated content, thereby fostering a sense of community and collaborative learning (Wan, Compeau and Haggerty, 2012). These reminders can also encourage learners to review materials before assessments, set goals, monitor their progress, and evaluate their learning outcomes. Such features not only motivate students but also foster a structured and interactive learning environment that aligns with educational objectives.

Based on the reviewed literature and self-regulated learning tenets (seeking peer/instructor/ manager/IT-expert assistance, social interaction), we conceptualise another functional design principle. According to the design principle schema, the principle reads as follows: for LMS providers to enable communication and collaboration within the system for users across environments, develop synchronous and asynchronous communication tools as they mimic traditional classroom dynamics and enhance social presence, provide flexibility and encourage active participation and collaboration.

FDP2. *Communication and collaboration*: develop synchronous and asynchronous communication tools

4.2.3 Functional Design Principle #3

Research underscores the effectiveness of incorporating games, quizzes, and other creative assessment methods in addition to regular assignments to make learning more enjoyable and engaging (Lee, Cheung and Chen, 2005). These interactive elements can transform the learning experience by making it more dynamic and personalised. For example, Moodle's Quiz activity, while partially effective, lacks critical features such as adaptive difficulty levels and motivational elements. These are essential for mimicking the progressive challenge model seen in video games, where learners must demonstrate mastery at one level before advancing to the next (Hijon-Neira *et al.*, 2015). To address these shortcomings, Hijon-Neira *et al.* (2015) introduced an add-on to Moodle LMS, which includes motivational elements like personal teacher-avatars and competitive features. This system encourages learner engagement by fostering a sense of competition and providing personalised feedback, while tracking and evaluating each student's progress relative to their peers (Hijon-Neira *et al.*, 2015). This tailored approach not only motivates students but also helps educators identify areas where individuals might struggle.

Furthermore, the scalability and efficiency of feedback mechanisms are crucial, especially in large learning environments. Studies have shown that automated grading systems can dramatically increase the speed of grading by orders of magnitude while maintaining high accuracy (Piccoli *et al.*, 2020). Such systems allow for immediate and continuous feedback, enabling learners to retry tests or quizzes and receive instant evaluations. This approach ensures that learning is an ongoing process, where students can independently or collaboratively address their misunderstandings immediately after they occur.

This model of immediate, continuous feedback is vital. It ensures that each step of learning builds on the previous one, allowing students to correct misconceptions in real-time and solidify their understanding as they progress through the material (Lee, Cheung and Chen, 2005). Moreover, the accessibility of practice solutions and the specific focus of learner inquiries during open labs contribute to a more efficient and focused learning environment, where students arrive well-prepared to tackle precise issues.

Based on the reviewed literature and self-regulated learning components (self-evaluation, self-consequences, rehearsing and memorising, social comparison), we conceptualise third functional design principle. According to the design principle schema, the principle reads as follows: for LMS providers to enable optimal increase student motivation and educational outcomes of users across environments, develop interactive and adaptive assessments with real-time, personalised feedback as it mimics game features, increasing engagement and enabling immediate learning corrections.

FDP3. *Performance assessment and feedback*: develop interactive and adaptive assessments with real-time, personalised feedback

4.2.4 Functional Design Principle #4

Nguyen *et al.* (2021) emphasise the vast amounts of data generated in educational settings, highlighting the potential for these data to significantly impact educational practices if effectively captured and analysed. However, the collection and analysis of educational data remain underutilised in many institutions, suggesting a need for better data gathering and analysis mechanisms (Nguyen *et al.*, 2021). The study by Zhang (2017) emphasised the importance of integrating robust monitoring tools that allow for real-time adaptation to learner engagement and needs. Such tools not only support immediate feedback but also enable a deeper understanding of learning patterns, thereby facilitating continuous improvement in learning strategies and outcomes. Advanced analytics that tailor interventions to demographic and behavioural data can further refine the utility of LMS, as suggested by Leung *et al.* (2023) who observed varied responses to feedback based on learners' goal orientations.

Li, Wang and Wang (2021) demonstrated how peer information interventions integrated into LMS could reduce procrastination by leveraging social norms, showing that knowing the progress of peers can spur individuals to conform to or surpass the normative behaviours. Similarly, Huang *et al.* (2021) found that displaying the percentage of peers who have completed assignments can expedite assignment submission. However, they also noted that deadline reminders might sometimes increase procrastination, suggesting a more nuanced application of such features based on student profiles and course loads (Huang *et al.*, 2021).

Wan, Compeau and Haggerty (2012) further elucidated the benefits of incorporating self-regulated learning strategies into e-learning platforms, advocating for the addition of features like progress charts and automatic reminders that encourage learners to adopt self-regulated learning practices.

Effective use of data can transform an LMS from a simple content delivery platform into a dynamic educational tool that adapts to the needs of each learner. Thus, the systems should include features that enhance self-regulation, leverage social influences, and provide (near) real-time monitoring/analytics and interventions, all tailored to the individual needs and contexts of learners. This strategic use of data significantly enhances learning environments, thereby improving educational outcomes. As a result, according to the design principle schema and based on self-regulated learning components (self-evaluation, goal setting and planning, keeping records and monitoring, environmental structuring, social comparison), the principle reads as follows: for LMS providers to enhance personalised learning experiences and support informed decision-making for users across environments, implement data-driven features that monitor learner progress, support adaptive feedback and interventions based on individual behaviours and needs as it extends the user's decision-making and self-regulation capabilities.

> **FDP4.** *Reporting and analytics*: implement data-driven features that monitor learner progress, support adaptive feedback and interventions based on individual behaviours and needs

Table 4.2 below organises the relationship between functional design principles and the components of social cognitive theory, illustrating how each principle aligns with the specific theoretical aspects of self-regulated learning to enhance LMS.

Table 4.2: Functional Design Principles basis on Social Cognitive Theory Components

Functional Design Principles	Self-Regulated Learning Components														
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
FDP1. Course and content management		**X**		**X**		**X**		**X**	**X**						
FDP2. Communication and collaboration										**X**	**X**	**X**	**X**		**X**
FDP3. Performance assessment and feedback	**X**						**X**	**X**						**X**	
FDP4. Reporting and analytics	**X**		**X**		**X**	**X**								**X**	

(1) self-evaluation, (2) organising and transforming, (3) goal setting and planning, (4) seeking information, (5) keeping records and monitoring, (6) environmental structuring, (7) self-consequences, (8) rehearsing and memorising, (9) reviewing, (10) seeking peer assistance, (11) seeking instructor assistance, (12) seeking manager assistance, (13) seeking IT-expert assistance, (14) social comparison, (15) social interaction

5 Results: Development and Evaluation

5.1 Design and Development

In the design and developmental phase of our IT artefact (LMS prototype), we have placed emphasis on creating a user interface that is both intuitive and efficient, facilitating seamless interaction with the system, its components and other integrated systems. The prototype incorporates a coherent suite of pages, specifically designed to enhance navigability and accessibility. Such enhancements are anticipated to significantly foster educational outcomes and user satisfaction, a linkage underscored by recent scholarly research (Mtebe, 2020; Maslov, Nikou and Hansen, 2021).

Current subchapter illustrates the translation of the conceptual principles gathered in the previous chapter into tangible features within the prototype. It demonstrates the pervasive integration of Quality Design Principles across all functionalities of the system. That is why we elaborate on the representation of each Functional Design Principle while correlating it with the Quality Design Principles showcased in the prototype's functionalities.

5.1.1 Course and content management

The implementation of the first principle (FDP1) within our LMS prototype is represented through the prototype's structured and logical organisation of course pages and associated with them functions, facilitating intuitive navigation and straightforward access to course materials. The division of courses into "active" and "completed" categories, as demonstrated in Figure 5.1, allows users to effectively manage their learning paths by providing immediate visibility into their current engagements and past accomplishments. This categorisation aids efficient browsing and searching, aligning with the noted importance of relevant content organisation and effective search mechanisms (Hoehle and Venkatesh, 2015). Furthermore, the prototype further demonstrates a robust search across all contents (at the top) and filtering system that allows students to sort courses based on their status ("everything is alright" or "attention needed") and completion progress. This feature not only aids in personal time management but also aligns with the approach of minimising system complexity and enhancing the interface's intuitiveness. The option to view courses that require attention helps students prioritise their activities and address any potential issues proactively, supporting the need for a system that caters to varied technological proficiencies and learning styles.

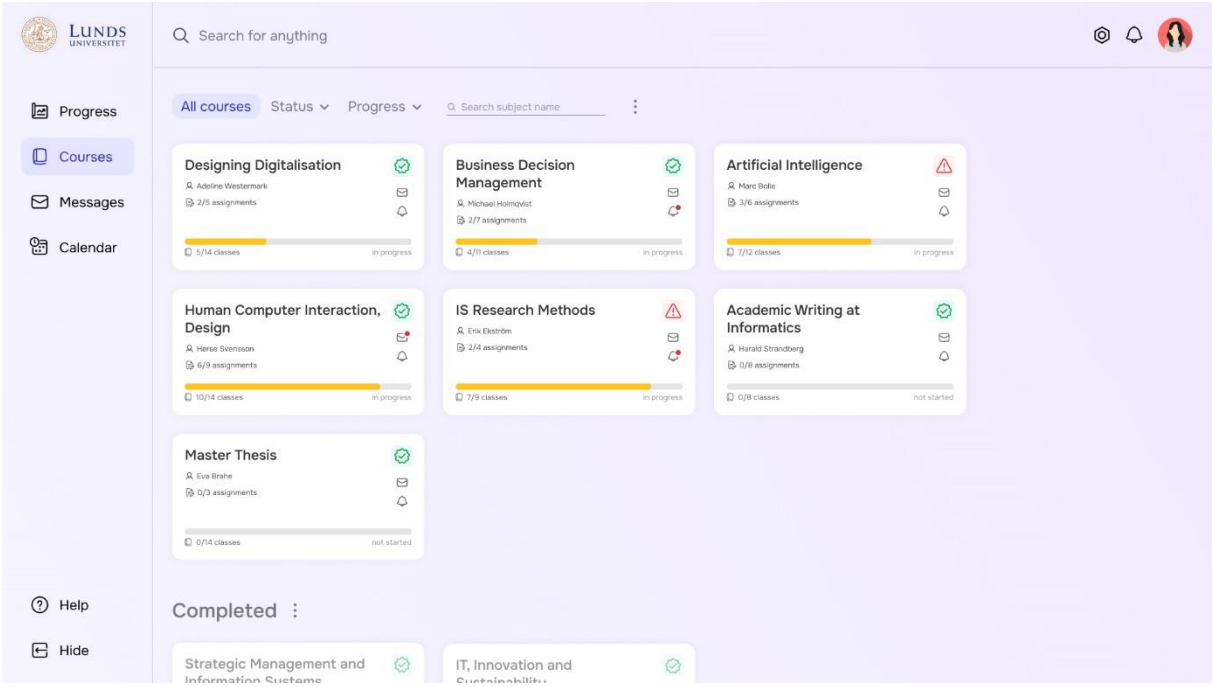

Figure 5.1: Module Courses: a list of courses

By clicking on one of the courses tile a user is redirected to the chosen course. The course content pages further illustrate the principle by presenting educational resources in a structured and accessible format. For instance, the home page (Figure 5.2) consolidates all lectures, materials, and important dates in a user-friendly layout that encourages engagement and reduces the cognitive load on students (Freire, Arezes and Campos, 2012).

