Write here your dedication!

Cover

Acknowledgment

Resumo

Esta dissertação apresenta o desenvolvimento do Learning Scorecard 3.0, uma iteração de uma plataforma de análise de aprendizagem gamificada anteriormente desenvolvida como uma aplicação web independente, implementada como um sistema de plug-ins nativo do Moodle. Esta iteração aborda limitações críticas de implementações anteriores e serve como uma prova de conceito para reconceituar a arquitetura da plataforma como um componente integrado do sistema de gestão de aprendizagem. Esta solução aproveita a autenticação nativa do Moodle, o controlo de acesso baseado em funções e os dados abrangentes das atividades dos alunos para eliminar pontos de atrito, preservando ao mesmo tempo a mecânica da gamificação, incluindo pontos de experiência, sistemas de classificação hierárquica e tabelas de classificação competitivas.

As principais contribuições técnicas incluem uma arquitetura de base de dados híbrida que integra tabelas personalizadas com o esquema de base de dados existente do Moodle, cálculo de experiência em tempo real através de observadores orientados por eventos e um sistema de plug-ins modular e extensível. Este sistema demonstra o mapeamento bem-sucedido do conceito entre os elementos do Learning Scorecard e os recursos nativos do Moodle, numa tentativa de alcançar uma integração perfeita ao implementar recursos personalizados de gamificação.

Esta pesquisa contribui para a compreensão dos desafios da integração da tecnologia educacional e demonstra a viabilidade de incorporar sistemas sofisticados de gamificação em plataformas de gestão de aprendizagem estabelecidas.

Abstract

This dissertation presents the development of the Learning Scorecard 3.0, an iteration of a gamified learning analytics platform previously developed as a standalone web application, implemented as a native Moodle plugin system. This iteration addresses critical limitations of previous implementations and serves as a proof of concept to reconceptualize the platform's architecture as an integrated learning management system component. This solution leverages Moodle's native authentication, role-bsed access control and comprehensive student activity data to eliminate friction points while preserving gamification mechanics including experience points, hierarchical ranking systems and competitive leaderboards.

Key technical contributions include a hybrid database architecture that integrates custom tables with Moodle's existing database schema, real-time experience calculation through even-driven observers and a extensible and modular plugin system. This system demonstrates successful concept mapping between Learning Scorecard elements and Moodle's native capabilities, in an attempt to achieve seamless integration while implementing custom gamification features.

This research contributes to understanding educational technology integration challenges and demonstrates the feasibility of embedding sophisticated gamification systems wihtin established learning management platforms.

Contents

CHAPTER 1

Introduction

1.1. Background & Context

The landscape of higher education has undergone significant transformation through the widespread adoption of digital technologies and learning management systems. This digital evolution has created unprecendented opportunities for institutions to leverage data analytics and innovative pegagogical approaches in order to enhance student learning outcomes and insitutional effectiveness. Within this context, the integration of gamification principles with educational analytics represents a promising avenue for addressing persistent challenges in student engagement, motivation and academic performance monitoring.

The concept of gamification, defined as the application of game design elements in non-game contexts [**1**], has gained considerable traction in educational settings as a mechanism for increasing student motivation and engagement. When combined with learning analytics, which involves the measurement, collection, analysis and reporting of data about students and their contexts for purposes of understanding and optimizing learning, gamification can prove to be a powerful tool for both students and teachers, both to monitor and improve the learning process.

The Learning Scorecard perfectly exemplifies this convergence of gamification and educational analytics. Originally conceived as an academic performance management system, the LS has evolved through multiple iterations to become a platform that merges business intelligence methodologies with educational gamification strategies. The platform's core objective is to provide the students and faculty with actionable insights into the learning progress while maintaining high levels of student engagement through game-like mechanics.

However, the evolution of the Learning Scorecard has revealed, throughout the years, significant architectural and operational limitations that constrain its effectiveness and adoption within institutional contexts. These limitations, particularly regarding system integration, data collection efficiency and user accessibility, have urged a fundamental reconceptualization of the platform's technical infrastructure and deployment strategy.

1.2. Statement of the Problem

The current implementation of the Learning Scorecard (version 2.0) platform presents several critical challenges that prevent its effectiveness and widespread adoption within higher education institutions. These challenges can be categorized into three primary domains: technical architecture, operational efficiency and institutional integration.

The existing Learning Scorecard operates as a standalone web application with external infrastructure dependencies, including cloud-hosted databases and third party service integrations. This architectural approach creates several complications: first, it requires a separate authentication system and user management processes that exist parallel to institutional systems; second, it requires ongoing maintenance of external infrastructure, increasing operational costs and security vulnerabilities; third, it creates data silos, isolated collections of data that prevent seamless integration and data sharing with existing institutional learning management systems.

The current system requires substancial manual data entry from both students and faculty in order to populate the platform with the necessary academic and performance information. This manual input requirement creates multiple friction points: Students must duplicate the effort of entering information that already exists in institutional systems; faculty members face additional administrative burdens in maintaining accurate records of data across multiple platforms, for example, the need to create another account, leading to another set of credentials and the requirement to input the quiz and exercises grades from all students manually into the platform; the potential for data inconsistencies and errors increases significantly due to human input mistakes.

Perhaps most critically, the standalone nature of the current Learning Scorecard creates barriers to institutional adoption and sustained usage. Students and faculty must actively choose to visit the external platform, creating an additional step in their academic workflow. The platform lacks integration with existing institutional systems, preventing it from leveraging the data already collected through learning management systems like Moodle.

The Learning Scorecard stemmed from an investigation project and had no institutional support in its development or maintenance. The development was made in ISCTE, by students, but the goal was always to create a scalable learning tool that could be integrated seamlessly in other universities or learning institutions.

These challenges collectively result in a reduced user adoption, increased maintenance costs and compromised data accuracy.

1.3. Aims and Objectives

This dissertation addresses the identified limitations through the development and evaluation of a Learning Scorecard version 3.0, which fundamentally reconceptualizes the platform's architecture and deployment strategy by inverting it and explore the feasibility of integrating the Learning Scorecard with the moodle system and infrastructure.

From a technical perspective, this dissertation aims to: (1) design and implement a modular plugin architecture that could seamlessly integrate with ISCTE's Moodle infrastructure; (2) develop automated data collection mechanism that leverage Moodle's comprehensive student activity and performance data; (3) create user interfaces that maintain consistency with Moodle's design patterns while providing functionality of the Learning

Scorecard platform; (4) ensure data security and privacy protection through adherence to Moodle's established security frameworks.

This dissertation also seeks to validate the effectiveness of the integrated approach through: (1) demonstration of reduced manual input requirements compared to previous Learning Scorecard versions; (2) evaluation of user experience improvements resulting from seamless integration with existing academic workflows; (3) assessment of system performance and scalability within the Moodle environment; (4) analysis of the platform's potential for broader institutional adoption given its integration with existing infrastruture.

Beyond technical and empirical considerations, this dissertation aims to contribute to the broader understanding of how gamification platforms can be effectively integrated within established educational technology ecosystems. The findings will provide insights into best practices for developing educational technology solutions that complement rather than compete with existing institutional systems.

1.4. Methodological Approach

This dissertation employs a lean agile methodology, combining the iterative nature of software development with a sprint-based approach with clearly defined objectives. The lean agile methodology allowed for a more organic and streamlined process, without abandoning the agile's iterative concept but letting go of some traditional agile cerimonies unecessary for an individual academic research team.

The initial phase involved an analysis of existing Learning Scorecard implementations, detailed examination of Moodle's plugin architecture and Service API capabilities and systematic requirements gathering. This phase includes mapping the Learning Scorecard concepts to Moodle's existing data structures and functionality, identifying integration opportunities and constraints and developing a system architecture that addresses the identified limitations while preserving core platform capabilities.

The development phase focused on delivering functional components that can be tested and refined throughout the process. The development approach emphasizes modular design and adherence to Moodle coding standards to ensure compatibility with Moodle's ecosystem. Key deliverables include a block plugin to exemplify a user interface component of the student interface and a local plugin for main functionality and who's responsible for the addition of database schemas that integrate with Moodle's existing data structures.

1.5. Structure of the Dissertation

This dissertation is organized into seven chapters that systematically address the objectives and present the development, implementation and evaluation of Learning Scorecard 3.0.

Chapter 2 provides comprehensive background on learning management systems, with particular focus on Moodle's architecture and capabilities and examines the theoretical foundations and practical applications of gamification in educational contexts. This chapter establishes the theoretical framework that suplements the design decisions throughout the dissertation.

In chapter 3 the historical development of the Learning Scorecard is traced through its various iterations, analyzing the lessons learned from previous implementations and establishing the conceptual framework of the Learning Scorecard.

Chapter 4 presents the technical architecture of the Learning Scorecard 3.0, including detailed requirements analysis, system design decisions, plugin architecture specification and database design. It's also presented a detailed mapping of Learning Scorecard concept to Moodle's existing functionality and its mapping feasibility. This chapter provides the technical foundation for understanding the implementation approach and design rationale.

Chapter 5 describes the key deliverables and presents the proposed solution and serves as a demonstration of some functionality from the Learning Scorecard and its feasibility as Moodle integrated plugins.

Chapter 6

CHAPTER 2

Literature Review

2.1. Learning Management Systems

Learning Management Systems (LMS) represent sophisticated software applications engineered to administer, track, report, automate and deliver educational courses, training programs and comprehensive learning materials. Following their initial emergence in the late 1990s, these platforms have achieved significant adoption across higher education institutions globally. Recently, the unprecedented expansion of LMS usage has been significantly accelerated by the institutional shift toward remote learning by the COVID-19 pandemic. [**2**]

There are several LMS available for educational institutions, with commercial and open-source platforms representing the two primary categories of LMS offerings [**3**]. Commercial LMS are either available in the market for a price or, although very rarely, proprietary and developped by the institution. In contrast, the open source alternative is available at no cost to the institution, although technical expertise is required as well as regular functional assessments. Open-source systems provide publicly accessible source code that institutions can modify and improve to meet their specific requirements and needs [**4**].

Moodle (Modular Object-Oriented Dynamic Learning Environment) stands as one of the most widely adopted open-source learning management systems globally. According to a recent systematic review on tendencies in the use of LMS, Moodle is the most popular and preferred open-source LMS [**5**]. The platform's extensive reach is evidenced by its current deployment across 238 countries, serving approximately 468 million users worldwide [**6**].

From a technical perspective, Moodle is built on a layered architecture (Figure 1) that ensures flexibility and scalability. The presentation layer handles the user interface and allows users to interact both on desktop and mobile devices. The application layer accommodates core functionalities and acts as an intermediary between the presentation and data layer, supporting the installation of plugins and modules to customize features. The data layer includes the database management system, typically SQL-based, which stores and manages all the data. This modular design allows institutions to customize the functionality and appearance through an extensive plugin ecosystem.

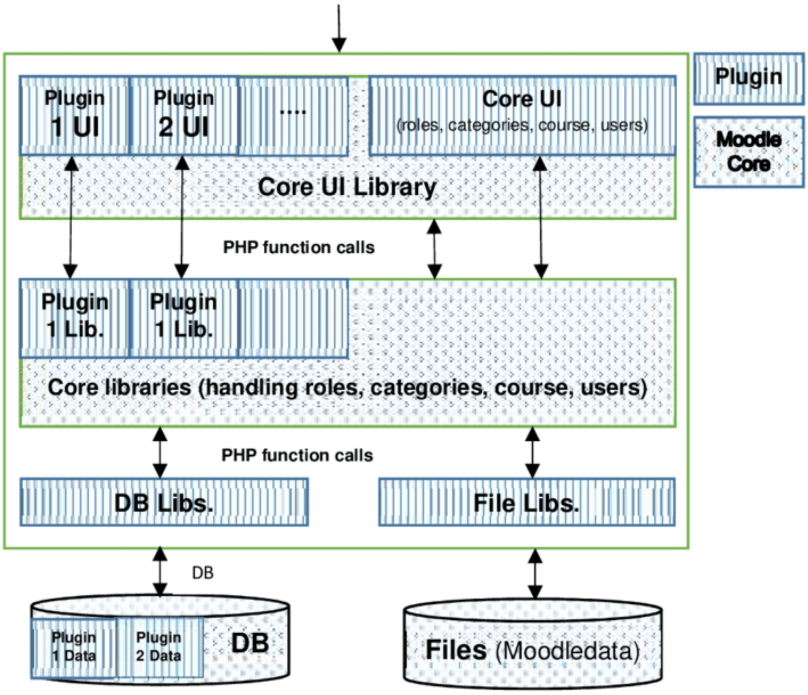


FIGURE 1. Moodle three tier architecture. Source: Dolawattha et al. [7].

