Analistrator: a Visual Novel Serious Game for Human Anatomy Education

Josiel Costa dos Santos Júnior[1], **Giovanna Leão Rodrigues**[2], **Fabiane Rodrigues Fernandes**[2], **Tiago Bonini Borchartt**[1]

[1]Ciência da Computação – Universidade Federal do Maranhão (UFMA)
Avenida dos Portugueses, 1966 - Bacanga, São Luís - MA, CEP: 65080-805

[2]Design – Universidade Federal do Maranhão (UFMA)
Avenida dos Portugueses, 1966 - Bacanga, São Luís - MA, CEP: 65080-805

{josiel.junior, giovanna.lr}@discente.ufma.br
{fabiane.fernandes, tiago.bonini}@ufma.br

Abstract. Introduction: *The teaching-learning process of Human Anatomy is complex, traditionally relying on rote memorization and facing structural limitations such as cadaver scarcity. While Digital Game-Based Learning (DGBL) tools have been adopted to mitigate these issues, many current applications permit player progression through random guessing rather than demanding genuine clinical reasoning.* ***Objective:*** *This paper presents the design, development, and preliminary evaluation of Analistrator, a 2D Visual Novel serious game focused on teaching the human muscular system through applied clinical diagnostics.* ***Methodology:*** *Guided by the Design Science Research (DSR) paradigm and Design Thinking, the project encompassed an immersion phase with 74 undergraduate healthcare students, a heuristic evaluation of existing tools by design experts, and software development using the Unity engine. The artifact underwent expert clinical validation and was empirically evaluated through playtesting sessions using a qualitative observational approach and open-ended feedback.* ***Results:*** *Playtesting data indicated that the lightweight 2D narrative format effectively minimized visual cognitive load. Crucially, the implementation of a summative assessment mechanic (Day 6 penalty system) showed potential to inhibit trial-and-error behaviors, compelling players to correlate spatial anatomy with patient symptomatology.*

Keywords *Serious Games, Human Anatomy, Game Design, Digital Game-Based Learning, Visual Novel.*

1. Introduction

Human Anatomy (HA) is a foundational discipline in undergraduate healthcare programs, typically introduced in the first semesters to establish the basis for professional training [Ruzycki et al. 2019]. Despite its crucial role, the teaching-learning process of HA is notoriously complex. It demands extensive rote memorization and the spatial comprehension of interconnected structures [Silva e Melo 2019]. Consequently, students often struggle to contextualize this dense, abstract knowledge within practical clinical scenarios, which frequently leads to demotivation and superficial learning [Schultz 2017, Oliveira e Wolkers 2020].

Traditionally, HA instruction has relied heavily on cadaveric dissection. However, this approach faces significant structural barriers, including the scarcity of biological materials, high maintenance costs, rapid degradation, and ethical or infrastructural constraints [de Oliveira et al. 2020, Mourthé Filho et al. 2016, Cocce et al. 2017, Fornazieiro et al. 2021]. To mitigate these issues, educational institutions have increasingly adopted digital tools and active methodologies, such as Digital Game-Based Learning (DGBL) [Santiago et al. 2021]. While immersive 3D atlases and gamified quizzes offer high initial engagement, many fall short in pedagogical effectiveness. They often lack narrative depth and permit progression through non-cognitive strategies—such as random trial-and-error—failing to foster genuine clinical reasoning [Oliveira e Wolkers 2020, Purificação et al. 2021]. Furthermore, highly complex 3D applications often present usability and hardware processing constraints for students using personal mobile devices in standard classroom environments.

To address this methodological and technological gap, this paper presents the design and development of *Analistrator*, a 2D Visual Novel Serious Game focused on teaching the human muscular system to healthcare students. By integrating a clinical simulation mechanic within a rich narrative, the player acts as a medical professional tasked with diagnosing patients to recover lost anatomical data. The game shifts the cognitive load from passive spatial memorization to applied clinical problem-solving [Campos et al. 2021, Santiago et al. 2021]. Most importantly, Analistrator introduces a gameplay loop that actively penalizes random guessing, demanding the real consolidation of anatomical knowledge to progress.

The main objective of this study is to describe the conception, game design architecture, and preliminary evaluation of *Analistrator*, highlighting its potential as a low-cost, accessible, and scalable tool for active learning. The remainder of this paper is organized as follows: Section 2 discusses related work and the current landscape of anatomy teaching tools; Section 3 details the game design, narrative, and core mechanics; Section 4 outlines the methodology, including requirements elicitation and development; Section 5 presents the playtesting evaluation and results; and Section 6 concludes the paper, discussing limitations and future work.