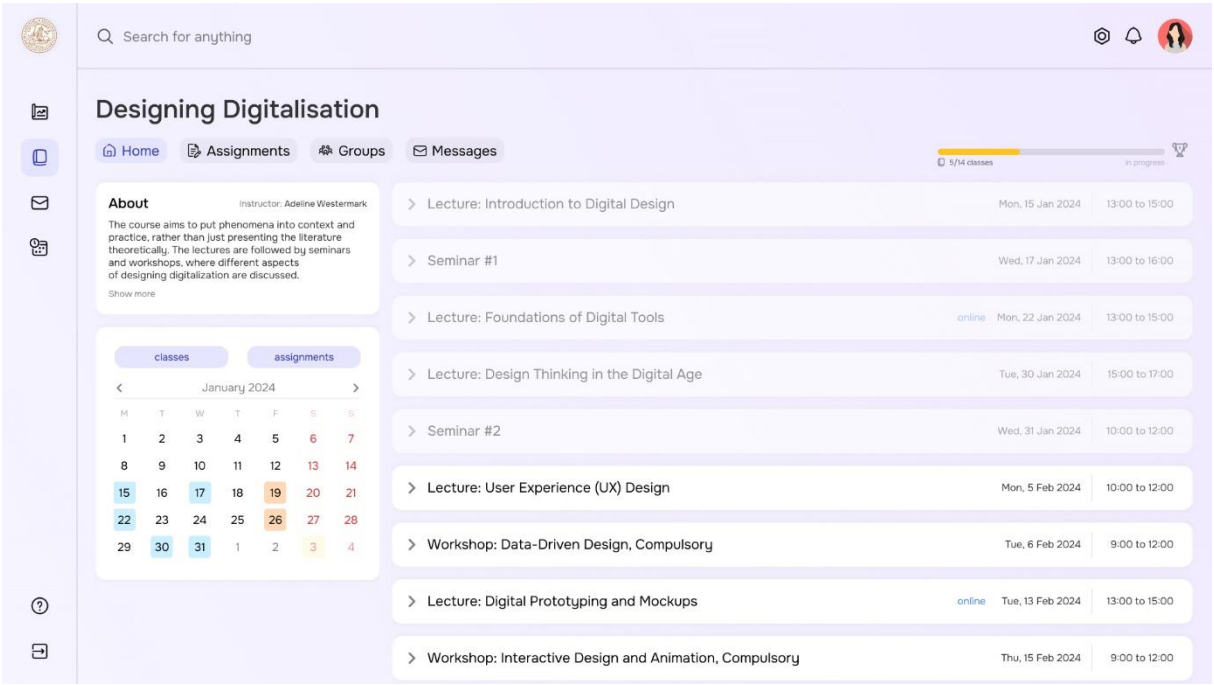

Figure 5.2: Module Courses: a course's home page

The calendar feature (Figure 5.3) exemplifies strategic content organisation by enabling users to view academic deadlines and events in monthly and weekly formats, which assists in their effective time management and ensures that students are well-prepared for their academic responsibilities.

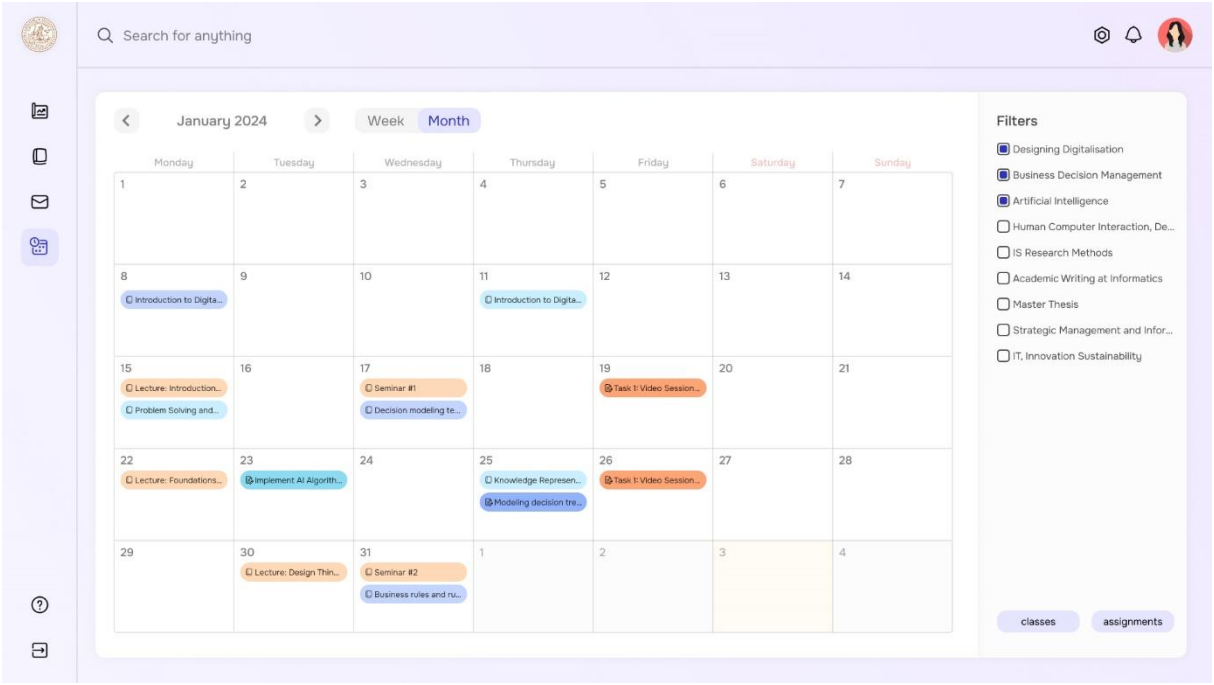

Figure 5.3: Module Calendar

Module Help is designed to offer immediate, easy-to-access support and guidance for users who may encounter difficulties or have questions about navigating the system or accessing course materials (Figure 5.4). By providing a centralised and straightforward way to seek assistance, the Help module ensures that all users, regardless of their technological proficiency, can effectively utilise the LMS features.

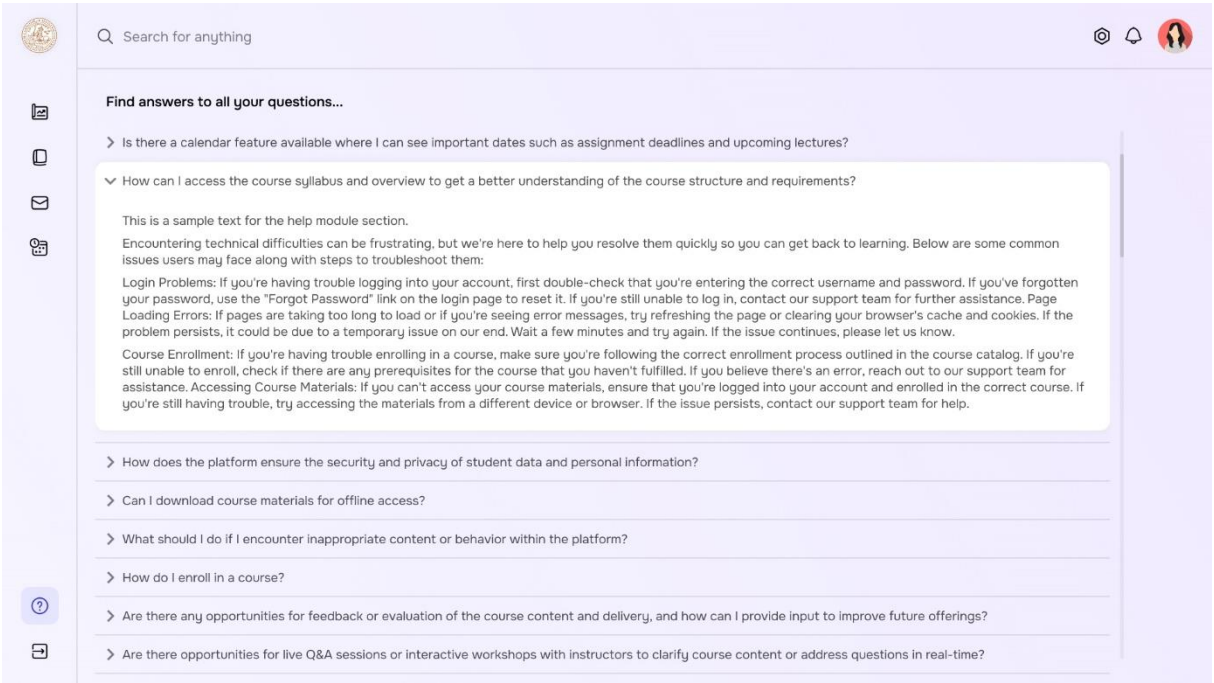

Figure 5.4: Module Help

Through the demonstration of the first principle's implementation in our LMS prototype, which prioritises proper course and content management, we see a seamless reflection of QDP2a (Actionable Information) and QDP2b (Impactful Information Delivery) principles. The prototype enables optimal educational outcomes and supports informed decision-making by

enabling the provision of actionable information through the system's logical and easy-to-navigate architecture that includes both structured categorisation and robust search functionalities but not limited to them. This tailored approach ensures that students can prioritise their studies effectively, directly influencing their behaviours and learning habits.

QDP2c (Interoperability) is evident in the integration of the calendar and course modules, which sync information about class schedules, deadlines, and online meeting links. Furthermore, seamless connectivity between different functionalities—like linking directly to video conference services for online classes—in course pages and calendar module ensures that students have a cohesive learning experience. Such integration reflects an accurate and holistic view of the students' educational commitments and activities, supporting better time management and preparation.