Moodle offers many plugins that allow for functionality expansion. There are multiple types of plugins from local plugins, block plugins all the way to antivirus plugins. Each with its own purpose and place in the moodle folder structure.

2.2. Gamification and Motivation in Education

Gamification is the process of applying game elements, design and mechanics to non-game contexts [1] and when applied to higher education it demonstrated a noticeable positive effect on learning outcomes [8]. However, when poorly designed and implemented, particularly when relying solely on points, badges and leaderboards without supporting intrinsic motivation, gamification can undermine student motivation [9] and create anxiety through excessive competition [10]. The field faces significant methodological challenges with 50% of studies showing inconclusive results [11].

2.2.1. Theoretical Foundations of Gamification

The Self-Determination Theory (SDT) provides the dominant theoretical lens for understanding gamification effectiveness in educational contexts [12]. According to Deci and Ryan, SDT poses that human motivation stems from satisfaction of three innate psychological needs: autonomy (self-determination and willing action), competence (mastery and effectiveness) and relatedness (social connection and belongingness), The theory distinguishes between intrinsic motivation (engaging in activities for inherent satisfaction) and extrinsic motivation (from purely reward-driven to fully internalized values) [10]. Ryan and Deci's later update demonstrates that autonomy-supportive environments enhance student motivation, engagement, performance and well-being across diverse cultural contexts.

The application of SDT to game design emerged with Ryan, Rigby and Przybylski's [**13**] work demonstrating that video game enjoyment stems not from surface features but from need satisfaction. Ryan and Rigby [**14**] explicitly applied these principles to educational contexts, arguing that game-based learning satisfies needs through meaningful choices (autonomy), optimal challenges with clear feedback (competence) and collaborative interaction (relatedness), while warning that superficial gamification relying solely on extrinsic rewards threatens these very needs.

Empirical research confirms SDT's power for gamification outcomes. Sailer et al. experimentally tested how specific game design elements influence need satisfaction, finding that different mechanisms satisfy different needs: avatars and storylines increased perceived autonomy; leaderboards and performance graphs increased perceived competence; teammates and meaningful narratives increased perceived relatedness. Xi and Hamari [**15**] demonstrated that need satisfaction mediates the relationship between gamification features and positive outcomes, providing empirical support for matching game mechanics to psychological needs.

Csikszentmihalyi's [**16**] Flow Theory complements SDT by describing the construction of the optimal experience, complete absorptionin an activity characterized by nine dimensions including challenge-skill balance, clear goals, unambiguous feedback, total concentration, sense of control and transformation of time. Flow occurs when challenges and skills are both high and balanced, creating intrinsically rewarding experiences distinct from simple instantaneous pleasure. The original description positioned flow as the antidote to both boredom (when skills exceed challenges) and anxiety (when challenges exceed skills).

The integration of SDT and Flow Theory provides a comprehensive motivational framework: SDT explains why gamification works through need satisfaction, while Flow Theory describes the optimal state when competence needs are met through balanced challenge-skill dynamics, supported by autonomy and relatedness. Proulx et al. proposed integrating learning mechanics with game mechanics under this dual theoretical lens, distinguishing between game mechanics (rules and procedures) and learning mechanics (pedagogical strategies) while ensuring alignment with psychological need satisfaction.

2.2.2. Gamification Mechanics

The critical factor determining whether gamificatin supports or undermines motivation appears to be implementation approach. Koivisto and Hamari [**17**] reviewed gamification research and indentified a gap between promise and practice, noting that the most effective implementations are grounded in motivational theory rather than superficial application of game elements.

Leaderboards exemplify gamification's most controversial element driving engagement for some learners while creating anxiety and demotivation for others. Li and Fryer's [**18**] systematic review of empirical evidence in higher education concluded that leaderboards remain amongst the most popular gamification elements but should be used with clear ranking rules and goal-related feedback to avoid detrimental effects. Leaderboards may benefit high-performing students but have negative consequences for underperforming ones, shifting focus from learning to ranking.

Points systems represent the most fundamental gamification mechanic, providing immediate quatitative feedback for actions and achievements. Park and Kim [**19**] distinguished between qualitative points (high/low scores displayed on leaderboards) and quantitative points (accumulative token-like currencies), noting that points are the most widely used game mechanics but improper use causes learners to focus on earning points without genuine learning purpose.

Despite criticisms, well-designed points systems demonstrate usefulness. Experience points (XP) and leveling systems create a sense of continuous progress by providing granular feedback that makes small actions worthwhile. Paiva et al. [**20**] found that XP systems combined with badges created a sense of constant progress, proving powerful in learning applications where skill development occurs incrementally.

Progress bars and visual feedback leverage what Park and Kim [**19**] identify as the Zeigarnik effect, the psychological need to complete unfinished tasks. They provide immediate visual feedback that makes abstract advancement concrete and visible.

When properly implemented, with theorectical rigor, gamification demonstrates genuine potential to enhance cognitive, motivational and behavioral outcomes. The challenge for higher education is moving beyond the superficial implementation toward sophisticated applications that follow what motivational psychology teaches about human learning and development.

CHAPTER 3

The Learning Scorecard: Concept and Evolution

3.1. Genesis and Conceptualization of the Learning Scorecard

The Learning Scorecard emerged from a fundamental pedagogical challenge identified within higher educational institutions: the lack of understanding by faculty members regarding the difficulties experienced by students in relation to the content taught in curricular units as well as the students lack motivation in respect to the academic autonomous work. Initially, this platform was conceptualized as an academic performance management system designed to support both students and faculty through data-driven insights that assist teachers in continuously monitoring the curricular units they teach while enabling students to visualize their performance in each course in which they are enrolled. Their main mission was to offer higher education students an analytic environment that allows progress monitorization through a familiar game-like scope, contributing for a better learning experience.

The platform was originally conceptualized with three distinct user perspectives: student view, teacher view and administrative view. The student view provides essential visualizations that enable students to understand their learning trajectory in a specific curricular unit while offering tools that provide important data for continuous monitoring by faculty. The teacher view provides management, evaluations and visualization tools for educators regarding each curricular unit they teach, offering various visualizations to track the collective students progress through all phases of the curricular unit along with assessment tools.

3.2. Evolution Through Iterative Development

3.2.1. Historical Overview of Versions

The Learning Scorecard concept began in the 2015/16 academic year as a collaborative project project undertaken by a group of Computer Science masters students enrolled in the Information Systems of Decision Support II curricular unit under the advice of Prof. Elsa Cardoso. This group defined in a very basic and introductory way what the LS would be, later being picked up by Daniela Costa [**21**] who built upon this concept, improving it and setting the course for the following iterations..

The development timeline reflects the progression of features and refinements with each major version addressing specific limitations and opportunities identified through previous implementations. This iterative approach has enabled the platform to evolve in response to changing technological landscapes, pedagogical insights and institutional requirements while maintaining consistency in core design principles.

Learning Scorecard Version 0

The inaugural version of the Learning Scorecard was developed by Daniela Costa as part of her master's dissertation at ISCTE-IUL [**21**], whose primary objective was to create a web-based platform that would integrate Business Intelligence techniques with gamification elements in order to foster improved student learning experiences in higher education contexts.

This version adopted conventional three-tier web application architecture, comprising distinct presentation, application and data layers. This architectural pattern, while traditional, provided a stable foundation for the initial implementation and facilitated separation of concerns accross system components.

The presentation layer was constructed using fundamental web technologies including HTML5, CSS3 and JavaScript. The Bootstrap framework[**22**] was incorporated to ensure responsive design principles and provide pre-built user interface components. Chart.js [**23**], a JavaScript visualization library, was integrated to facilitate the creation of interactive dashboard and data visualizations, essential for performance monitoring. The application layer was built upon Node.js, with Express.js as the web application framework, providing routing capabilities and middleware integration. MySQL [**24**] was selected as the relational database management system (RDBMS), choosen for its compatibility with Node.js's [**25**] asynchronous architecture and its widespread adoption in academic environments. The database schema was designed to accommodate user profiles, course information, assessment data and gamification elements.

This platform was deployed in the SIAD I (Data Warehouse and Business Intelligence) course during the 2016/2017 academic year. Comparative analysis with the previous academic year (2015/2016, without LS implementation) revealed statistically significant improvements accross multiple performance indicators. The approval rate of students increased from 86% to 92%, the mean grade improved from 13.25 to 13.74 (on a 0-20 scale), the number of failed students decreased from 17 to 10 students and the number of students that withdrew from the course also decreased from 21 to 12 students.

Post-implementation analysis revealed several technical and functional limitations, such as the absence of proactive notification mechanisms for approaching quest deadlines, limited diversity in quiz question formats and assessment types, code modularity deficiencies impeding extensibility, scalability constraints when supporting large concurrent user populations and suboptimal code organization affecting maintainability.

Learning Scorecard Version 1

Version 1 represented an evolutionary refinement of the Learning Scorecard developed collaboratively by Francisco Rações and Tiago Pedroso during the 2017/2018 academic year.

Rather than representing a single unified dissertation, their work constituted two complementary master's research projects that addressed distinct but interconnected dimensions of the Learning Scorecard: systematic gamification enhancement through theoretical frameworks (Pedroso) and advanced information visualization and dashboard design (Rações).

The primary motivation driving version 1 development stemmed from identified limitations in version 0 and broader challenges in educational gamification and learning analytics.

Educational gamification implementations frequently suffer from superficial application of game elements, often limited to points, badges and leaderboards (PBL), without systematic consideration of how these mechanics connect to student motivation and desired learning outcome. Pedroso's focus was to analyze how gamification can be systematically designed to enhance student's engagement and motivation. Rações however, focused on how student learning progress in higher education courses is typically not monitored in real-time. His contribution was mainly on students perception of their learning progress through well-designed dashboards and visualization techniques.

This version maintained and incrementally enhanced the core technological foundation estabilished in version 0 with the key technical enhancements being: (1) expanded data collection mechanisms for additional learning indicators; (2) enhanced dashboard rendering capabilities, supporting more complex visualizations; (3) improved gamification element tracking and state persistence; (4) refined user interface components with a more responsive design and (5) optimized database queries for performance improvements.

The central theoretical innovation of version 1 was Pedroso's systematic application of the MDA (Mechanics, Dynamics, Aesthetics) framework proposed by Hunicke, Leblanc and Zubek [**26**]. The MDA framework represents a formal approach to game design and game research, providing an analysis methodology for understanding how game elements interact and how they can be applied outside traditional gaming contexts.

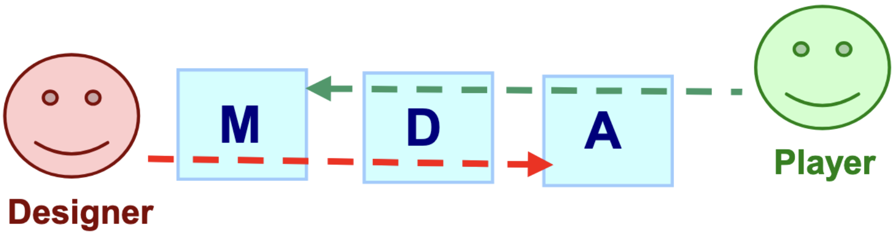


FIGURE 1. MDA Perspectives. Source: Hunicke R. et al. [**26**].

Following the MDA framework, Pedroso designed and implemented gamification mechanics intended to generate specific dynamics and aesthetic outcomes.

Implemented Mechanics

1. Experience Points (XP) System

   - Awarded for completion of learning activities (quizzes, assignments, etc.).
   - Cumullative XP tracking throughout the semester.
   - Transparent XP calculation rules communicated to students.
2. Badge System
   - Achievement recognition for specific accomplishments.
   - Categories: content mastery, participation, consistency and excellence.
   - Visual representation with iconography.
   - Badge collection displayed in student profiles.
3. Leaderboard
   - Ranked display of student performance based on XP.
   - Multiple leaderboard views (class-wide, groups, etc.).
   - Regular updates maintaining current standings.
4. Quest System
   - Structured learning activities with clear objectives and deadlines.
   - Multiple quest types: practical assignments, exercises, quizzes and forum discussions.
   - Progress tracking with completion status visualization.
   - XP rewards tied to quest completion and quality.
5. Level System
   - Hierarchical progression indicators based on cumulative XP.
   - Level thresholds established to create meaningful advancement milestones.
   - Level-up notifications providing motivational reinforcement.
   - Visual representation of current level and progress toward next level.
6. Progress Visualization
   - Dashboards showing advancement through course content.
   - Timeline representations of quest deadlines and completion.
   - Comparative visualizations (individual vs. class average).