As evident from the presented figures, the prototype incorporates an integrated user experience design (QDP3) by combining aesthetics, functionality, and interactive features. The logical organisation of courses, intuitive navigation, and aesthetically pleasing interface designs generate positive emotional responses from users (Tractinsky *et al.*, 2006; Sheng and Joginapelly, 2012). The prototype also promotes user engagement and autonomy through its customisable interface and content settings (QDP4). Features that allow students to filter and sort courses based on their status and completion progress empower them to personalise their educational experiences while enhancing their sense of ownership and active participation autonomy (Nguyen *et al.*, 2021; Matook *et al.*, 2024). These elements improve user perceptions and foster a sense of internal commitment to their educational goals, enhancing overall user acceptance and sustained interaction with the system (Wan, Compeau and Haggerty, 2012).

5.1.2 Communication and collaboration

The prototype embodies this principle (FDP2) by integrating both synchronous and asynchronous communication tools. The course pages feature allows students to see the groups they belong to (Figure 5.5) and interact within these groups through dedicated group chats. This includes a group chat with the course instructor and specific chats for student sub-groups within the course (Figure 5.6), facilitating both peer-to-peer and student-instructor interactions.

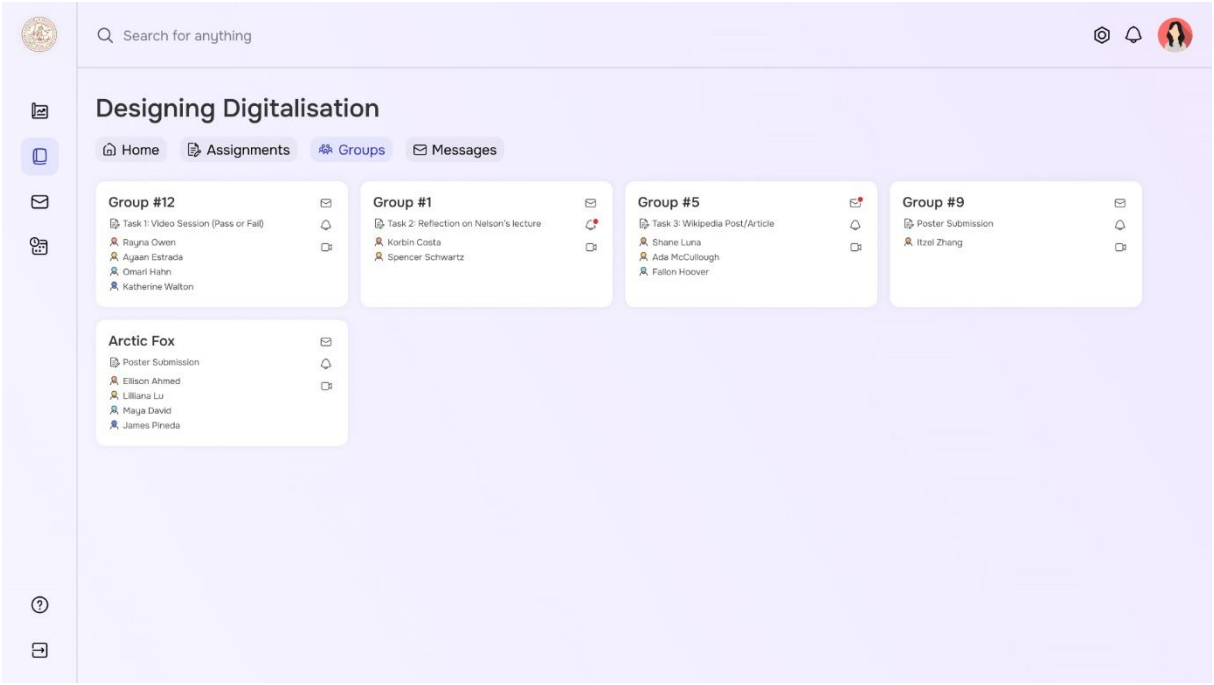

Figure 5.5: Module Courses: a list of groups a user is a part of in the current course

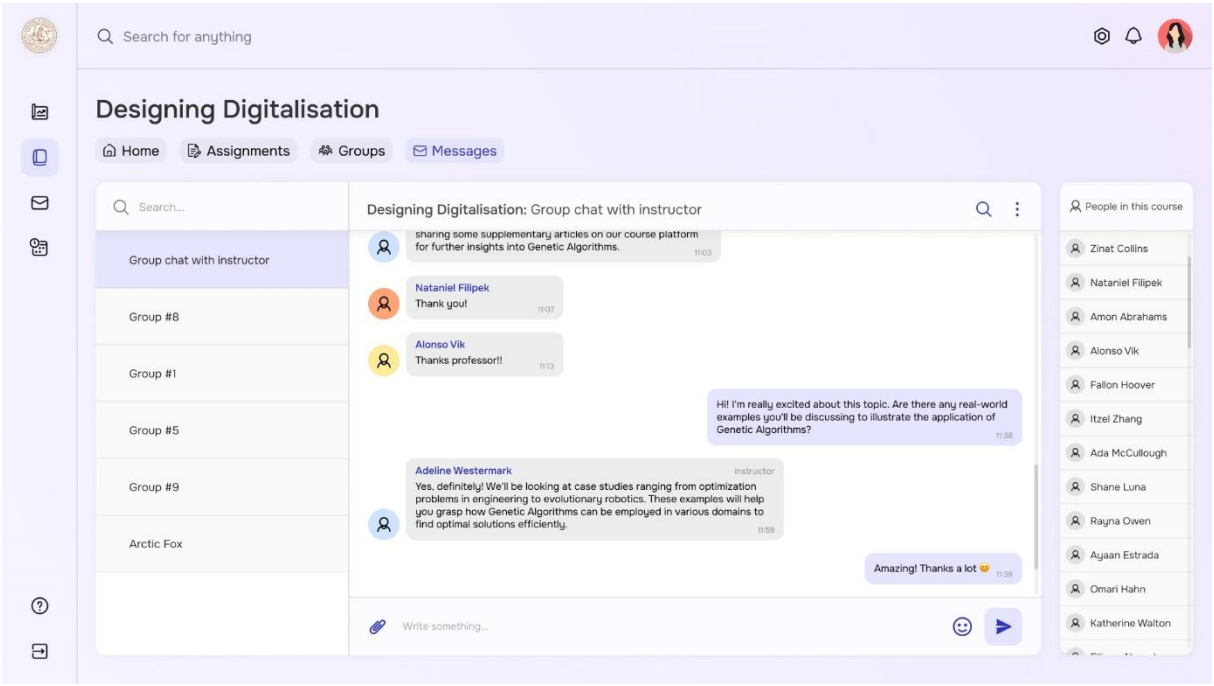

Figure 5.6: Module Courses: a course's messages page

The Module Messages further extends this functionality by enabling group chats that span across the entire programme, allowing for communication beyond individual courses (Figure 5.7). This module also supports custom group chats and private messaging, ensuring that students and instructors can engage in real-time, synchronous communication as well as asynchronous interactions. This dual approach of synchronous and asynchronous tools fosters a more engaging and interactive educational environment, as advocated by Wan, Compeau and Haggerty (2012), Hoehle and Venkatesh (2015), and Mtebe (2020). Additionally, the visible integration of these tools within the system, supported by user-friendly interfaces and prompts,

promotes their frequent use and addresses the common issue of underutilisation due to lack of awareness or training, thereby encouraging active participation and collaborative learning.

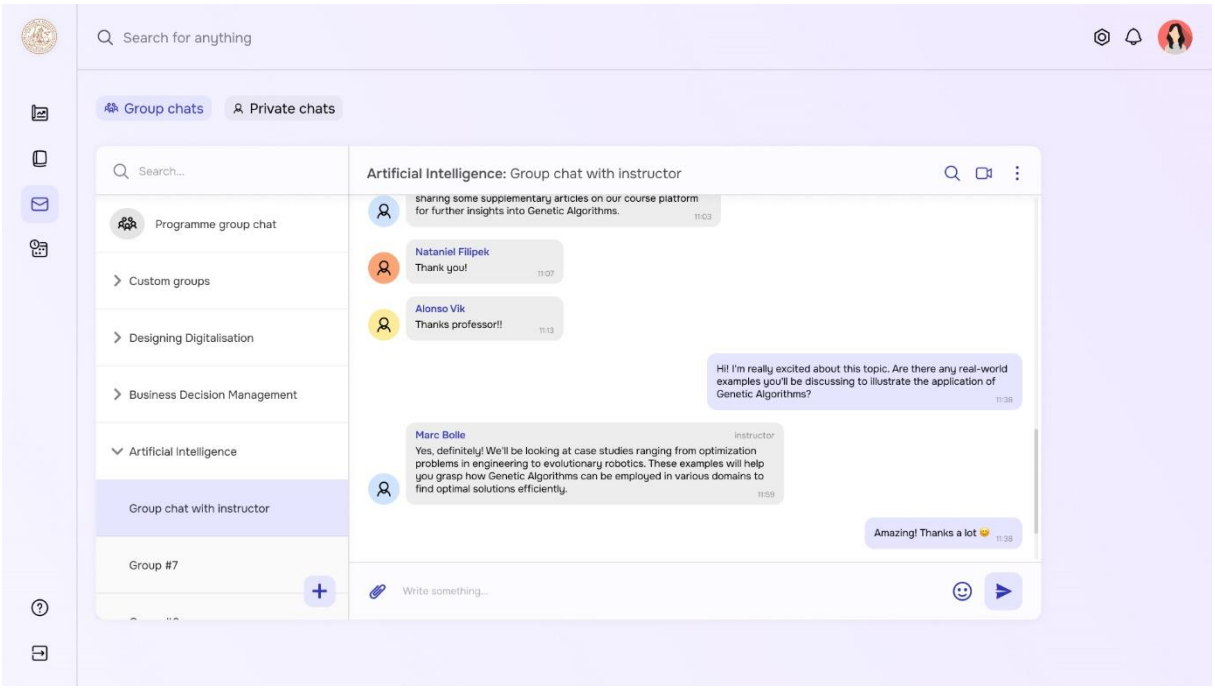

Figure 5.7: Module Messages

The discussed functional design principle of communication and collaboration within the LMS prototype aligns with and supports several key quality design principles, enhancing the overall educational experience. The integration of synchronous and asynchronous communication tools in the LMS allows for the delivery of valid, specific, and useful information to users (QDP2a). For instance, using the designed infrastructure group chats and course-specific messages provide real-time updates and context-specific information that extend users' decision-making capabilities. Coupled with these functions, the notification system ensure that students receive immediate feedback and guidance (QDP2b), facilitating better reflection on their learning processes and enabling timely adjustments to their educational strategies.

The integration of video chat tools (Figure 5.7, right upper corner of the messages window) within the messaging system ensures that users can easily connect and collaborate, reflecting a more accurate and dynamic picture of educational interactions.

Following the first functional design principle, FDP2 represents integrated user experience design in a similar way (QDP2c). However, the prototype supports user control and customisation through features like custom group chats and private messaging (QDP3). These options allow users to personalise their communication settings and interactions.

5.1.3 Performance assessment and feedback

The design principle (FDP3) of incorporating interactive and adaptive assessments with the possibility of strategically delayed or real-time, personalised feedback is effectively represented in the LMS prototype through its streamlined assignments page (Figure 5.8). This page consolidates access to tests, assignments, and their relevant materials, significantly enhancing the educational experience by reducing the time students spend searching for resources (Hoehle

and Venkatesh, 2015). Upon completion of an assignment, students can immediately access grades and feedback from their professor, enabling continuous reflection on their academic performance.

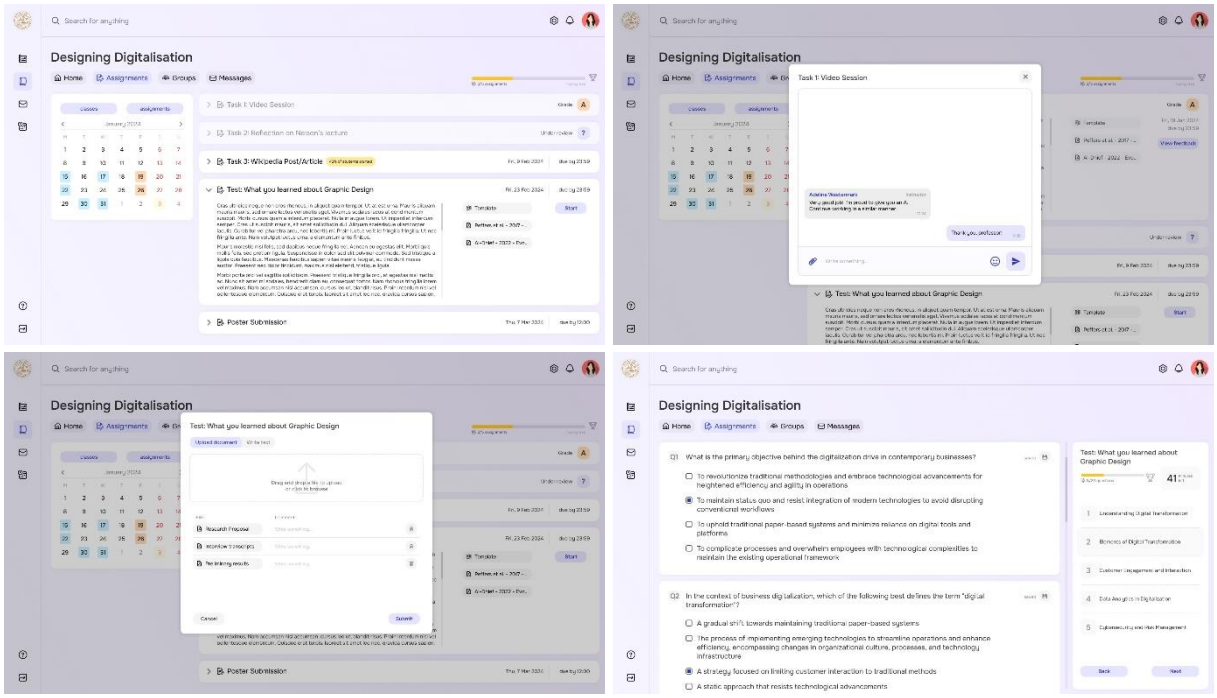

Figure 5.8: Module Courses: a course's assignments pages

In the upper left picture (Figure 5.8), the upcoming assignment displays peer information. This aligns with Huang *et al.*'s (2021) findings on the effectiveness of displaying peer completion percentages and deadlines to expedite submissions, albeit with a nuanced approach to avoid increasing procrastination.

While continuing to support QDP3 and QDP4 in the ways similar to described in the previous two subchapters, a course's assignments pages have distinct contributions to the quality design principles. For instance, the aggregation of materials and feedback in one accessible location ensures that students receive actionable information precisely when needed (QDP2a, QDP2b). This way students can easily see their progress and understand the areas where they need to focus, which leads to more effective study habits and improved academic performance (Dawson, Gašević and Siemens, 2015; Nguyen *et al.*, 2021).

5.1.4 Reporting and analytics

The prototype demonstrates the principle (FDP4) of leveraging data-driven features to enhance personalised learning experiences and support informed decision-making. The dashboard features a "Courses progress" that along with adjacent sections below visually represents the user's progress across enrolled courses (Figure 5.9), aligning with Nguyen *et al.*'s (2021) emphasis on capturing and analysing educational data. This section not only indicates overall progress but also breaks it down into completed, in-progress, and upcoming courses, facilitating real-time monitoring and adaptation as advocated by Zhang (2017). The inclusion of progress charts and performance analytics, particularly in the single course quick overview (left-bottom tile), exemplifies the principle of adaptive feedback and interventions tailored to individual behaviours and needs, enhancing learners' self-regulation and decision-making capabilities.

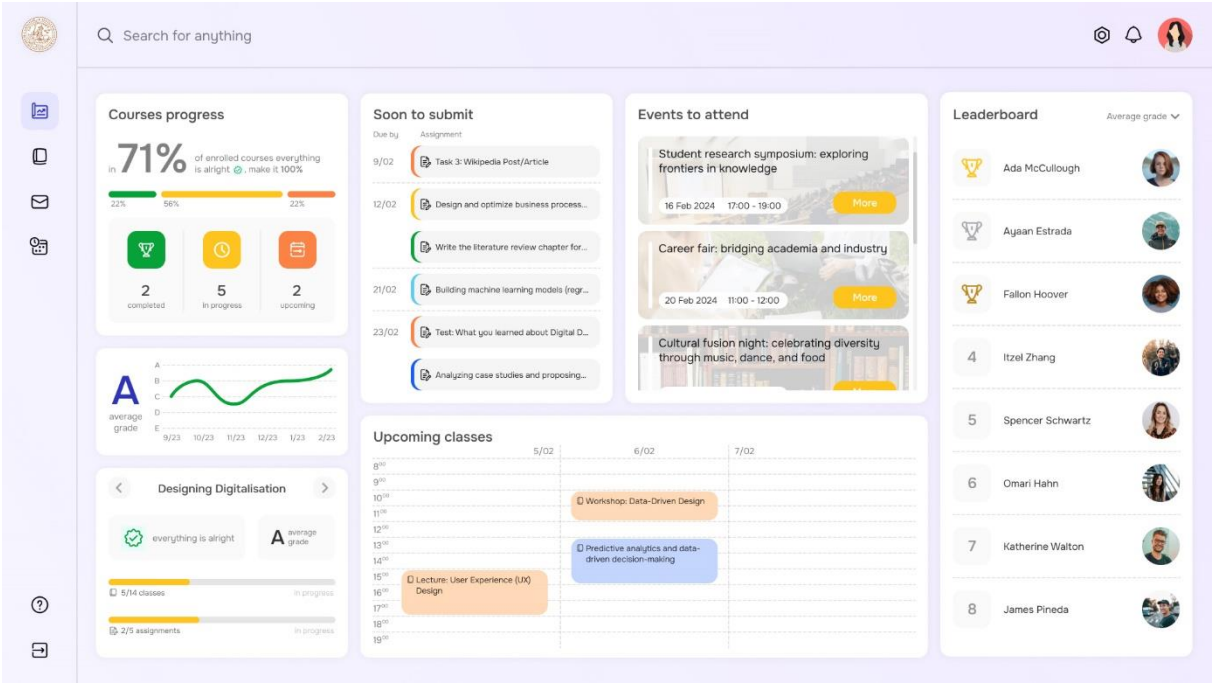

Figure 5.9: Module Progress

The "Soon to submit" and "Upcoming classes" sections list upcoming assignment deadlines and classes keeping users constantly informed on what to expect, while the "Events to attend" section offers ads and reminders for educational events. Moreover, the integration of a leaderboard displaying peers' average grades further leverages social influences, as demonstrated by Li, Wang and Wang (2021), promoting competitive yet collaborative learning environments.

The LMS prototype most vividly exemplifies the information related quality design principles through its adaptive and integrated design, which delivers actionable, impactful, and interoperable information to enhance educational outcomes and decision-making. The "Courses progress" and "Soon to submit" sections provide key and specific information tailored to individual user needs, enabling students to make informed decisions about their study schedules and priorities (QDP2a). The system's real-time updates and comprehensive formats, such as detailed progress charts and on-demand availability, allow learners to reflect on their performance and adjust their educational strategies effectively (QDP2b). All this enabled by the prototype's ability to integrate various data sources into a cohesive dashboard, which reflects strong interoperability, offering a holistic view of the student's learning environment and supporting a deeper understanding of student profiles and learning processes across different contexts (QDP2c).

The prototype incorporates QDP3 and QDP4 to enhance user acceptance and engagement. The intuitive and visually appealing interface as discussed before seamlessly integrates aesthetics, functionality, and interactive features. At the same time, greater highlighted customisation options presented in progress module, allowing users to personalise their dashboard by focusing on the most relevant information, such as specific courses, deadlines, and progress metrics. Together, these principles ensure a cohesive and adaptive educational environment that supports sustained interaction and effective learning.

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It is important to mention that it is difficult to fully represent the Robust System Design principle (QDP1) in our LMS prototype because it is only a prototype and not a full system. Therefore, it does not reflect the qualities of a final product described in QDP1, such as availability, scalability, performance, reliability, and maintainability, due to its platform and architecture limitations. However, we still evaluated this principle through a number of interview questions, which we thoroughly describe in the next chapter.

5.2 Demonstration and Evaluation

During this stage of our research, we conducted 10 in-depth interviews with students. Each interview lasted just under one hour. The metadata for the interviews is provided in the Table 5.1 below.

Table 5.1: Interviews metadata

Interview N.	Date	Duration (mins)	LMS used before
Interview 1	10.05	55	Canvas, IBM Training Digital Learning Platform (DLP)
Interview 2	10.05	46	Canvas
Interview 3	11.05	45	Canvas
Interview 4	11.05	51	Canvas
Interview 5	11.05	45	Canvas
Interview 6	12.05	48	Canvas
Interview 7	12.05	57	Canvas, Moodle
Interview 8	12.05	55	Canvas
Interview 9	13.05	47	Canvas
Interview 10	13.05	44	Canvas, Blackboard

The analysis of the participants' input provided extensive insights into the users' perception of the conceptualised design principles, particularly focusing on the robustness of the system design. This detailed examination revealed how crucial a modern, intuitive design, reliable system performance, and adequate privacy and security measures are to the overall user experience. In the following subsections, we delve into the key recurrent themes associated with the principle of robust system design, highlighting its significant impact on user satisfaction and learning effectiveness.