Targeted Dynamics

- Competition: Leaderboards and public XP totals create competitive motivation between students.
- Progression: Level advancement provides clear sense of forward movement.
- Goal-Orientation: Quest structures with defined objectives focus student effort.
- Social Comparison: Peer performance visibility enables self-assessment in context.
- Achievement Recognition: Badges provide symbolic acknowledgement of accomplishments.
- Time Management: Quest deadlines encourage consistent engagement rather than cramming.

Intended Aesthetics

- Challenge: Encouraging mastery through structured, progressively difficult learning objectives.
- Discovery: Facilitating exploration of course content and connections between concepts.
- Progression: Providing clear sense of advancement and competence development.
- Fellowship: Creating awareness of collective class journey and peer community.
- Narrative: Structuring semester as coherent learning journey milestones.

Rações's contributed mainly by developing comprehensive dashboard interfaces for both students and faculty and by indentifying and implementing core learning indicators categorized in three dimensions: engagement indicators, coginitive indicators and social indicators.

Engagement indicators measured the interactions with the learning contents, frequency of access to the platform and submission timeliness. Whereas cognitive indicators tracked grade and performance trends, quiz attempts before achieving success, performance consistency and improvement trajectories. The social indicators provided a measure on forum posting frequency and consistency, peer interaction patterns and collaborative activity participation and contribution quality.

In regards to the dashboards, he made improvements on the students view providing actionable insights while focusing on information clarity through visualization components such as:

- Line charts tracking temporal patterns of engagement (platform access and forum activity over weeks).
- Bar charts for comparing quiz grades across multiple assessments.
- Radar charts for multi dimensional performance profiling.
- Progress indicators as a visual representation of quest completion and level advancement.
- Tables with detailed statistical breakdowns of quiz performance and attempt histories.

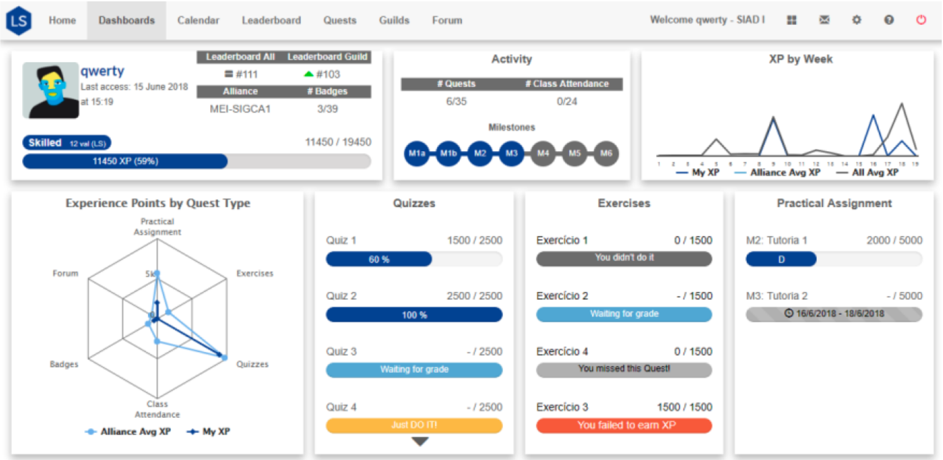
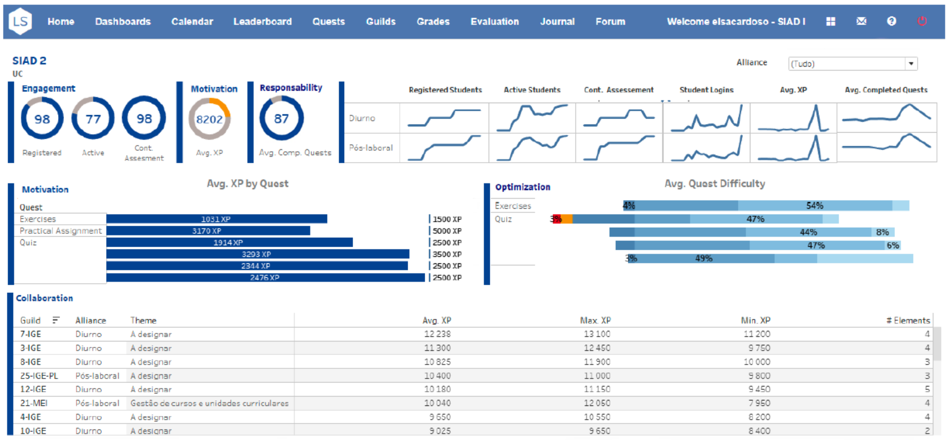


Figure 2. Student Dashboard (Version 1). Source: Rações F. [27].

On the faculty view, he designed the dashboards according to Business Intelligence best practices for analytical decision support with the following key metrics being displayed:

- Number of active vs. inactive students.
- Average quiz grades with trend indicators.
- Forum participation rates across the entire class.
- Assignment submission delay distributions.
- At-risk student identification based on multiple indicator thresholds.



Guild	Alliance	Theme	Avg. XP	Max. XP	Min. XP	# Elements
7-IGE	Diurno	A designar	12 238	13 100	11 200	4
3-IGE	Diurno	A designar	11 300	12 450	9 750	4
8-IGE	Diurno	A designar	10 825	11 900	10 000	3
25-IGE-PL	Pós-laboral	A designar	10 400	11 000	9 800	3
12-IGE	Diurno	A designar	10 180	11 150	9 450	5
21-MEI	Pós-laboral	Gestão de cursos e unidades curriculares	10 040	12 050	7 950	4
4-IGE	Diurno	A designar	9 650	10 550	8 200	4
10-IGE	Diurno	A designar	9 025	9 650	8 400	2

Figure 3. Teacher Dashboard (Version 1). Source: Rações F. [27].

Version 1 was deployed during the 2017/2018 academic year at ISCTE-IUL in two courses: SIAD I (first semester) and SIAD II (second semester). This represented the platforms third and fourth consecutive semester deployments, building upon the foundation established the previous academic year.

Despite significant advances, this version retained limitations, motivating future development and iteration:

- Technical Limitations

    - Code Modularity: While improved over version 1, codebase still exhibited architectural constraints limiting extensibility
    - Scalability Concerns: Performance characteristics with large user populations remained uncertain
    - Data processing: Some analytics required manual calculation or batch processing rather than real-time computation
- Functional Limitations
    - Difficuty Assessment: Lacking mechanisms to capture student-perceived difficulty of content topics
    - Adaptive Learning: Limited capability to personalize learning paths based on individual student characteristics
    - Predictive Analytics: No predictive modeling of future student and class performance
- Pedagogical Considerations
    - Self-Reported Data: Reliance on faculty to input the information regarding students grades, performance, etc.
    - Generalizability: Implementation validated in SIAD courses, applicability to other courses uncertain

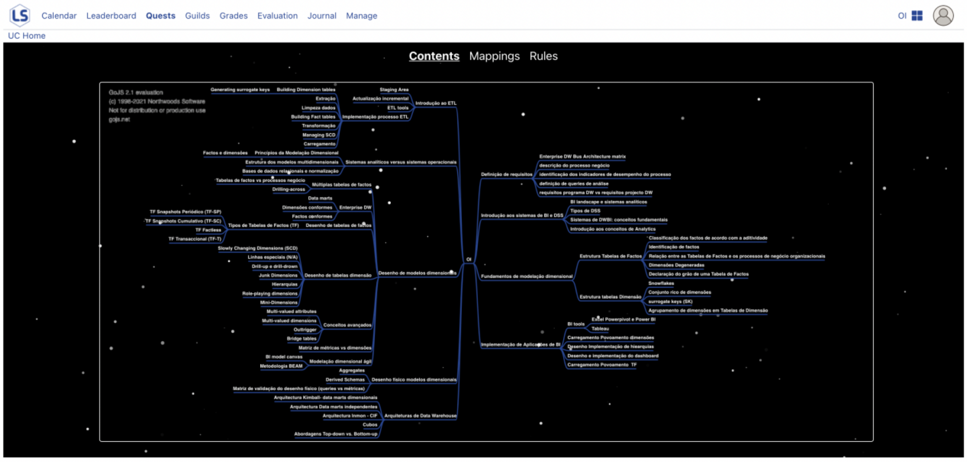
While version 1 achieved significant pedagogical and user experience improvements, these identified technical and functional limitations motivated Miguel Lopes' [**28**] subsequent comprehensive architectural reimagination (version 2), which would address scalability concerns and integrate semantic web technologies while preserving the gamification and visualization innovations contributed by Pedroso and Rações.

Learning Scorecard Version 2

The latest version of Learning Scorecard, version 2, developed by Miguel Lopes [**28**] during the 2020/2021 academic year at ISCTE-IUL. This version constituted a complete platform redevelopment rather than incremental enhancement, motivated by critical limitations that had accumulated across three previous iterations.

Lopes' [**28**] key contributions to this version were the implementation of a semantic web through the application of ontologies and integration of a GraphQL [**29**] semantic database, the application of a structured mechanism for continuous student feedback on learning difficulties and a shift from the monolithical three tier architecture into a cloud-native, microservices design that enabled scalability and multi-institutional deployment.

In this version, the sylabus contents could be stored in the GraphDB database and displayed to the students as a better way to visualize the course's contents as shown in figure 4.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Quests
Guilds
Grades
Evaluation
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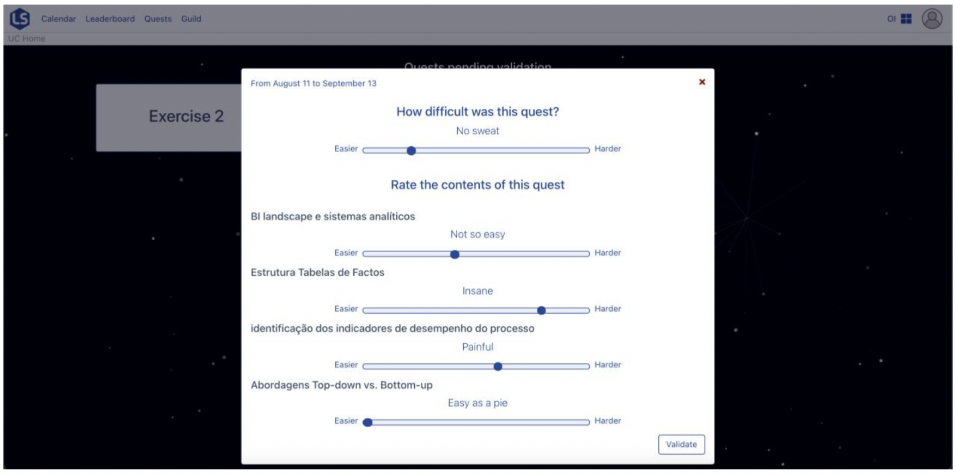
Extração
Limpeza dados
Building Fact tables
Transformação
Managing SCD
Carregamento
Sistemas analíticos versus sistemas operacionais
Princípios da Modelação Dimensional
Factos e dimensões
Estrutura dos modelos multidimensionais
Bases de dados relacionais e normalização
Desenho de modelos dimensionais
Múltiplas tabelas de factos
Tabelas de factos vs processos negócio
Drilling-across
Enterprise DW
Data marts
Dimensões conformes
Factos conformes
Desenho de tabelas de factos
Tipos de Tabelas de Factos (TF)
TF Snapshots Periódico (TF-SP)
TF Snapshots Cumulativo (TF-SC)
TF Factless
TF Transaccional (TF-T)
Desenho de tabelas dimensão
Slowly Changing Dimensions (SCD)
Linhas especiais (N/A)
Drill-up e drill-drown
Junk Dimensions
Hierarquias
Role-playing dimensions
Mini-Dimensions
Conceitos avançados
Multi-valued attributes
Multi-valued dimensions
Outtrigger
Bridge tables
Matriz de métricas vs dimensões
Modelação dimensional ágil
BI model canvas
Metodologia BEAM
Desenho físico modelos dimensionais
Aggregates
Derived Schemas
Matriz de validação do desenho físico (queries vs métricas)
Arquiteturas de Data Warehouse
Arquitectura Kimball- data marts dimensionais
Arquitectura Data marts independentes
Arquitectura Inmon - CIF
Cubos
Abordagens Top-down vs. Bottom-up
Definição de requisitos
Enterprise DW Bus Architecture matrix
descrição do processo negócio
identificação dos indicadores de desempenho do processo
definição de queries de análise
requisitos programa DW vs requisitos projecto DW
Introdução aos sistemas de BI e DSS
BI landscape e sistemas analíticos
Tipos de DSS
Sistemas de DWBI: conceitos fundamentais
Introdução aos conceitos de Analytics
Fundamentos de modelação dimensional
Estrutura Tabelas de Factos
Classificação dos factos de acordo com a aditividade
Identificação de factos
Relação entre as Tabelas de Factos e os processos de negócio organizacionais
Dimensões Degeneradas
Declaração do grão de uma Tabela de Factos
Estrutura tabelas Dimensão
Snowflakes
Conjunto rico de dimensões
surrogate keys (SK)
Agrupamento de dimensões em Tabelas de Dimensão
Implementação de Aplicações de BI
BI tools
Excel Powerpivot e Power BI
Tableau
Carregamento Povoamento dimensões
Desenho implementação de hiearquias
Desenho e implementação do dashboard
Carregamento Povoamento TF

Figure 4. Sylabus Contents of an UC. Source: Lopes M. [**28**].