5.2.1 QDP1. Robust system design

Interviewees consistently emphasised the importance of robust system design. **System reliability was a significant concern**, with users recalling negative experiences with Canvas, which unfortunately have negatively impacted their learning experiences.

> *"There were times when the system would be very slow to load, especially during peak times like right before assignment deadlines. This made it really*

> *frustrating to access materials and submit work not on time. It definitely affected my learning experience negatively, as I had to plan extra time just to deal with the slow system." – Int. 6.*

Regarding privacy and security, in contrast to the previous research (Duin and Tham, 2020) users generally express **confidence in their LMS's ability to protect their personal information**. They appreciate that the LMS does not request sensitive information beyond what is necessary for educational purposes, which reinforces their trust in the system's privacy measures and contributes to their overall sense of security while using the platform.

> *"I'm not too concerned about that since each student has their own credentials. It doesn't require any financial details. It just has the details we will give to the university such as the courses." – Int. 4.*

5.2.2 QDP2a. Actionable information

From the interviewees' input, it is evident that **information clarity** is a significant factor contributing to user satisfaction with the LMS. Users consistently highlight the clear presentation of assignments, deadlines, and progress as instrumental in helping them stay organised and aware of their responsibilities. This clarity is particularly enhanced by the LMS's **dashboard** and Progress tab, which provide a comprehensive overview of tasks, deadlines, and performance, and are highly valued by users for their utility in managing academic workload.

> *"The Progress tab is very helpful. It gives a clear overview of what I've completed and what's still pending. This helps me prioritise my tasks and focus on areas that need more attention." – Int. 6.*

> *"The dashboard combined with the calendar is super cool." – Int. 1.*

Well-designed **notification systems** play a crucial role in managing assignments and schedules. Users appreciate the ability to customise notifications, allowing them to receive timely alerts for upcoming deadlines and new grades, thereby enhancing their ability to stay on top of their academic responsibilities.

> *"I also like that I can set my preferences for notifications. Getting alerts for deadlines or new grades is very useful. In Canvas, these options are more limited, so this feels like a big upgrade." – Int. 6.*

5.2.3 QDP2b. Impactful information delivery

The interviews reveal a consistent appreciation for well-designed information delivery, particularly **interactive features that track progress**, which help users stay organised and motivated. One user emphasised the effectiveness of the courses tab, stating:

> *"One element that particularly caught my attention is the courses tab. It shows how many classes are completed or pending, similar to Ladok, but in a good way. You can interact and see your progress easily." – Int. 3.*

The interviews reveal that dashboards serve as an essential tool for users in staying organised and motivated, which adds to the necessity of well-design information delivery. A majority of users appreciate dashboards that provide a comprehensive overview of their progress. They

highlight the importance of **clear indicators** for task completion and pending assignments, which are crucial for efficiently prioritising their workload.

> *"I like the progress tab because it provides an overview similar to a data sheet, summarising all the website's information. It's really cool." – Int. 1.*

5.2.4 QDP2c. Interoperability

Interoperability features were highly valued by the participants, who appreciated the ability to integrate the LMS with other tools and systems. In addition to the showcased integration, many interviewees highlighted the importance of **integrating the LMS with platforms like Google Calendar, Google Drive and even WhatsApp** to streamline their academic schedules and communication. One participant noted,

> *"It would be really helpful if it could integrate with Google Calendar. Syncing my class schedules and assignment deadlines automatically would be a huge time-saver" – Int. 6.*

> *"It would be easier if I could access WhatsApp or Zoom directly from the messages. For instance, being able to access my Google Calendar from the calendar section would make life easier for everyone" – Int. 1.*

Additionally, users suggested that **integrating external resources like library systems and plagiarism checkers** would further benefit their work processes by providing easy access to necessary research materials and ensuring the integrity of their work

> *"I've always thought it would be nice to have the Ladok system and the library's LubSearch integrated into the learning platform. Currently, they are separate UIs, but if they were included in this platform, it would also help in showing the availability of articles and books that we need. Integrating these features would be really beneficial because finding articles and then having to go to Lund Library to check if a book is available or taken by someone else can be cumbersome." – Int. 2.*

> *"…it would be great if a plagiarism tracker could be integrated into this system to check the percentage before we submit the assignments" – Int. 4.*

These integrations are perceived as essential enhancements that could significantly improve user productivity and satisfaction by reducing the need to switch between multiple platforms and allowing for a more cohesive and streamlined digital environment.

5.2.5 QDP3. Integrated User Experience Design

The design and layout of the prototype were highly praised for having **modern, intuitive, and engaging design**. Participants consistently expressed a preference for a clean and uncluttered UI, highlighting that **ease of navigation is at most importance**. They noted that interfaces requiring minimal clicking and providing easy access to information contribute to a more efficient and pleasant user experience. This design approach minimises frustration and maximises productivity, making the LMS a more effective tool for learning.

> *"The overall impression is quite impressive. The UI is very eye-catching and fits the vibe well. It doesn't seem outdated, so I'd say it catches up to 2024, which is good." – Int. 3.*

> *"When I compare it to the existing app called Canvas, I think this is better. I can understand the UI much better because when I'm using Canvas, it's like I have to search for the notification tab to access certain assignments. It was kind of difficult when I first joined the university, because some professors just put the assignments into the discussion or assignment tab. It was very difficult to find out where the particular tab was. But this system is very intuitive." – Int. 2.*

The interviewees also show a strong consensus that the **overall design of an LMS significantly influences their motivation and effectiveness in learning**. Users emphasised that when the design is aesthetically pleasing and user-friendly, they are more likely to interact with the platform regularly. The integrated user experience design was seen as a significant improvement over previous LMS platforms, contributing to a more engaging and effective learning environment. The design's ability to **reduce cognitive load** by presenting information clearly and logically was highlighted as a key factor in improving learning outcomes.

> *"Definitely, the design has a big impact on my motivation. When the interface is clean and modern, it makes me more inclined to engage with it regularly." – Int. 6.*

> *"…if the design is not good, it might affect my learning effectiveness in some ways. If I'm not able to find something, like my reading articles, it might delay my learning process." – Int. 2.*

> *"It makes you want to log in to the system and actually do some work rather than using a system like Canvas. Both of them get the job done, but this has more features and is easy to use." – Int. 4.*

5.2.6 QDP4. User Control and Customisation

Interviewees generally found the customisation features of the LMS prototype limited and expressed a need for more options. They noted the effectiveness of existing customisation options, like filtering in the calendar and messages, but highlighted the absence of more **advanced customisation features** that could enhance user experience, such as detailed filtering capabilities and customisable ribbons.

> *"The customisation options are somewhat limited. I could change some visual themes and set up my notification preferences, but there isn't much beyond that. More options for personalising the layout would be beneficial." – Int. 9.*

Interviewees pointed out that the prototype allowed for some visual preferences, but suggested a **need for more layout customisation** to better cater to individual preferences. The importance of robust customisation was emphasised by an interviewee who rated it as "very important," especially for international students who rely heavily on a user-friendly interface to navigate their new educational environment.

> *"…having the option to create a very nice UI for a learning experience is crucial, and I would rate its* [customisation] *importance as a five. When you come to a university that offers an international experience, you rely heavily on such apps for everything." – Int. 2.*

5.2.7 FDP1. Course and Content Management

The **ease of navigating** the Courses tab was a recurring theme. Participants described the navigation as "very easy" and appreciated the use of tiles. The clear organisation and minimal need for extensive clicks were particularly valued and compared to the current solutions.

> *"It's very easy to see, you can just go and get the lectures, slides, reading material, course syllabus. This is very organised compared to, like, the current LMS we have." – Int. 1.*

> *"The courses tab is well-organised, and the use of tiles makes it visually clear where everything is. Compared to Canvas, where I often had to dig through menus, this is a breath of fresh air." – Int. 6.*

However, some areas for improvement were identified. For instance, the need for **clear colour coding in the calendar** and the suggestion for a descriptive guide for colour meanings were mentioned.

> *"…maybe the colour coding could be like, improved, or there is like a description for the colour coding other than that, it's nice." – Int. 1.*

> *"…the meaning of these colours isn't immediately clear. If you could indicate that blue is for classes and orange is for assignments, it would make things much easier." – Int. 5.*

The interviews also underscore the importance of a **well-designed mobile application** for accessing course content on the go, reflecting a broader trend towards mobile accessibility in educational technologies.

> *"If this also has a good mobile application, it will be amazing." – Int. 1.*

5.2.8 FDP2. Communication and Collaboration

The prototype's capacity to facilitate active participation and collaboration was evident in the positive feedback regarding **group management** features. Users found it beneficial to see group members and assigned tasks clearly displayed, which supports efficient collaboration and task management. However, there were suggestions for minor enhancements, such as displaying group limits and clearer labels for group discussions.

> *"The UI for managing groups is really neat. It shows the group members, tasks assigned to them, and everything else. However, I have a suggestion. It would be helpful to have a group limit displayed…" – Int. 2*

The prototype's **synchronous and asynchronous communication tools** were well-received. Interviewees appreciated the flexibility provided by these communication tools, which cater to different user needs and preferences. The **integrated messaging system**, which includes both

individual and group chat options, was described as easy to use and similar to familiar platforms like WhatsApp, enhancing user comfort and adoption. The inclusion of video chat features directly within the LMS was also noted as a significant advantage, as it reduces the need for external tools, thereby streamlining communication and cohesive learning environment.

Interviewees highlighted the **convenience of the messages tab within course pages**, stating that it helps maintain focus and clarity during group projects. More than that, one of them indicated that it avoids the confusion often experienced with external messaging apps like WhatsApp, where different groups can overlap across various courses.

> *"To me, I think, yeah, having a messages tab in the courses section is kind of useful. Like this is for only this particular course, right? Because we have so many different groups. You know, my WhatsApp is filled with a lot of groups." – Int. 2*

5.2.9 FDP3. Performance Assessment and Feedback

The interviewees found the performance assessment and feedback functionalities clear and accessible. The visibility of deadlines, the ease of submitting assignments, and accessing instructor feedback were all positively reviewed. The overall process of submitting assignments and taking tests is perceived as straightforward and user-friendly. Participants consistently appreciated the **intuitive design** features, such as the **drag-and-drop functionality** for assignment submission and the clearly marked start buttons for tests, which facilitate a seamless user experience. This ease of use is a significant factor in user satisfaction, as it minimises the potential for technical difficulties and confusion during critical academic tasks.