The learning difficulties of students could be gathered through a questionnaire after every quest (see figure 5), presented to students as a quest validation that would give the quests XP upon completion. This would provide the faculty a better view of the students challenges and feedback on the lessons, as well as what needed to be revised as demonstrated in the figure 6.



From August 11 to September 13

How difficult was this quest?

No sweat

Easier ○ Harder

Rate the contents of this quest

BI landscape e sistemas analíticos

Not so easy

Easier ○ Harder

Estrutura Tabelas de Factos

Insane

Easier ○ Harder

identificação dos indicadores de desempenho do processo

Painful

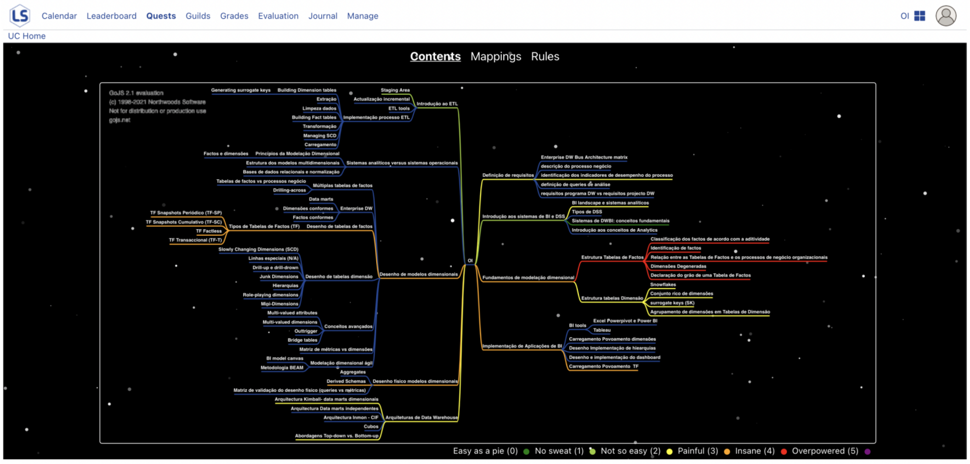
Easier ○ Harder

Abordagens Top-down vs. Bottom-up

Easy as a pie

Easier ○ Harder

Figure 5. Difficulty questionnaire (quest validation). Source: Lopes M. [**28**].


LS
Calendar
Leaderboard
Quests
Guilds
Grades
Evaluation
Journal
Manage
OI
UC Home
Contents
Mappings
Rules
GoJS 2.1 evaluation
(c) 1998-2021 Northwoods Software
Not for distribution or production use
gojs.net
Generating surrogate keys
Building Dimension tables
Staging Area
Extração
Actualização incremental
Introdução ao ETL
Limpeza dados
ETL tools
Building Fact tables
Implementação processo ETL
Transformação
Managing SCD
Carregamento
Factos e dimensões
Princípios da Modelação Dimensional
Estrutura dos modelos multidimensionais
Sistemas analíticos versus sistemas operacionais
Bases de dados relacionais e normalização
Tabelas de factos vs processos negócio
Múltiplas tabelas de factos
Drilling-across
Data marts
Dimensões conformes
Enterprise DW
Factos conformes
TF Snapshots Periódico (TF-SP)
TF Snapshots Cumulativo (TF-SC)
Tipos de Tabelas de Factos (TF)
Desenho de tabelas de factos
TF Factless
TF Transaccional (TF-T)
Slowly Changing Dimensions (SCD)
Linhas especiais (N/A)
Drill-up e drill-drown
Junk Dimensions
Desenho de tabelas dimensão
Desenho de modelos dimensionais
Hierarquias
Role-playing dimensions
Mipi-Dimensions
Multi-valued attributes
Multi-valued dimensions
Conceitos avançados
Outtrigger
Bridge tables
Matriz de métricas vs dimensões
BI model canvas
Modelação dimensional ágil
Metodologia BEAM
Aggregates
Derived Schemas
Desenho físico modelos dimensionais
Matriz de validação do desenho físico (queries vs métricas)
Arquitectura Kimball- data marts dimensionais
Arquitectura Data marts independentes
Arquitectura Inmon - CIF
Arquiteturas de Data Warehouse
Cubos
Abordagens Top-down vs. Bottom-up
OI
Definição de requisitos
Enterprise DW Bus Architecture matrix
descrição do processo negócio
identificação dos indicadores de desempenho do processo
definição de queries de análise
requisitos programa DW vs requisitos projecto DW
Introdução aos sistemas de BI e DSS
BI landscape e sistemas analíticos
Tipos de DSS
Sistemas de DWBI: conceitos fundamentais
Introdução aos conceitos de Analytics
Fundamentos de modelação dimensional
Estrutura Tabelas de Factos
Classificação dos factos de acordo com a aditividade
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Implementação de Aplicações de BI
BI tools
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Tableau
Carregamento Povoamento dimensões
Desenho Implementação de hiearquias
Desenho e implementação do dashboard
Carregamento Povoamento TF
Easy as a pie (0) ● No sweat (1) ● Not so easy (2) ● Painful (3) ● Insane (4) ● Overpowered (5) ●

Figure 6. Syllabus contents with difficulty perceived by students. Source: Lopes M. [28].

Further technical investigation will come when analyzing the current state of the application in chapter 4 of this dissertation.

3.2.2. Lessons Learned from Prior Iterations

The evolutionary development of the Learning Scorecard has yielded important insights into the challenges and opportunities associated with educational technology implementation in higher education contexts. These lessons have directly informed the design decisions underlying Learning Scorecard 3.0 and provide valuable guidance for future LS development efforts.

Previous iterations consistently revealed the critical importance of seamless integration with existing institutional systems and workflows. Standalone implementations, while providing flexibility and autonomy, created barries to adoption through the requirement for separate authentication, manual data entry and navigation between multiple platforms. These experiences highlighted the need for deeper integration with institutional learning management systems to achieve sustainable adoption and effectiveness.

Analysis of user behavior accross previous versions revealed important patterns regarding the factors that drive sustained engagement with educational technology platforms. Students demonstrated higher levels of engagement when gamification elements were seamlessly integrated with existing academic workflows rather than requiring separate platform visits or additional effort investment. Faculty adoption correlated strongly with the availability of actionable insights that directly supported pedagogical decision-making without creating additional workload or administrative burden.

The operational experience of maintaining standalone Learning Scorecard implementations revealed significant challenges related to infrastructure costs, security management and version compatibility. These experiences demonstrated the advantages of leveraging existing institutional infrastructure and support systems rather than maintaining separate technological stacks that require independent updates, security monitoring and user support.

3.3. Learning Scorecard Conceptual Framework

The Learning Scorecard (LS) conceptual framework encompasses a comprehensive set of interconnected concepts designed to support gamified learning experiences in higher education. This framework is organized around four primary domains that reflect different aspects of the educational experience: Academic Structure and Organization, Gamification Mechanics, Social Learning. These concepts can be organized into four primary domains: Academic Structure, Gamification Mechanics, Social Learning and Recognition and Achievement Systems. Each domain contains interconnected concepts that work together to create a comprehensive educational technology ecosystem that supports both individual learning, cooperation and institutional objectives.

3.3.1. Academic Structure and Organization

The academic foundation of the Learning Scorecard is built upon traditional higher education organizational structures, adapted to support digital learning environments.

Courses and Curricular Units. The system recognizes a two-tier academic structure where *Courses* represent overarching academic programs (e.g., "Computer Science") that encompass multiple *Curricular Units*. Each Curricular Unit corresponds to an individual subject with specific learning objectives, content and assessments that students must complete as part of their academic progression. This hierarchical organization maintains consistency with traditional academic frameworks while enabling digital tracking and gamification.

Students and Faculty. The system accommodates two primary user roles: *Students*, who are enrolled in one or more Curricular Units and participate in gamified learning activities and *Teachers* or Faculty members, who are responsible for creating and managing curricular content, designing learning activities and monitoring student progress within their assigned Curricular Units.

Syllabus Contents, Calendar and Timeline. *Syllabus Contents* encompass all learning materials, resources and educational content within a Curricular Unit. The organizational framework includes both *Calendar* and *Timeline* concepts that serve as complementary planning systems, enabling students and faculty to organize learning activities and maintain temporal awareness of curricular progression.

3.3.2. Gamification Mechanics

The core gamification elements provide the foundation for student engagement and progress tracking through game-like mechanics adapted to educational contexts.

Experience Points and Ranks. *Experience Points* (XP) serve as the fundamental currency of progress within the platform, earned through completion of various educational activities. The *Rank* system establishes hierarchical progression levels based on accumulated XP, including ranks such as Newbie (entry level at 0 XP), Rookie, Skilled Expert, Master and Legendary. Faculty members can configure rank thresholds dynamically, with each rank unlocking new privileges and recognition within the platform.

Quests. *Quests* represent the core educational activities that students complete to earn XP and demonstrate learning. The system categorizes quests into five distinct types: Class Attendance, Practical Assignment, Quiz, Exercise and Event. Each quest can be designated as mandatory (milestone quests) or optional, providing flexibility in curriculum design while maintaining educational objectives.

Last Chances. The *Last Chance* mechanism provides opportunities for recovery and continued engagement when students fall behind or make mistakes, preventing permanent failure states that could lead to disengagement and ensuring continued participation throughout the academic term.

3.3.3. Social Learning

The social components of the Learning Scorecard foster collaboration and healthy competition among students through structured group dynamics.

Alliances. *Alliances* function as large-scale organizational units that typically correspond to academic classes or programs (e.g., LEI or ETI). These structures facilitate competition and comparison at the class level while maintaining educational coherence, enabling students to compare their progress through dedicated leaderboards and participate in alliance-specific activities.

Guilds. *Guilds* represent smaller collaborative units within alliances, typically corresponding to project teams or study groups. The guild system promotes cooperative learning by encouraging mutual assistance among members, with guild-specific achievements, badges and leaderboards fostering team spirit while maintaining individual accountability within the collaborative framework.

3.3.4. Recognition and Achievement System

The recognition framework provides multiple pathways for acknowledging student accomplishments and maintaining motivation through visible achievements.

Badges. The *Badge* system provides targeted recognition for specific accomplishments and behaviors, featuring 39 different badges organized into four categories: individual achievements, guild-based accomplishments, forum participation and final questionnaire completion. Each category includes multiple tiers (bronze, silver, gold and platinum) corresponding to increasing levels of difficulty and commitment.

Trophies. *Trophies* represent the highest level of achievement, awarded to top performers in various leaderboard categories including overall rankings (Best Score Player), guild performance (Best Guild) and combined metrics (Best Triathlon Player). Each trophy provides substantial XP rewards (typically 1000 XP) and serves as a highly visible symbol of excellence.

Avatars. The *Avatar* system enables profile customization while serving as a visual indicator of progression. Students unlock new avatar options as they advance through rank levels, with both male and female options available at each tier, allowing for personal expression while maintaining the connection between visual representation and academic achievement.

Leaderboards. Multiple *Leaderboard* systems enable various forms of competition and comparison through five distinct categories: overall individual rankings, guild-based comparisons, exercise-specific performance, quiz results and combined metrics. Each leaderboard displays position, username, rank, avatar and XP totals, creating transparency in academic performance while fostering healthy competition among participants.

CHAPTER 4

System Architecture and Design

4.1. Requirements

An imperative aspect in any application conceptualization is a thorough requirement analysis. These requirements can be functional (FR) or non functional (NFR) and shape the architectural decisions that are made during its development as well as assessing whether a system will succeed.

Functional Requirements (FR)

It's important to define what an engineer should strive for when determining functional requirements as it will ultimately be what defines an application, molds its functionality and consequently decides it's architecture. Functional requirements are the essential characteristics that the system should deliver that the end-user specifically demands. [**30**] A simpler way to perceive it is that they define what the system should perform. It's important with any version increment of the LS to maintain fidelity to the previous requirements and adjust them when appropriate. Costa [**21**] identified base functional requirements which I will evaluate and integrate into my system architecture, but also define some myself.

FR1 The LS platform must use Moodle's existing authentication and user management systems.

FR2 The LS platform must be integrated with the e-learning system, providing seamless access to student data, course data and activities.

FR3 The LS Platform must use Moodle's role-based access control mechanisms, distinguishing between student and teacher user types with corresponding permissions and interfaces.

FR4 The LS platform must have a dashboard for individual student performance monitorization (students view)

FR5 The LS platform must have a dashboard for class performance monitorization (teacher view)

FR6 The LS platform must have a course chronogram with deadlines and study guidelines, personalized by the teacher/faculty

FR7 The LS platform must include gamification elements (score, ranks, quests, leaderboards)

Non-Functional Requirements (NFR)

Another important aspect of the requirement analysis is to define the non-functional requirements. These, differently from their functional counterpart must define how the system should perform, rather than what. While not directly visible as features they are vital in shaping the user experience and ensuring the system's long-term success. A few examples of these requirements could be performance, security, reliability, etc. Costa [**21**] also layed out base non-functional requirements which I will also evaluate, adapt and integrate into my system architecture, in addition to some identified by myself. From Costa's non-functional requirements:

NFR1 Portability for the different web browsers, including mobile devices

NFR2 Intuitive and user-friendly interface (least possible manual input by students)

NFR3 The user identification data must be private (ethical requirement), the teacher/faculty must only have access to the class agregated data, even for at risk students.

This last non-functional requirement, as Costa [**21**] correctly identified is a missed opportunity as the faculty will have no way of knowing which student is at risk and ultimately take advantage of such introspective metrics on student performance. As the system is integrated into moodles learning environment and all this information is already available to the faculty I believe this NFR should be altered into a more transparent requirement and only require anonymization of students the data if the Learning Scorecard extended its functionality to allow for a predictive model to be set in place to predict the outcome of the students grade based on current effort. Therefore, the corrected NFR3 is:

NFR3 The user identification data must be private (ethical requirement) in case it's used in colaboration with a predictive model for the grades. The teacher must only have access to the class agregated data.

Throughout the study and conceptualization of the system a few more non-functional requirements were identified:

NFR4 The system must be installable as standard Moodle plugin(s) without requiring server modification.

NFR5 The system must maintain visual consistency with the Moodle theme.

NFR6 The system must store all data within the Moodle database structure.

4.2. Overview of LS Architecture

4.2.1. Evolution from Standalone Architecture

The LS architecture has withstood many iterations throughout the years and has become more complex and polished through them, as new features have been added, alternatives and changes in architecture have been thought as most adequate. Let's suppose we take the latest version as a baseline and dive into what can be improved.

In the latest version of the Learning Scorecard, version 2.0, as documented by Miguel Lopes [**28**] the technological stack consisted of React [**31**] frontend components communicating with Express [**32**] (NodeJS [**25**]) backend services, which in turn interfaced through REST with a cloud-hosted NoSQL MongoDB database [**33**] and GraphDB [**29**] system deployed in Azure infrastructure [**34**] primarily hosted in Heroku [**35**].

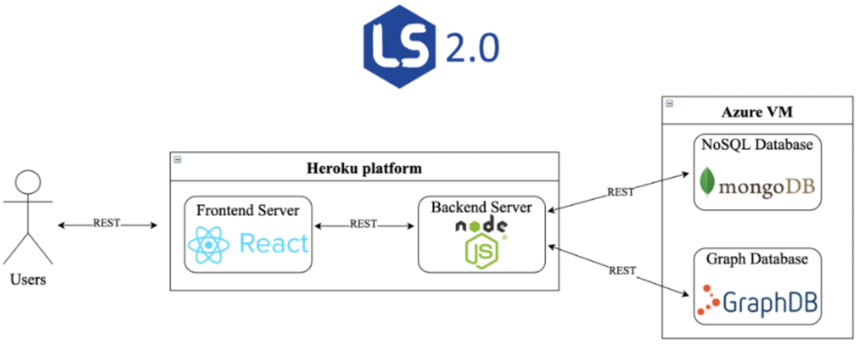


FIGURE 1. LS 2.0 architecture. Source: Lopes M. [**28**].

While this architecture demonstrated scalabilty, modularity and adherence to modern web development practices, it presented several critical limitations, mainly in the fact that it is not integrated with the ISCTE Moodle environment (FR2), relying on manual input by the faculty and students making it not an ideal system and one that would become more of a chore for teachers who have most commonly multiple classes to teach, register and manage and students who also have multiple classes, quizes and exercises to keep track of.

We must then conjure a system that is integrated with the ISCTE moodle environment and satisfies all functional and non-functional requirements set previously.

At first glance, it is possible to achieve a more integrated system making use of the platform developed previously with the use of the moodle native web services, although the standalone nature necessitated separate authentication systems, creating friction for users who must maintain multiple credentials and navigate between distinct platforms. The external infrastructure dependencies resulted in ongoing operational costs, particularly following Heroku's discontinuation of free tier services [**36**], and introduced security vulnerabilities through external data hosting that may not align with institutional data governance policies.

4.2.2. Plugin-Based Architecture Benefits

The Learning Scorecard 3.0 plugin-based architecture approach addresses these limitations through direct integration with Moodle's comprehensive infrastructure and Service API ecosystem. This approach provides several critical advantages that enhance both technical capabilities and institutional viability.

Infrastructure Integration By operating within Moodle's establish infrastructure, LS 3.0 eliminates external hsting requirements and associated costs while ensuring compliance with institutional security and data governance policies. The platform leverages existing ISCTE server infrastructure, Apache web servers and database systems without requiring additional resources or maintenance overhead.

Authentication and User Management Integration with Moodle's authentication system erases the need for separate user credentials and login processes, reducing friction for students and faculty while ensuring consistency with institutional access policies. The platform automatically inherits Moodle's sophisticated role and permission systems, enabling fine-grained access control without additional implemenetation complexity.

Data Ecosystem Access Perhaps most critically, the plugin arhitecture provides direct access to Moodle's comprehensive student activity and performance data, enabling automated data collection and real-time analytics without manual input requirements. This access includes quiz results, assignment submissions, forum participation, resource access patterns and completion tracking data that can be seamlessly integrated into gamification and analytics workflows.

User Experience Consistency The plugin approach ensures visual and functional consistency with existing institutional interfaces, reducing learning curves for users and promoting adoption through familiar interaction patterns. Students and faculty can access Learning Scorecard fuctionality without leaving their established academic workflows.

4.2.3. Concept Mapping & Integration Analysis

The successful integration of Learning Scorecard functionality within Moodle's existing architecture requires comprehensive analysis of conceptual alignments and implementation feasibilities. This mapping process identifies opportunities for leveraging existing Moodle capabilities while determining areas that require custom implementation to preserve Learning Scorecard's legacy features.

Table 1. Learning Scorecard vs Moodle Concept Mapping

Concept	Moodle	Feasibility
	Academic	
Course	Course Categories	T
Curricular Unit	Course	T
Student	Users & Roles	T
Teacher / Faculty	Users & Roles	T
Syllabus Contents	Course Modules & Tags	T
Calendar	Calendar Events	P
Timeline	Activity Completion & Progress	P
	Gamification	
Experience Points	Grade Items & Custom Fields	P
Ranks	Custom Implementation	P
Quests	Activities	T
Alliances	Groups & Cohorts	T
Guilds	Groups	T
Badges	Badges System	T
Trophies	Badges System & Custom Impl.	P
Avatars	User Profiles, Files & Custom Impl.	P
Leaderboards	Gradebook & Custom Views	P
Last Chance System	Conditional Activities	P

T - Total Mapping P - Partial Mapping

Total Mappings (T)

Total mappings exist when there are Moodle native functionalities that directly support the LS concept, no additional data structures or logic are required, integration can be achieved through standard API or database access or the semantic meaning aligns perfectly. That's the case for the concepts:

- Course: Moodle natively supports course categorizations that represent university courses such as "Computer Science".
- Curricular Unit: Perfect mapping, each LS curricular unit corresponds direcly to a Moodle course.
- Student/Teacher: Moodle's role-based access control system directly supports student and teacher roles. Permissions and course access are natively managed.
- Sylabus Contents: Moodle's course module system supports 16 content types (files, URLs, pages, quizzes, etc.). Tags provide semantic classification that LS requires.
- Quests: Direct conceptual mapping of LS quests and Moodle activities. All necessary attributes available (deadlines, grading, completion tracking, etc.).
- Alliances/Guilds: Moodle's native group system supports both course level groups (guilds) and institution-wide cohorts (alliances).

- Badges: Moodle includes a native badge system, with support for criteria-based awarding and display.

Partial Mappings (P)

A partial mapping occurs when Moodle provides a foundation but lacks specific LS requirements. These requirements can be achieved through custom development of business logic, user interface or data structures or the concept requires extending or combining multiple Moodles features. This additional effort is evident in the following concepts:

- Calendar: While Moodle has a native calendar, extra quest metadata (XP values, difficulty, etc.) is not native and thus requires additional implementation.
- Timeline: Moodle tracks activity completion but doesn't provide LS's chronological timeline view, it requries pulling data from multiple tables and creating a custom visualization.
- Experience Points: Moodle's gradebook can store percentage/point-based values but isn't designed for XP systems. Further development is needed, such as creating custom tables to store XP per activity and logic to calculate and award XP based on quest completion through events and to display it.
- Ranks: Moodle has no concept of progression ranks. It is required to create entirely new data structures, rank-up notifications and visualization of rank and rank progress.
- Trophies: While badges provide the base, trohpies have specific implementation efforts required, such as leaderboard-based logic and visualization.
- Avatars: Moodle allows profile pictures but not customizable avatar systems. Further development in avatar selection/customization interfaces and storage as well as logic for the unlocks is required.
- Leaderboards: Moodle's gradebook presents grades but not competitive rankings. Additionally, it has no native leaderboard view and requires aggregating data from multiple tables.
- Last Chance System: Moodle's conditional access provides a foundation but lacks "second chance" mechanics. Complex business logic beyond Moodle's simple conditional rules is required.

4.3. Development Environment and Technical Infrastructure

The establishment of a robust, consistent and production-like development environment proved critical for the successful implementation of LS 3.0. The complexity of Moodle plugin development, combined with the need for the system to mimick the production environment as much as possible, required careful consideration of development infrastructure and tooling decisions.

4.3.1. Development Environment Evolution

The development environment configuration process revealed important insights into the requirements and challenges of Moodle plugin development, ultimately leading to the identification of optimal approaches for maintaining development productivity and most importantly, system reliability.

The initial development approach employed XAMPP [**37**] to provide a local PHP environment, apache server and Mysql database infrastructure, imperative for standalone Moodle instance execution. However, this approach demonstrated significant limitation that compromised development reliability and consistency. File persistence issues following server restarts and unpredicatable system behavior created an unstable foundation that was incompatible with the production-like development environment required for plugin implementation.

The second development approach investigated Docker containerization [**38**] with orchestrated Bitnami Moodle image [**39**] to achieve improved consistency and reproducibility. While this approach initially showed promise through improved container persistence and more predictable behavier, plugin integration revealed critical limitations. The Bitnami image implemented included automated Moodle configuration processes that incorrectly identified plugin additions as corrupted system files, triggering unwanted fresh installations that compromised the continuity of the plugin's development and was therefore excluded from consideration for the final Moodle development environment.

The final development environment employed custom docker container orchestration with separate Apache server and MariaDB database [**40**] images, enabling manual Moodle configuration that avoided the automated configuration issues encountered with pre-built images (like Bitnami's). Although with the increased effort of configuring the apache server and installing the same Moodle version as the production ISCTE 2024/2025 Moodle instance (version 4.4.1) and all the necessary dependencies this approach provided the stability, consistency and production-like behavior expected and required for reliable plugin development.