> *"…the assignment submission process was straightforward. You just had to click on the upload file and then submit. As for the tests, they were multiple choice and also straightforward. You would choose your answers and then click on submit." – Int. 7.*

> *"For submitting assignments, I can upload files and write text directly in the submission area. There's a toggle option available too, which is really good." – Int. 2.*

Instructor feedback is found to be easily accessible and beneficial for user further actions. Feedback is clearly displayed, allowing users to understand areas needing enhancement. However, there is a strong suggestion for incorporating more **interactive feedback methods**, such as video comments, which could provide a richer and more engaging feedback experience.

> *"One click away, it's colour coded. So it's easy to see. And I like that it's a shot. So it's not a message. It's not an email. It's informal. I like it." – Int. 1.*

> *"Yes, the feedback is detailed and provides good guidance on areas of improvement. However, it would be great to have more interactive feedback options, like video comments from instructors." – Int.8.*

> *"The functionality is good, but it could be improved with more detailed feedback options, like annotated comments or audio feedback from instructors." – Int. 10.*

5.2.10 FDP4. Reporting and Analytics

The progress tab, one of the most popular features among the interviewees, is particularly appreciated for its ability to **provide a comprehensive overview of learner progress**. Interviewees find this feature highly beneficial for understanding their progress and areas needing attention, with one user stating it feels like a summary of the entire website, indicating its integral role in extending users' decision-making and self-regulation capabilities. The inclusion of a "soon to submit" section and clear deadline visibility are noted as critical in preventing users from missing important dates, thus supporting timely interventions based on individual needs.

> *"I really, really, really like, actually, it feels like a summary of the whole website. So it's like a dashboard." – Int. 1.*
>
> *"The information is very relevant and helpful. It provides a clear overview of my progress and highlights areas where I need to improve." – Int. 8.*
>
> *"The deadlines are very visible, which I appreciate. They're highlighted at the top of the assignments page, so there's no way to miss them." – Int. 6.*
>
> *"The soon to submit would make me like the plan better. So it would affect my planning and things are easy to start." – Int. 1.*

The **leaderboard**, however, **received mixed feedback**. While it can foster a competitive yet motivating environment and some users find this motivational, others feel it can be stressful or even detrimental, indicating the need for customisable options to cater to diverse preferences.

> *"The leaderboard is a good addition. Like I said earlier, a little friendly competition is good for everyone. It makes learning more exciting." – Int. 4.*
>
> *"The leaderboard is important to me. It definitely influences my study habits as I strive to improve my ranking and perform better." – Int. 9.*
>
> *"It's somewhat important to me. Being competitive, I like to see where I stand. It definitely influences my study habits because I aim to be near the top, but I can see how it might stress some people out." – Int. 6.*
>
> *"I would compare myself to others and get depressed. So no..." – Int. 1.*

***

To sum up, the analysis highlights the importance of a modern, intuitive design in enhancing user motivation and learning effectiveness within an LMS. Key aspects such as system reliability, clear and actionable information, and seamless integration with external tools are crucial for a positive user experience. Users greatly value customisation options and robust communication and collaboration features, which facilitate group work and interaction. Efficient course management and navigation, alongside streamlined assessment processes and clear feedback, contribute significantly to learning efficiency. Comprehensive progress tracking and analytics tools help users stay organised and motivated. The interviews also revealed areas for improvement, including the need for more detailed feedback options, and enhanced customisation capabilities. Thus, these insights underscore the necessity for an LMS to be user-centric, reliable, and integrative, ensuring it meets the diverse needs of its users.

5.3 Formalisation: Revision of Design Principles

Based on the results of the evaluation, we have made several key revisions to our design principles to better align with user needs and expectations. Firstly, we rephrased some difficult-to-understand phrases. For instance, for actionable information principle (QDP2a), we have emphasised the necessity of delivering *clear, valid, and user-specific information*, moving away from the broader "useful for the user" to ensure precision and clarity in the provided information. This change addresses feedback on the need for more straightforward and relevant information that users can easily understand and apply. For integrated user experience design (QDP3), we advised to prioritise aesthetics, functionality, and interactive features and not just include to ensure a more engaging and visually appealing interface, reflecting user feedback on the importance of a visually pleasing and easy-to-navigate platform. We also recommended to enhance user control and customisation (QDP4) by implementing *extensive* customisation options. This change was driven by user demand for more control over their educational experiences to better match their personal learning styles and preferences. For interoperability (QDP2c), we expanded the scope to include seamless data flow not just within our system and with online communication tools but also with other diverse institution's and third-party platforms.

In the area of functional design principles, there are also a few changes. For course and content management (FDP1), we now include interaction with the content as a part of the streamlined navigation and access. This revision ensures that users can engage more directly and intuitively with the course material, enhancing their learning experience. In performance assessment and feedback (FDP3), we have introduced the possibility of delayed feedback in addition to real-time feedback, providing flexibility to cater to different assessment needs and timing preferences, as highlighted by the users.

These revisions are implemented into final design principles represented in the Table 5.2 (see full version in Appendix B. Final Design Principles). Collectively these principles aim to create a more user-centric, integrated, and flexible educational platform that better meets the diverse needs of users, as evidenced by our evaluation findings.

Table 5.2: Overview of Revised Design Principles

DP N.	Design Principle	Specification
QDP1	Robust system design	develop strategies and technologies that enhance availability, scalability, performance, reliability, privacy, security, and maintainability
QDP2a	Actionable information	develop adaptive technologies that deliver clear, valid, and user-specific information
QDP2b	Impactful information delivery	develop technologies for providing information and feedback on demand and in a comprehensive form and format
QDP2c	Interoperability	develop data integration and interoperability mechanisms ensuring seamless data flow across the

		institution's and third-party platforms *and* the system, and within the system's various modules
QDP3	Integrated user experience design	implement user-centred design that prioritises aesthetics, functionality, and interactive features
QDP4	User control and customisation	implement extensive customisation options for both the interface and content settings
FDP1	Course and content management	implement intuitive interfaces, streamlined navigation, access and interaction with the content
FDP2	Communication and collaboration	develop synchronous and asynchronous communication tools
FDP3	Performance assessment and feedback	develop interactive and adaptive assessment options with the possibility of delayed and real-time personalised feedback
FDP4	Reporting and analytics	implement data-driven features that monitor learner progress, support adaptive feedback and interventions based on individual behaviours and needs

6 Discussion

In this chapter, we summarise the performed work and discuss our contributions in the relation to the literature on LMS and educational IS described in the chapters "Literature Review" and "Conceptualisation of Design Principles". We also provide explicit description of how our research contributes to the body of knowledge within IS field and beyond, as well as practice.

Despite the extensive adoption and advanced features of LMS, numerous studies have highlighted significant usability and functional shortcomings that impede user experience and learning outcomes (e.g., Kakasevski *et al.*, 2008; Freire, Arezes and Campos, 2012; Duin and Tham, 2020; Mtebe, 2020). These issues, such as confusing content layout, inconsistent interface designs, and limited interaction capabilities, hinder the full potential of LMS to support educational practices (Freire, Arezes and Campos, 2012). By responding to these challenges, our research aimed to develop a set of actionable design principles tailored specifically for LMS for enhancing their functionality, usability, and overall quality. Thus, through this research, we have proposed a comprehensive solution for the development of a system that addresses technological and pedagogical needs within higher education settings.

Through an iterative and structured design science research approach, we have gone through four steps: problem formulation, formulation of design principles, design and development of a prototype, and its demonstration and evaluation (Peffers *et al.*, 2007). We identified gaps in existing learning management systems through an analysis of academic literature and industry insights, highlighting the need for improved educational support features. To address these shortcomings, we developed design principles based on extensive scientific literature review. We then created a medium-fidelity LMS prototype using Figma's prototyping functionalities, ensuring the design aligned with theoretical knowledge and practical needs. The prototype underwent real-world demonstrations and user evaluations, leading to refinements of the prototype and revision of the design principles based on empirical evidence and user feedback.

While developing the prototype, we focused on creating an intuitive and efficient user interface. Key features included structured course and content management, robust communication tools, interactive performance assessments, and comprehensive reporting and analytics. Each feature was designed to enhance navigability, accessibility, and user satisfaction, supported by scholarly research and subsequently feedback from users. The design principles were effectively translated into the prototype's functionalities, ensuring a coherent and user-friendly experience and the possibility to assess them.

We conducted 10 in-depth observations and semi-structured interviews with students to gather feedback on the LMS prototype. The evaluation participants provided extensive insights into the workability of the design principles implemented in the LMS prototype. They consistently emphasised the importance of robust system design, clear and actionable information, seamless interoperability, user-centred design, and extensive customisation options. Their feedback underscored the need for ongoing enhancements to ensure that LMS platforms not only meet but exceed user expectations, ultimately leading to improved educational outcomes and user satisfaction.

Based on this feedback, we adjusted the prototype and revised our design principles to better align with user needs. Changes included minor wording adjustments and advising on enhancements of customisation options. We also expanded the scope of interoperability to include seamless data integration with an extended range of platforms. These revisions aim to

create a set of design principles that strive for a more user-centric, integrated, and flexible educational platform (see full list of principles in Table 5.2).

6.1 Relating the Results to the Literature

As previously stated, the design principles and the prototype we developed are firmly rooted in the extensive literature on educational IS and LMS within information systems field and beyond. The alignment between our design choices and existing research ensures that our prototype both adopts well-documented best practices and addresses common LMS's gaps identified in prior studies.

6.1.1 Quality design principles

Robust system design is critical for ensuring consistent availability, scalability, and reliability, which are essential for LMS (QDP1). Literature emphasises the necessity of a dependable LMS, especially during peak usage times like submission of assignments/tests. For instance, Nguyen *et al.* (2021) and Baskerville, Kaul and Storey (2017) highlight the importance of maintaining service continuity to prevent disruptions in educational activities. These studies suggest that service interruptions can significantly hinder educational processes, making reliability a key concern. Our design principle of robust system design incorporates strategies to mitigate downtime, enhance error management, and ensure data privacy and security, aligning with the insights from Ifenthaler, Gibson and Dobozy (2018) who emphasise the importance of continuous accessibility. The evaluation participants echoed this need, expressing frustration with previous systems like Canvas that suffered from slow loading times and technical issues. They appreciated the focus on reliability and privacy, noting that a secure and consistently operational LMS would significantly enhance their learning experience.