4.4. Plugin Integration with Moodle

There are multiple types of moodle plugins and depending on their purpose we should select the most adequate. According to the specification of the Learning Scorecard we would need to evaluate what plugin type is better suited.

Moodle's comprehensive plugin architecture [**41**] provides multiple plugin types, each optimized for specific functionality categories and integration patterns. The Learning Scorecard implementation requirements necessitated evaluation of plugin types to ensure appropriate functionality distribution and optimal integration with Moodle's existing systems.

Block plugins emerged as the optimal choice for user-facing dashboard and metric displays. The block architecure's deisgn for small, configurable information displays that can be positioned throughout Moodle's interface aligns perfectly with Learning Scorecard's requirement for accessible gamification metrics within existing workflows. block plugins enable experience point displays, ranking information and progress metrics to be seamlessly integrated into student and faculty dashboards without requiring navigation to separate interfaces.

Local plugins generic specification provide the appropriate architecture for additional LS functionality, including leaderboards, Learning Scorecard configuration, database table creation, etc.

The modular plugin approach requires appropriate directory organization within Moodle's established file structure. Block plugins are installed within the *"/blocks"* directory, while local plugins reside in the *"/local"* directory, ensuring compliance with Moodle's architectural standards and enabling proper plugin discovery and management through Moodle's administrative interfaces.

CHAPTER 5

Learning Scorecard 3.0

5.1. Methodological Approach

The development methodology employed for the Learning Scorecard 3.0 synthesizes principles from agile software development. This methodological approach recognizes the iterative nature where continuous refinement throughout the development process is imperative for successful delivery.

Initially it was intended for the implementation to follow a structured sprint-based approach with clearly defined objectives for each development iteration. Initial sprints focused on setting up a stable, production-like development environment, ensuring that the subsequent feature development could proceed upon a robust technical foundation.

Subsequent stories tackled the core functionalities of the LS 3.0, such as leaderboards, experience points, database aggregation and finally, the block plugin.

Even though the story implementations were ongoing and iterative, the dissertation development however did not follow the methodology strictly. This decision stemmed from the adoption of a lean agile approach tailored to individual academic research. In the absence of a development team, traditional agile ceremonies such as daily standups, sprint planning and team retrospectives were deemed unnecessary overhead. In this context, the methodology evolved organically toward a more streamlined process that preserved agile's iterative essence while acknowledging the realities of solo development in an academic setting. Weekly review sessions with supervisors Prof. Elsa Cardoso and Prof. José Barateiro functioned as consolidated sprint reviews and retrospectives, providing critical feedback loops while maintaining development momentum.

This adapted approach enabled rapid iteration and continuous validation while maintaining academic rigor throughout the development process.

5.2. Database Design and Data Integration

When designing the database for this dissertation's proof of concept it was imperative to adhere to the objectives previously defined, integrate with Moodle's infrastructure and guarantee the security and integrity of the student data.

The Learning Scorecard 3.0 employs a hybrid database architecture that combines Moodle's native database with custom LS-specific tables that support the gamification features. To ensure seamless integration with Moodle and maintaining data integrity and security, LS 3 employs Moodle's standardized schema definition approach for adding custom tables to the Moodle database.

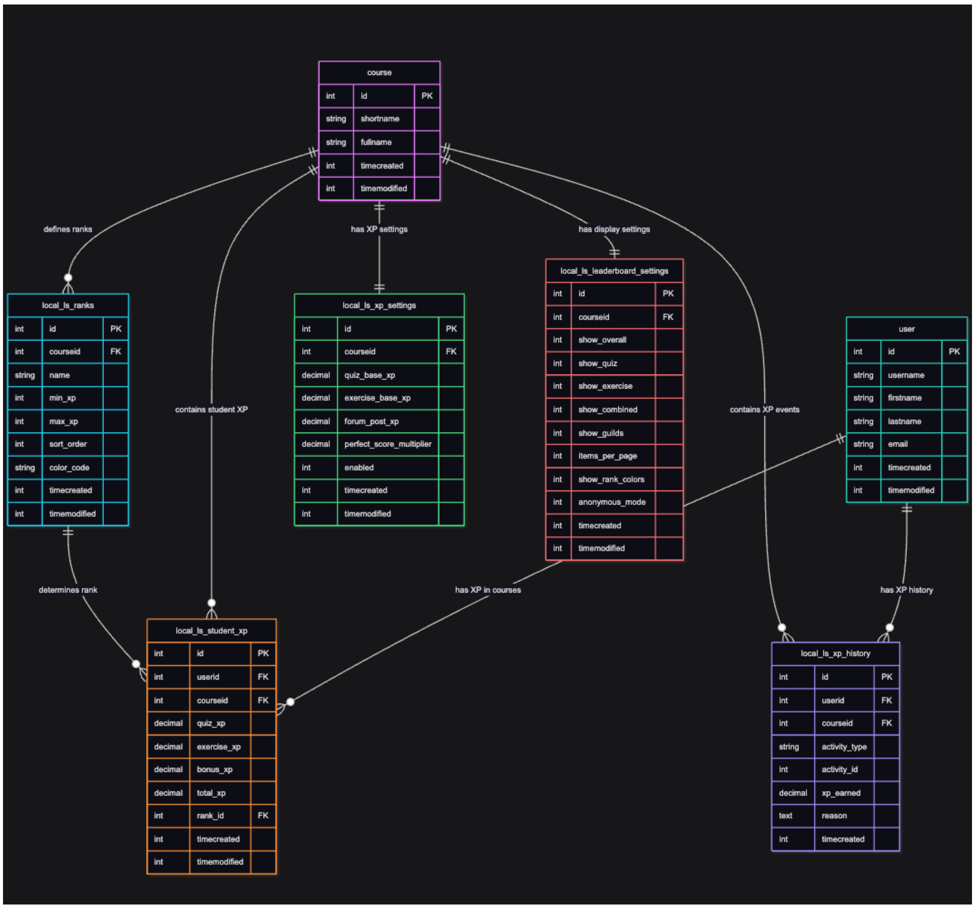
Following Moodle's plugin development best practices, LS 3 defines it's custom database schema using the XML Database Definition Language. The file *db/install.xml* specifies the structure of gamification related tables that are automatically created during plugin installation. This solution provides several advantages:

- Version Control: Schema changes are tracked and can be upgraded systematically through moodle upgrade mechanism.
- Database Portability: The XML definition ensures compatibility across different database management systems (MySQL, MariaDB, PostgreSQL, etc.).
- Automatic Installation: Tables are created during the LS plugin's installation, avoiding manual database setup.
- Moodle Integration: The custom tables follow Moodle's naming convention *"mdl_*"* and integrate seamlessly with Moodle's database API.

By leveraging Moodle's database access LS 3 is able to extract and perform event-driven processing of activity data using the observer pattern, it is also able to make direct database queries to native tables, real-time calculation of XP when events are triggered and data validation of grades to ensure only valid and released grades are displayed and able to provide XP.

LS 3, in this first iteration, provides five extra tables:

1. *local_ls_ranks*: Table for storing the rank name, color and thresholds per course
2. *local_ls_student_xp*: Table for storing calculated XP totals and rank per student/course
3. *local_ls_xp_settings*: Configuration table for XP calculation parameters per course
4. *local_ls_leaderboard_settings*: Configuration table for Leaderboard visualization per course
5. *local_ls_xp_history*: Audit trail table for logging every XP transaction



course		
int	id	PK
string	shortname	
string	fullname	
int	timecreated	
int	timemodified	

local_ls_ranks		
int	id	PK
int	courseid	FK
string	name	
int	min_xp	
int	max_xp	
int	sort_order	
string	color_code	
int	timecreated	
int	timemodified	

local_ls_xp_settings		
int	id	PK
int	courseid	FK
decimal	quiz_base_xp	
decimal	exercise_base_xp	
decimal	forum_post_xp	
decimal	perfect_score_multiplier	
int	enabled	
int	timecreated	
int	timemodified	

local_ls_leaderboard_settings		
int	id	PK
int	courseid	FK
int	show_overall	
int	show_quiz	
int	show_exercise	
int	show_combined	
int	show_guilds	
int	items_per_page	
int	show_rank_colors	
int	anonymous_mode	
int	timecreated	
int	timemodified	

user		
int	id	PK
string	username	
string	firstname	
string	lastname	
string	email	
int	timecreated	
int	timemodified	

local_ls_student_xp		
int	id	PK
int	userid	FK
int	courseid	FK
decimal	quiz_xp	
decimal	exercise_xp	
decimal	bonus_xp	
decimal	total_xp	
int	rank_id	FK
int	timecreated	
int	timemodified	

local_ls_xp_history		
int	id	PK
int	userid	FK
int	courseid	FK
string	activity_type	
int	activity_id	
decimal	xp_earned	
text	reason	
int	timecreated	

Figure 1. Entity Relations diagram (course is a moodle table shortened for context)

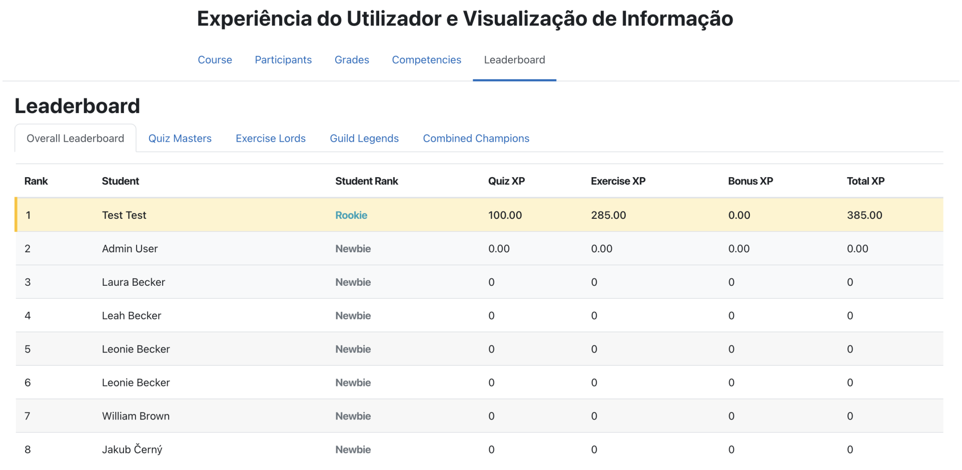
5.3. Core Features

Learning Scorecard 3.0 serves as a proof of feasibility of the system's architecture and thus this iteration will provide the basis of the previous functionality while being extensible to future iterations. At the current state of this dissertation the LS has the folowing core features.

5.3.1. Leaderboards

This iteration of the Learning Scorecard provides five distinct leaderboards: Overall, Quiz Masters, Exercise Lords, Guild Legends and Combined Champion. Each present different metrics and calculate the rankings differently.

Overall Leaderboard is the aggregation of all quest XP and calculates the ranking based on overall course performance.

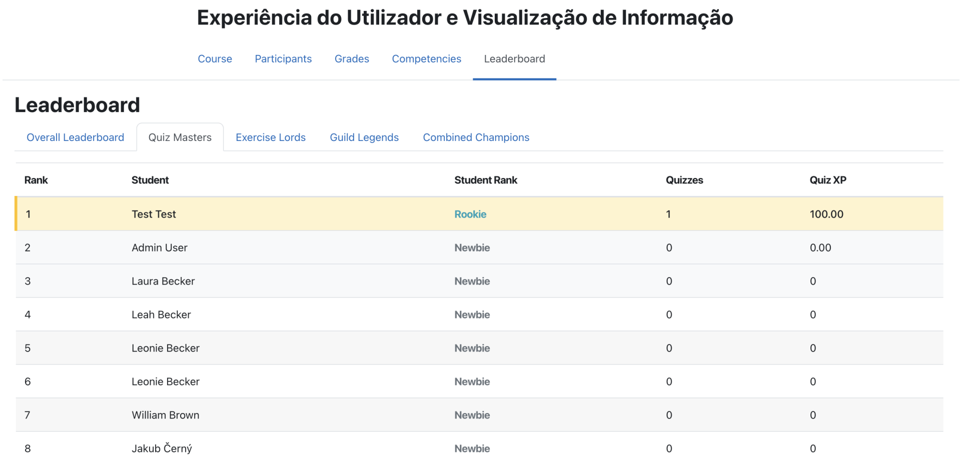


Leaderboard

Rank	Student	Student Rank	Quiz XP	Exercise XP	Bonus XP	Total XP
1	Test Test	Rookie	100.00	285.00	0.00	385.00
2	Admin User	Newbie	0.00	0.00	0.00	0.00
3	Laura Becker	Newbie	0	0	0	0
4	Leah Becker	Newbie	0	0	0	0
5	Leonie Becker	Newbie	0	0	0	0
6	Leonie Becker	Newbie	0	0	0	0
7	William Brown	Newbie	0	0	0	0
8	Jakub Černý	Newbie	0	0	0	0

FIGURE 2. Overall Leaderboard Interface

Quiz Masters focuses on the quiz quest XP and the rankings are calculated based on it and bonus XP, experience points that are the multiplication of the grade by the score multiplier defined in the courses LS settings.

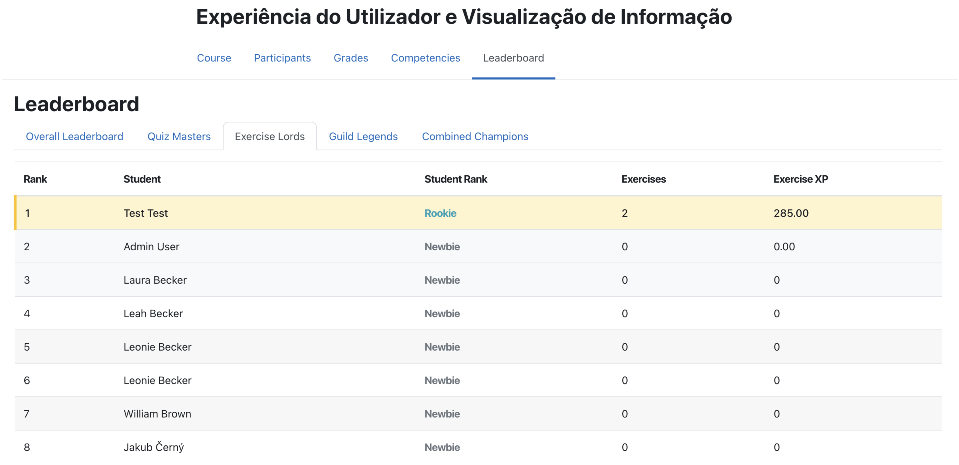


Leaderboard

Rank	Student	Student Rank	Quizzes	Quiz XP
1	Test Test	Rookie	1	100.00
2	Admin User	Newbie	0	0.00
3	Laura Becker	Newbie	0	0
4	Leah Becker	Newbie	0	0
5	Leonie Becker	Newbie	0	0
6	Leonie Becker	Newbie	0	0
7	William Brown	Newbie	0	0
8	Jakub Černý	Newbie	0	0

FIGURE 3. *Quiz Masters* Leaderboard Interface

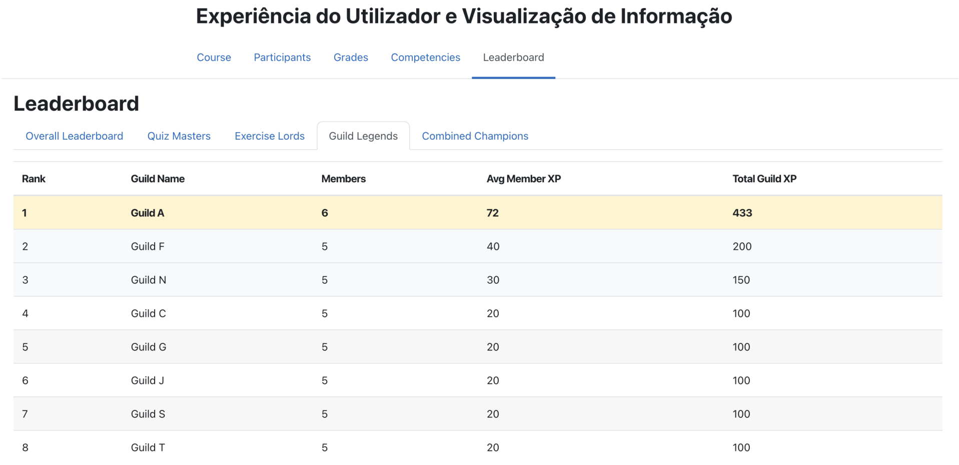
Exercise Lords follows the same formula, exercise quest XP plus the product of the grade by the score multiplier.



Rank	Student	Student Rank	Exercises	Exercise XP
1	Test Test	Rookie	2	285.00
2	Admin User	Newbie	0	0.00
3	Laura Becker	Newbie	0	0
4	Leah Becker	Newbie	0	0
5	Leonie Becker	Newbie	0	0
6	Leonie Becker	Newbie	0	0
7	William Brown	Newbie	0	0
8	Jakub Černý	Newbie	0	0

Figure 4. *Exercise Lords* Leaderboard Interface

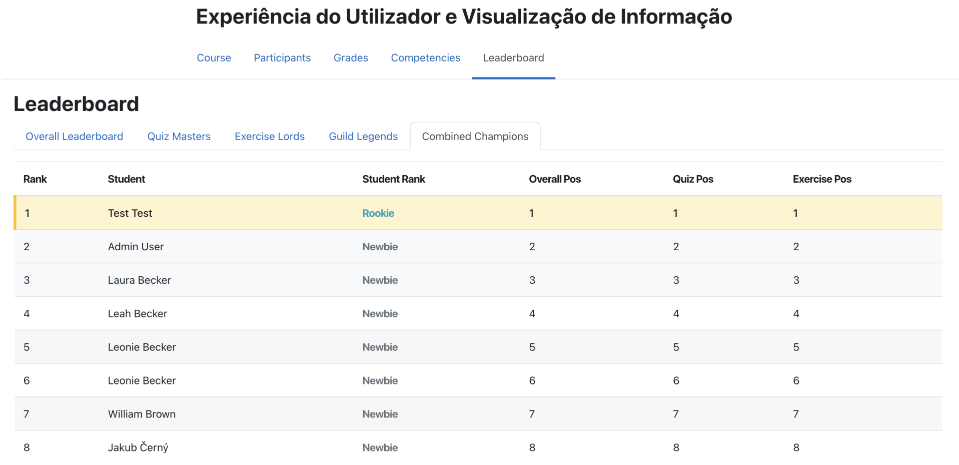
Guild Legends is a leaderboard for the guilds, all members of the guilds contribute equally for the guild's ranking in this leaderboard. It is achieved through the Moodle's native groups that the teacher or faculty can create.



Rank	Guild Name	Members	Avg Member XP	Total Guild XP
1	**Guild A**	**6**	**72**	**433**
2	Guild F	5	40	200
3	Guild N	5	30	150
4	Guild C	5	20	100
5	Guild G	5	20	100
6	Guild J	5	20	100
7	Guild S	5	20	100
8	Guild T	5	20	100

Figure 5. *Guild Legends* Leaderboard Interface

Combined Champion's rankings are calculated by the accumulation of all other guild's (except for the Guild Legends) leaderboard positions. The student with the highest rankings on average will be ranked first in it.



Rank	Student	Student Rank	Overall Pos	Quiz Pos	Exercise Pos
1	Test Test	Rookie	1	1	1
2	Admin User	Newbie	2	2	2
3	Laura Becker	Newbie	3	3	3
4	Leah Becker	Newbie	4	4	4
5	Leonie Becker	Newbie	5	5	5
6	Leonie Becker	Newbie	6	6	6
7	William Brown	Newbie	7	7	7
8	Jakub Černý	Newbie	8	8	8

FIGURE 6. *Combined Champions* Leaderboard Interface

These leaderboards have dynamic ranking, meaning that the positions are calculated in real-time, providing the most accurate and actual results for the students. Displayed, there is the position in the leaderboard, the student's name and the student's rank, except for the guild leaderboard where a guild name is preferred.

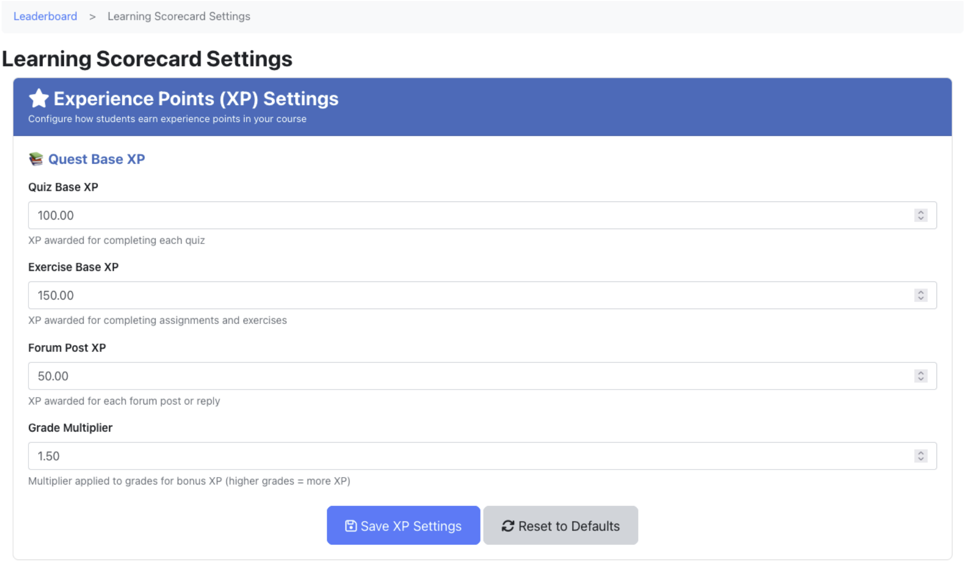
The user interfaces are built using Moodle's native tab navigation for seamless integration and styling consistency, maintaining the classic Moodle look without appearing out of place in the course page.

5.3.2. Learning Scorecard Settings

The Learning Scorecard settings page provides an administrative interface for teachers and faculty to customize the gamification parameters of the course. This configuration system allows fine-grained control over how students earn experience points, ranks and of the LS interfaces.

The settings page is only accessible to user with course management capabilities, ensuring that only teachers and faculty can modify the LS parameters. The page integrates with Moodle's security framework through session key validation and capability checks. The settings are also contextually aware and only apply to the course they is accessed in.

Present in this page are a total of three major sections that can be modified: (1) The experience points (XP) settings are where the base XP for different activities and the grade multiplier can be modified; (2) The student rank configuration defines the rank names, color, thresholds and where the teacher can also create or remove ranks. (3) The Leaderboard display settings that customizes how the leaderboards are displayed to the students, has properties to toggle the visibility of the different leaderboards, insert pagination, display the rank colours and an anonymous mode that hides the student names.



Leaderboard > Learning Scorecard Settings

Learning Scorecard Settings

Experience Points (XP) Settings

Configure how students earn experience points in your course

Quest Base XP

Quiz Base XP: 100.00

XP awarded for completing each quiz

Exercise Base XP: 150.00

XP awarded for completing assignments and exercises

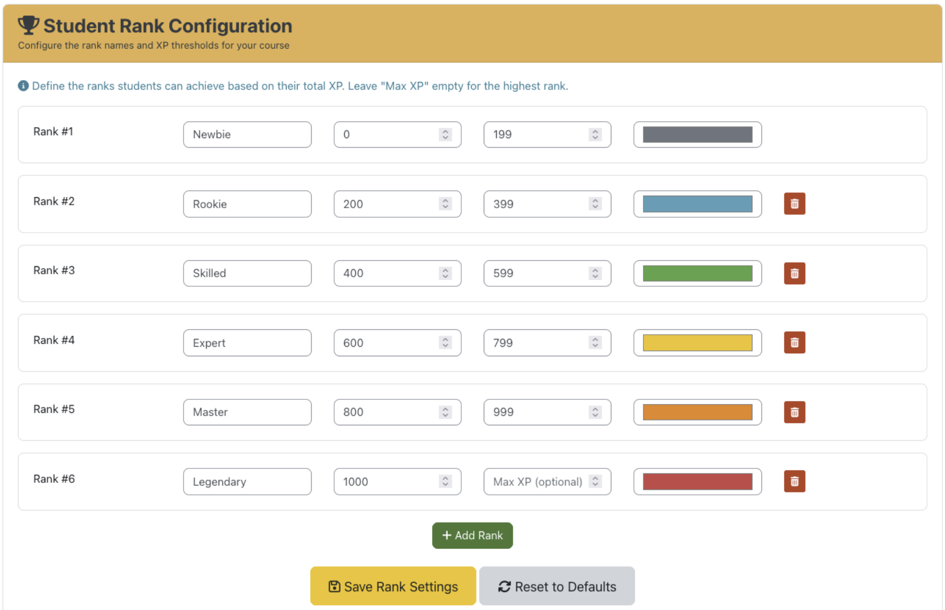
Forum Post XP: 50.00

XP awarded for each forum post or reply

Grade Multiplier: 1.50

Multiplier applied to grades for bonus XP (higher grades = more XP)

FIGURE 7. XP Settings Interface



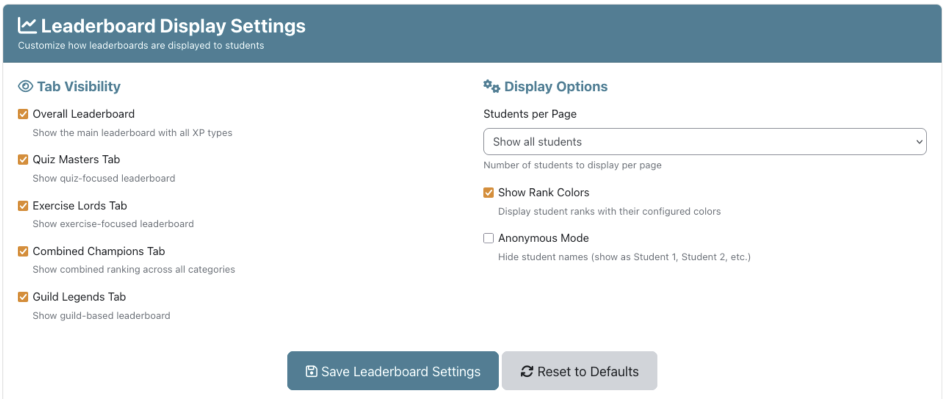
Student Rank Configuration

Configure the rank names and XP thresholds for your course

Define the ranks students can achieve based on their total XP. Leave "Max XP" empty for the highest rank.