The principles of providing actionable information in an impactful way aim to enhance the clarity and relevance of the data delivered to users (QDP2a, QDP2b). Studies by Dawson, Gašević and Siemens (2015) and Nguyen *et al.* (2021) stress the importance of timely, specific feedback for productive learning. Dawson, Gašević and Siemens (2015) particularly emphasise the role of learning analytics in delivering actionable insights that can inform instructional strategies. Our prototype's design integrates clear dashboards and progress tabs that consolidate assignments, deadlines, and performance metrics, which participants found particularly useful for staying organised and managing their workload. The ability to customise visuals and interventions was also highly valued, allowing users to receive timely alerts for important updates, thus enhancing their ability to stay on top of academic responsibilities.

Ensuring seamless data flow across various platforms and modules is essential for a cohesive learning experience (QDP2c). Chatti *et al.* (2014) and Siemens (2013) underscore the importance of integrating disparate data systems to reflect an accurate picture of learners' progress. Siemens (2013) emphasises the role of continuous data integration in supporting personalised learning experiences. Our LMS prototype's integration features, such as interconnection of modules and integration with online conference platforms and other external tools, were well-received by users. They appreciated the convenience of having all their educational tools and schedules in one place, which simplifies navigation and reduces the cognitive load. Participants also suggested further integrations with university library systems and plagiarism checkers, highlighting the ongoing need for interoperability to enhance user productivity. This is reflected in detail in one of the final design principles (QDP2c).

A user-centred design that prioritises aesthetics, functionality, and interactive features is crucial for user engagement (QDP3). Human-computer interaction research, such as that by Tractinsky *et al.* (2006) and Hibbeln *et al.* (2017), indicates that a well-designed interface can significantly influence emotional responses and technology acceptance. Tractinsky *et al.* (2006) specifically highlight how aesthetics can enhance user satisfaction and engagement. Our prototype's modern and intuitive design received positive feedback from participants, who noted that it made the system more engaging and easier to navigate compared to existing platforms like Canvas. The clean, uncluttered interface was particularly appreciated, as it reduces frustration and enhances productivity, as inferred from the evaluation feedback.

Empowering users with extensive customisation options allows them to tailor their learning experience to their preferences (QDP4). This principle aligns with findings by Nguyen *et al.* (2021) and Matook *et al.* (2024), which emphasise the importance of learner autonomy. Nguyen *et al.* (2021) discuss how autonomy in learning systems fosters a sense of ownership and responsibility towards learning. While the prototype offered some customisation features, users expressed a desire for more advanced options, such as detailed filtering capabilities and customisable layouts. Providing these options would cater to diverse user needs and enhance engagement by fostering a sense of ownership and responsibility towards their learning process.

6.1.2 Functional design principles

Well-designed course and content management is fundamental for user navigation and access to educational resources (FDP1). Research by Hoehle and Venkatesh (2015) supports the need for intuitive interfaces and streamlined navigation. Hoehle and Venkatesh (2015) argue that user-friendly design is critical for efficient course management. Our prototype's structured organisation of course pages and a list of courses, with features like categorising courses into "active" and "completed" and the representation of the robust search functionality, directly addresses these needs. The evaluation participants found these features beneficial for managing their learning paths and prioritising their activities.

Facilitating communication and collaboration through synchronous and asynchronous tools is crucial for a dynamic learning environment (FDP2). Studies by Wan, Compeau and Haggerty (2012) and Mtebe (2020) highlight the importance of integrating these tools. The prototype's group chats, course-specific messages, and video chat integration were praised by users for enhancing interaction and collaboration. This dual approach of synchronous and asynchronous communication ensures flexibility and supports varied user preferences. This is consistent with findings by Hoehle and Venkatesh (2015), who note that effective communication tools in LMS platforms can significantly enhance user engagement and collaboration.

Interactive and adaptive assessment options with real-time or strategically delayed feedback are essential for continuous improvement in learning (FDP3). Dawson, Gašević and Siemens (2015) emphasise the need for immediate and actionable feedback. The prototype's streamlined assignments page, which consolidates tests, assignments, and feedback, was positively reviewed by the evaluation participants. They appreciated the clear display of feedback and the inclusion of peer information to encourage submissions, aligning with Li, Wang and Wang (2021) and Huang *et al.* (2021) findings. This approach supports self-regulated learning by providing students with the information needed to reflect on and improve their performance.

Leveraging data-driven features to monitor learner progress and support adaptive feedback is crucial for informed decision-making (FDP4). Zhang (2017) and Nguyen *et al.* (2021) highlight

the importance of capturing and analysing educational data. Zhang (2017) further emphasises the need for real-time adaptation to learner engagement and needs. Our prototype's dashboard, featuring progress charts and performance analytics, provided users with a comprehensive overview of their progress. The evaluation participants valued these features for their ability to support self-regulation and effective study habits.

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As it is clearly seen, the proposed design principles directly address the issues highlighted in the literature, providing a comprehensive framework for developing more effective and user-friendly LMS platforms. The feedback from the interviewees underscores the importance of these principles in creating a more intuitive, engaging, and effective LMS, ultimately leading to improved learning outcomes. Thus, we can state that our work has far-reaching theoretical and practical implications.

6.2 Contribution to the Body of Knowledge

Our research contributes significantly to the body of knowledge in the field of information systems by addressing a critical gap in the literature related to learning management systems. While existing IS research has broadly explored themes of technology acceptance, user engagement, and enhancement of learning outcomes, there has been a notable scarcity of focused studies on optimising LMS features to enhance learning experiences and outcomes (Lee, Cheung and Chen, 2005; Huang *et al.*, 2021; Leung *et al.*, 2023). By proposing a comprehensive set of design principles grounded in extensive literature review and user feedback, our research bridges this gap and provides a holistic framework for the development of more intuitive, engaging, and useful LMS platforms. This contribution not only can enhance the pedagogical and operational practices within educational institutions but also extends the applicability of information systems to the education sector, similar to their impact on business and healthcare (Leidner and Jarvenpaa, 1995; Yang, Su and Yuan, 2012), which increases the reliability of IS as a reference discipline.

Beyond the IS field, our research has broader implications for the evaluation and design of learning management systems. By evaluating user feedback and integrating best practices from usability evaluations (Freire, Arezes and Campos, 2012; Maslov, Nikou and Hansen, 2021), our study offers a holistic approach to LMS design and contributes to the literature on human computer interaction, educational technology and user experience. This multidisciplinary perspective ensures that the proposed design principles not only enhance functionality and user satisfaction but also directly contribute to better learning outcomes and higher engagement levels. This comprehensive approach addresses the noted deficiency in the literature regarding specific LMS functionalities and their impact on educational processes, providing a comprehensive framework for future research and development in the domain of educational technologies.

6.3 Practical Implications

The results of our research hold significant practical implications for higher education institutions and LMS providers, bridging the gap between theoretical discussions and practical applications in educational technology. Our findings on user engagement and system usability offer valuable insights for educational institutions aiming to implement or upgrade their LMS

platforms, thus fostering a more effective and inclusive learning environment. By addressing usability and functional shortcomings identified in existing LMS, the implementation of our developed design principles can enhance the overall user experience, potentially leading to improved learning outcomes. The structured course and content management features, robust communication tools, and interactive performance assessments facilitate more efficient and better educational practices. These enhancements are expected to reduce student frustration and cognitive load, thereby fostering a more engaging and productive learning environment. Through seeking for our design principles when choosing systems to adopt, institutions can ensure that their LMS are not only reliable and accessible but also tailored to meet the diverse needs of their users, ultimately contributing to higher student satisfaction and retention rates.

For LMS providers, our research offers a comprehensive set of actionable design principles that can guide the development of next-generation LMS platforms. By focusing on robust system design, actionable information delivery, seamless interoperability, user-centred design, and extensive customisation, providers can create more intuitive and enjoyable-to-use learning environments. Our prototype instantiates the practical application of these principles, showcasing features such as structured navigation, integrated communication tools, and detailed performance analytics. Having the prototype as a reference and incorporating these elements can significantly enhance user engagement and satisfaction, setting providers apart in a competitive market. Additionally, the emphasis on continuous feedback and iterative improvements based on user evaluations ensures that LMS platforms remain adaptable and responsive to evolving educational needs. Implementing these insights can help LMS providers deliver superior products that meet the technological and pedagogical demands of modern higher education institutions.

7 Conclusion

This study has comprehensively explored the design and functionality of learning management systems in higher education, addressing critical usability and operational issues identified in existing literature. By developing a set of detailed design principles, we have provided a robust framework aimed at enhancing the usability, functionality, and overall user experience of LMS platforms. These principles were validated through empirical evaluation, ensuring their practical relevance and applicability. Our findings underscore the importance of thoughtful design in bridging the gap between the potential capabilities of LMS platforms and the actual needs of educational environments.

7.1 Research Aims and Objectives Fulfilment

The primary aim of this research was to develop design principles for LMS that provide comprehensive support for educational practices in higher education. Through an iterative and staged methodology grounded in design science research as proposed by Peffers *et al.* (2007), we ensured that our principles were both theoretically sound and empirically validated. This approach informed our objectives that were to identify the main usability and functional shortcomings of current LMS platforms, propose actionable design principles to address these shortcomings, and validate these principles through empirical evaluation and user feedback.

Throughout our research, we have successfully fulfilled the aim and objectives and answered the research question—*how to design learning management systems that provide comprehensive support for educational practices in higher education?* By conducting a thorough literature review and gathering extensive feedback from the evaluation, we identified key issues such as confusing content layout, inconsistent interface designs, limited customisation and interaction capabilities, and ethical concerns related to security and data privacy. These insights informed the development of our design principles, which were systematically derived using the design principle schema proposed by Gregor, Chandra Kruse and Seidel (2020). The principles address the need for robust system design, actionable and impactful information delivery, interoperability, integrated user experience, extensive user control and customisation, and a set of essential functionalities (Table 5.2).

7.2 Limitations and Future Research

Despite the comprehensive approach taken in this research, several limitations must be acknowledged, which offer opportunities for future research and improvement. Firstly, in this study we focused exclusively on students' experiences and perspectives. While understanding student needs is crucial, incorporating insights from other stakeholders such as instructors, administrators, and IT staff would provide a more holistic view of the LMS's effectiveness and usability. Future research should consider a broader range of participants to capture the diverse needs and expectations of all LMS users. This inclusive approach would help in developing a more universal design principles and systems that addresses the concerns and requirements of the entire academic community.

Another limitation lies in the evaluation process, which consisted of only one round of assessments. A single evaluation round limits the depth of feedback and the ability to further refine the LMS prototype. Conducting multiple rounds of evaluations would allow for more

comprehensive testing and validation of the system's features, leading to more robust and user-validated design principles. Future research should further evaluate the proposed principles through multiple iteration, involving feedback collection, prototype refinement, and re-evaluation to ensure that the final product and principles meet user needs and resolve any issues identified during earlier stages.

The study was also confined to a single university, which restricts the generalisability of the findings. Different universities may have varying infrastructural capabilities, cultural contexts, and user expectations, all of which can influence the effectiveness and usability of an LMS. To enhance the applicability of the research outcomes, future studies should include multiple universities with diverse characteristics. This broader scope would help in identifying universal design principles while also accommodating specific contextual variations, thereby creating a more adaptable and widely applicable LMS framework.

Furthermore, due to strict time constraints the number of evaluation participants was relatively limited, which may hinder the statistical significance and reliability of the findings. A larger participant pool would provide more robust data, increasing the confidence in the results and the validity of the conclusions drawn. Future research should aim to involve a larger and more diverse sample of participants to capture a wider range of user experiences and preferences. This approach would not only enhance the reliability of the findings but also ensure that the developed LMS is better suited to cater to the needs of a diverse student body.

Summing up, while this research has provided valuable insights into the development and implementation of LMS in higher education, acknowledging its limitations is essential for guiding future efforts. Following the suggested improvements is critical steps for future research. They will ensure that future LMS are more comprehensive, user-centred, and widely applicable, ultimately leading to even better and engaging educational experiences.

Appendix A. Interview Guide

Prototype Walkthrough (20 minutes, 20 tasks)

The prototype is accessible through the following the link.

Courses Tab
☐ Select the Courses tab from the sidebar to view the courses you are enrolled in (remember you can always show text in the sidebar by clicking on the arrow icon in the bottom left corner). ☐ Click on the **Designing Digitalisation course** to open its pages where you can access lectures, assignments, and other materials.
☐ In the **Home** section, skim through the About section and familiarize yourself with the schedule and deadlines for 3 months. *According to the calendar, when is the last assignment submission for the DD course? (Answer: 7/03)* ☐ Look through the classes (check out the online classes as well). *Which class is the next one to attend? (Answer: Lecture on UX Design)*
☐ In the **Assignments** section, check out your grades and the feedback. ☐ Try to submit an upcoming assignment (Task 3, upload file or write text). Then click Cancel. ☐ Now try to take a Test and answer question 3 (no need to read, just guess).
☐ In the **Groups** section, check out the groups you are in and open the chat with Group #5 (click the mail icon on the group tile; it won't open as it hasn't been designed; the main purpose is to see the redirect to messages). ☐ In the **Messages** section, check out the chat with the instructor. *What are the names of your classmates? (Answer: students listed in the pane on the right, "People in this course")*
Progress Tab
☐ Navigate to the **Progress** tab and familiarise yourself with the main dashboard layout including the sidebar menu and main interaction area. ☐ Review your overall course progress and individual course statuses. *What is the status of the AI course? (Answer: attention needed)* ☐ Look at the **Soon to Submit** tile to view pending assignments. Try to start "Test: What you learned about Digital D…". ☐ Go back to the Progress tab and look at the **Upcoming classes** tile. *In which classroom the Workshop: Data-Driven Design will take place? (Answer: 063)* ☐ Now look at the **Events to attend** tile. *On what date will the Hackaton take place? (Answer: 29/02)*

Messages Tab
☐ Navigate to the Messages tab and try to find your chat with Group #5 from the DD course. ☐ Now open a private chat with Spencer Schwartz.
Calendar Tab
☐ Click on the Calendar tab from the sidebar to view important dates. ☐ Toggle week view. *According to the calendar, what date is today? (Answer:3/02)*
Notifications
☐ Check the notifications at the top-right corner to stay updated on new assignments, tests, or announcements.
Help Tab
☐ Go to the Help tab (question mark) to access the FAQ.

Interactive Session (40 mins, 30 questions)

Quality Design Principles Evaluation

QDP3. Integrated User Experience Design
☐ What is your overall impression of the LMS's **design and layout**? What elements particularly caught your attention? ☐ How do you feel the design **impacts** your motivation to learn and overall learning effectiveness?
QDP4. User Control and Customisation
☐ Can you describe how you were able to **customise or personalise** your experience in the LMS? ☐ On a scale of 1 to 5, how would you rate the importance of these options for you? 1. *Very unimportant* 2. *Unimportant* 3. *Neutral* 4. *Important* 5. *Very important*
QDP2c. Interoperability

☐ Have you encountered any features that allow **integration** with other systems or parts of this prototype? Please describe them.

Functional Design Principles Evaluation

FDP1. Course and Content Management	**QDPs**
☐ How easy or difficult was it to navigate **the Courses tab**? ☐ Did you encounter any difficulties when searching for **the Designing Digitalisation course**?	3
☐ When accessing the course, how easy or difficult was it to understand the layout and access **materials within lectures and assignments**?	2b, 3
☐ In the **Calendar tab**, how would you describe the layout? ☐ How easy or difficult was it to visually distinguish between different types of events?	2a, 2b, 2c, 3, 4
FDP3. Performance Assessment and Feedback	**QDPs**
☐ When checking assignments, how visible are the **deadlines**? ☐ Describe your experience with submitting an assignment and taking a test.	2a, 2b, 4
☐ How easy or difficult was it to access the **instructor's feedback**? ☐ Do you think the presented functionality is sufficient to offer clear guidance on how to improve or where you excelled? If not, what do you think can be improved?	2a, 2b
☐ Does seeing your **peers' progress** (e.g., percentage started in assignments) motivate you?	2a, 2b
☐ In **the Progress tab**, you can find a **leaderboard** of your programme. How personally important is your position on the leaderboard to you? Would it influence your study habits?	2a
FDP2. Communication and Collaboration	**QDPs**
☐ What was your impression about **the list of groups** you are part of in the DD course?	2b, 3
☐ Based on your attempt to interact with Group #5, did **the messages section** in DD course pages seem useful to you? Or is the Messages tab (sidebar) enough?	2c

☐ In **the Messages tab**, how easy or difficult was it to find specific chats? ☐ Does it meet your needs for communication? If not, what should be improved?	2c, 3, 4
☐ Is the **video chat integration** (in Messages) useful for your needs, or do you prefer external tools? Why?	2c
FDP4. Reporting and Analytics	**QDPs**
☐ In the **Progress tab**, how relevant and helpful did you find the displayed information in understanding your progress and areas needing attention? ☐ What could you infer from the dashboard? Which information was the most important to you?	2a, 2b, 2c
Beyond Functional Design Principles	**QDPs**
☐ Evaluate the design and layout of **the Help tab**. What improvements would you suggest for enhancing user support through this tab?	2a, 2b

Overall Satisfaction and Improvements

☐ Overall, how **satisfied** are you with the prototype? Please rate on a scale of 1 to 5 1. *Extremely Dissatisfied* 2. *Dissatisfied* 3. *Neutral* 4. *Satisfied* 5. *Extremely Satisfied*
☐ What features of the LMS do you find most beneficial, and what would you most like to change?

Comparison with Prior Experience

☐ Have you used any LMS before? If so, which ones?
QDP1. Robust System Design
☐ Have you experienced any **issues with system downtime or slow performance** when using the LMS? Can you describe these situations? How did it affect your learning experience?
☐ Did you feel that your privacy was ensured and your personal information was **secure** when using the LMS? Why or why not?
☐ Please rate the prototype on a scale from 1 to 5 compared to the LMS you used before.

1. *Much less useful and much more difficult to use*
2. *Less useful and more difficult to use*
3. *Relatively the same*
4. *More useful and easier to use*
5. *Much more useful and much easier to use*

Appendix B. Final Design Principles

Quality Design Principles

QDP1. *Robust system design*: for LMS providers to ensure a robust operation of the system for users across environments, develop strategies and technologies that enhance availability, scalability, performance, reliability, privacy, security, and maintainability, as these combined efforts help meet users' expectations of a stable and efficient service while adapting to evolving demands and threats

QDP2a. *Actionable information*: for LMS providers to enable optimal educational outcomes and support informed decision-making for users in diverse informational contexts and across environments, develop adaptive technologies that deliver clear, valid, and user-specific information as they enable extending user's decision-making capabilities and positively influence behaviour

QDP2b. *Impactful information delivery*: for LMS developers to enable optimal educational outcomes and support informed decision-making for users in diverse informational contexts and across environments, develop technologies for providing information and feedback on demand and in a comprehensive form and format as it enhances learning by allowing for better reflection and adjustment of educational strategies

QDP2c. *Interoperability*: for LMS providers to provide comprehensive educational support for users across environments, develop data integration and interoperability mechanisms ensuring seamless data flow across the institution's and third-party platforms and the system, and within the system's various modules as it supports learning processes, providing a cohesive and integrated educational experience

QDP3. *Integrated user experience design*: for LMS providers to enhance user acceptance and sustained interaction with the system of users across environments, implement user-centred design that prioritises aesthetics, functionality, and interactive features as it generates positive emotional responses, improves user perceptions and fosters a sense of internal commitment to educational goals

QDP4. *User control and customisation*: for LMS providers to foster user engagement and autonomy of users across environments, implement extensive customisation options for both the interface and content settings as they promote learners' sense of ownership and active participation

Functional Design Principles

FDP1. *Course and content management*: for LMS providers to enhance user satisfaction with the system and educational outcomes of users across environments, implement intuitive interfaces, streamlined navigation, access and interaction with the content as it promotes usability and intuitive exploration, cater to varied technological proficiencies

FDP2. *Communication and collaboration*: for LMS providers to enable communication and collaboration within the system for users across environments, develop synchronous and asynchronous communication tools as they mimic traditional classroom dynamics and enhance social presence, provide flexibility and encourage active participation and collaboration

FDP3. *Performance assessment and feedback*: for LMS providers to enable optimal increase student motivation and educational outcomes of users across environments, develop interactive and adaptive assessment options with the possibility of delayed and real-time personalised feedback that mimics game features, increasing engagement and enabling immediate learning corrections

FDP4. *Reporting and analytics*: for LMS providers to enhance personalised learning experiences and support informed decision-making for users across environments, implement data-driven features that monitor learner progress, support adaptive feedback and interventions based on individual behaviours and needs as it extends the user's decision-making and self-regulation capabilities

Appendix C. AI Contribution Statement

In the development of this research, we used ChatGPT as an assistive tool to enhance the quality of our work. Specifically, it provided valuable feedback on the use of language, helping us increase clarity and coherence in our writing. During the axial coding process, ChatGPT assisted in generating ideas for themes. All other aspects of our research, including problem identification and formulation, literature review, conceptualisation of the principles, design and development of the prototype, data collection, analysis, and interpretation, as well as the refinement and formulation of final design principles, were performed independently by the research team without AI assistance.

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