Rank #1	Newbie	0	199	⬛	
Rank #2	Rookie	200	399	🟦	🗑
Rank #3	Skilled	400	599	🟩	🗑
Rank #4	Expert	600	799	🟨	🗑
Rank #5	Master	800	999	🟧	🗑
Rank #6	Legendary	1000	Max XP (optional)	🟥	🗑

FIGURE 8. Rank Settings Interface



Leaderboard Display Settings
Customize how leaderboards are displayed to students

Tab Visibility

☑ Overall Leaderboard
Show the main leaderboard with all XP types

☑ Quiz Masters Tab
Show quiz-focused leaderboard

☑ Exercise Lords Tab
Show exercise-focused leaderboard

☑ Combined Champions Tab
Show combined ranking across all categories

☑ Guild Legends Tab
Show guild-based leaderboard

Display Options

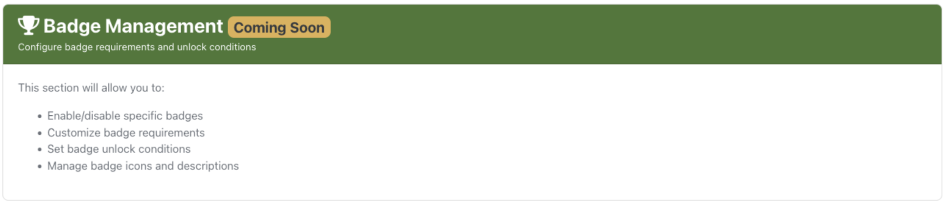
Students per Page: Show all students
Number of students to display per page

☑ Show Rank Colors
Display student ranks with their configured colors

☐ Anonymous Mode
Hide student names (show as Student 1, Student 2, etc.)

Figure 9. Leaderboard Settings Interface

In this page there is also a section for the badge management that is left there as a placeholder for future work and improvements.



Badge Management Coming Soon
Configure badge requirements and unlock conditions

This section will allow you to:

- Enable/disable specific badges
- Customize badge requirements
- Set badge unlock conditions
- Manage badge icons and descriptions

Figure 10. Badge Management Interface Placeholder

5.3.3. Experience Points (XP) and Ranking System

Present in this iteration is also a XP System that provides real-time XP calculation through event observers that trigger upon quiz completion and activity submission. Grade based XP multipliers and perfect score bonuses are also applied to every quest completed by the students.

The LS 3.0 provides an XP configuration system that allows per-course settings with customizable base XP values for different activity types, configurable grade bonus and an audit trail through an XP history table that logs every XP transaction. All XP settings are stored in the moodle database natively with fallback default values and automatic creation upon course initialization.

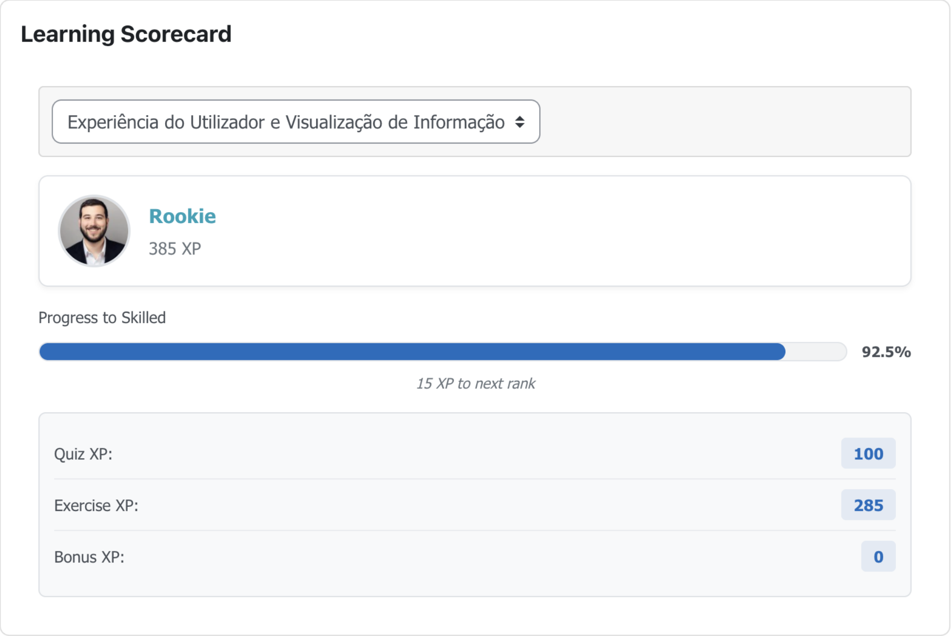
All XP accumulated by each student maps into a 6 tier ranking system that follows the definition found on previous versions: Newbie - Rookie - Skilled - Expert - Master - Legendary. These rank intervals are all available to be defined per course in the LS settings page. There are rank badges displaying both on the dashboard block of each student and on the leaderboards next to their name. On the dashboard there is also a percentage-based progress bar with ”XP to next rank” indicator.

With the notification system native to Moodle, the LS 3.0 can send a notification on rankup, in order to provide an extra boost of motivation as it was designed for in previous iterations of moodle.

5.3.4. Dashboard Block Plugin

The dashboard block plugin was created as a proof of concept of the learning scorecard previous version's dashboards with graphs and learning metrics. It was a achieved through a auxiliary plugin created within the moodle architecture that is only responsible for the UI blocks that the students can insert into the dashboard. There can be a lot of different blocks each with their defined metrics and graphs for a rich visualization interface of the students' learning performance.

The current and only block present in this plugin is a visualization of the student's rank (see Figure 11), progress to the next rank with a percentage-based progress bar and a breakdown of all XP earned. There is also an ability to cycle through multiple courses and display the XP for the course selected.



Learning Scorecard

Experiência do Utilizador e Visualização de Informação

Rookie
385 XP

Progress to Skilled 92.5%

15 XP to next rank

Quiz XP: 100
Exercise XP: 285
Bonus XP: 0

FIGURE 11. Dashboard block plugin student XP Interface

All data presented in the block is retrieved through queries to the moodle database and the tables that were appended through the Learning Scorecard Local plugin. This allows for a better division of responsibilities of each plugin and provides a much better and objective architecture that can be easily extended in the future.

Another topic to address is the language of the interfaces and text. Every plugin has two language packs, folders in the plugin configuration that provide translations of text and strings. Currently, the LS 3.0 is able to be translated into portuguese and english and the language packs are chosen automatically depending on your moodle's language.

5.4. Challenges & Limitations

Throughout the conception and development of the Learning Scorecard 3.0 there were a few challenges that proved difficult to resolve, requiring trade-offs and becoming contraints in the current implementation.

One big challenge from the LS 3.0 is the Moodle environment unapproachibility and inconsistency. The instance hosted by ISCTE changes versions regularly, proving to be possibly difficult to maintain and keep the LS 3.0 up to date, although the plugin architecture presents compatibility with Moodle 4.1+. In institutional environments with legacy Moodle installations this may limit deployment flexibility or even force them to abandon integration all together.

The current leaderboard position calculation methodology requires loading entire student datasets into memory for PHP-based sorting algoriths. This approach presents some scalability concerns, particularly evident in the combined leaderboard where multiple leaderboard arrays are maintained simultaneously. The current implementation could benefit with optimizations in the pagination and how the leaderboards are loaded and sorted to avoid memory exhaustion in courses with extensive enrollments. Not only that, the leaderboard generation system relies heavely on multiple sequential SQL queries and could be a potential performance bottleneck in high load intensity.

The XP audit trail could accumulate a substantial data volumes over time without implemented achival strategies. This design decision prioritizes complete historical data but presents long-term storage scaling challenges and query performance degradation as data accumulates.

The current database schema maintains a strict per course data separation, preventing cross-course analytics. While this architectural decision maintains data privacy, it restricts the potential for comprehensive learning analytics across multiple courses for both the teacher and the students.

It is imperative, when attempting to mature this proof of concept, to take in consideration these limitations and tackle the possible chockeholds of the application.

CHAPTER 6

Conclusions

This dissertation has demonstrated success transformation of the Learning Scorecard from a standalone web application to a fully integrated Moodle plugin system. Learning Scorecard 3.0, although just a proof of concept, represents a architectural evolution that addresses the critical adoption barriers identified in previous iterations while perserving core gamification capabilities and providing a stable foundation to build features that weren't ported to this version.

Practically, this dissertation delivers a functional proof of concept that eliminates the authentication hurdles, mnual data entry and infrastructure maintenance burdens that constrained previous implementations. The plugin-based architecture sucessfully leverages Moodle's student activity data, role-based access control and established user workflows to create a seamless integration and gamified learning experience.

6.1. Recommendations for Institutional Use

Higher educational institutions considering Learning Scorecard 3.0 adoption should take in consideration recommendations prior to a broad institutional use. A controlled pilot deployment within academic contexts focusing on courses with moderate enrollment sizes in order to validate system performance and gather ser feedback is critical and imperative to avoid scalability bottlenecks.

Technical infrastructure should be ensured by institutions in a way that alignes with the system requriements of the LS 3.0, including Moodle version compatibility (version 4.1 or higher) and adequate database performance capabilities.

In order for a successful institutional adoption its required faculty training that emphasize both technical configuration and pedagogical integration strategies. Faculty members should receive instruction on Learning Scorecard settings management, including experience point configuration, rank threshold configuration and leaderboard display options. It's important to address how gamification elements such as LS 3.0 can be aligned with existing pedagogical objectives.

6.2. Future Directions for LS

This iterations of the Learning Scorecard addresses the main concerns that would block institutional adoption, although it is imperative to continue developing and evolving this concept. Therefore, these are directions that successors in Learning Scorecard development should envision.

It is key to address the scalability limitations identified previously in the current implementation, particularly regarding leaderboard calculation and memory utilization.

Implementation of database-level ranking calculation, query optimization strategies and intelligent caching mechanisms would enable a wider and larger student population without a performance bottleneck.

The XP history table's data accumualtion necessiatetes development of archival and data lifecycle management strategies. Future iterations should implement automated archival processes or data compression techniques.

Machine learning integration could enable adaptive gamification systems that adjust experience point calculations, rank thresholds and later on, badge requirements. A predictive modeling able to identify at-risk students based on engagement patterns, performance trajectories and comparative analisys could benefit the faculty's use of the tool and provide a better insight to student performance while also providing a more balanced experience for the student.

Future iterations should expand gamification elements beyond the current experience point, ranking systems and leaderboards to include features that haven't been transformed to this new architecture. The ontology implementation could be a valuable asset to the Learning Scorecard and Moodle intitutional experience. There already is a basis for the badge implementation that served as a template for further development. The Learning Scorecard was created to be as extensible as possible, following a modular architecture.

The foundation established by this research provides a pathway for educational technology innovation that leverages, rather than competes with existing institutional infrastructures.

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