2. Related Work and Background

Recent research explores how serious games and broader game-based learning (GBL) can supplement traditional anatomy and medical teaching, focusing on knowledge gains, engagement, and design principles.

A systematic review [Habsi et al. 2025] evaluated the impact of serious games on anatomy education using PRISMA guidelines. Based on the analysis of 14 eligible studies, the authors reported positive outcomes regarding knowledge acquisition, student engagement, and skills development. Nevertheless, the review highlights that methodological inconsistencies across the studies—such as varying designs and sample sizes—limit the generalizability of the results. Ultimately, the authors conclude that while serious games serve as effective supplementary educational tools, future research must employ more rigorous randomized controlled trials combining both qualitative and quantitative evaluation approaches.

Furthermore, a recent meta-analysis [Barz et al. 2023] investigated the

effectiveness of Digital Game-Based Learning (DGBL) interventions compared to traditional instructional methods within school contexts, analyzing literature published between 2015 and 2020. The study evaluated cognitive, metacognitive, and affective-motivational learning outcomes. The random-effects models demonstrated a significant medium effect for overall learning ($g = .54$) and cognitive learning outcomes ($g = .67$), alongside a small effect for affective-motivational outcomes ($g = .32$). Although no significant effects were observed for metacognitive learning, these findings strongly corroborate the pedagogical potential of DGBL interventions. They reinforce the premise that gamified approaches can effectively enhance both cognitive acquisition and intrinsic student motivation when compared to conventional expository teaching strategies.

Highlighting the potential of serious games for long-term memory retention, a recent study [Hu et al. 2021] evaluated the efficacy of a computer-based serious game named "NEOGAMES" for neonatal resuscitation training among undergraduate medical students. Through a controlled trial involving 81 participants, the authors assessed knowledge acquisition via pre-training, post-training, and six-month follow-up tests. The results demonstrated that the experimental group, which utilized the serious game, exhibited long-term knowledge retention nearly three times higher than the control group ($p < 0.001$). These findings provide robust empirical evidence that integrating serious games into medical curricula not only supplements traditional simulation-based education but significantly enhances the long-term retention of complex medical protocols.

Gamified tools such as digital quizzes and mobile applications are widely used to dynamize theoretical classes [Silva e Melo 2019]. To systematically assess the efficacy and limitations of these active market solutions, a comparative heuristic evaluation was conducted on six prominent applications: Kahoot, Atlas 3D, Anatomia Multicor, Doctor Trivia, Complete Anatomy, and Medical Harbour.

Crucially, this evaluation was performed by a panel of eight design researchers rather than undergraduate healthcare students. The rationale behind this methodological choice relies on the fact that design experts utilize established heuristics to objectively assess Human-Computer Interaction (HCI) criteria—such as cognitive load, interface usability, and core mechanics—whereas student evaluations often conflate technical usability with subjective aesthetic appeal. The evaluation was conducted using a 5-point qualitative scale (ranging from 'Very Poor' to 'Very Good'). The final classification presented in Table 1 for each criterion represents the mode (highest relative frequency) of the scores assigned by the panel of eight expert evaluators.

Table 1. Synthesis of the heuristic evaluation of active market tools by design experts.

Tool	Gameplay	Aesthetics	Mechanics	Usability	Teaching
Kahoot	Good	Very Good	Very Good	Very Good	Good
Atlas 3D	Good	Good	Good	Medium	Medium
A. Multicor	Very Good	Good	Good	Good	Medium
Doc. Trivia	Very Good	Good	Very Good	Very Good	Good
C. Anatomy	Good	Very Good	Good	Very Good	Very Good
Med. Harbour	Good	Very Good	Good	Good	Medium

Table 2. SWOT Matrix synthesizing the pedagogical and technological landscape of HA education.

Internal Factors (HA Discipline)	
Strengths	**Weaknesses**
• High student interest in Human Anatomy content. • Clear perception of the subject's importance for future clinical practice.	• High demand for rote memorization of complex structures. • High cost, scarcity, and degradation of cadavers. • Disconnect between spatial memorization and clinical application.
External Factors (Technological Context)	
Opportunities	**Threats**
• Adoption of Digital Game-Based Learning (DGBL) to promote student protagonist roles. • Simulation of realistic clinical scenarios through narrative structures. • Use of 2D/lightweight apps to bypass hardware limitations.	• Current market tools allow progression via random guessing. • Lack of tools combining deep system-specific knowledge with clinical storytelling. • 3D applications are excessively heavy for standard mobile devices.

The heuristic evaluation revealed a critical pattern. While quiz-based applications (Kahoot, Doctor Trivia) excel in gamified competitive engagement, and structural platforms (Complete Anatomy, Medical Harbour) provide exceptional 3D aesthetic fidelity, they frequently present a functional gap in "direct teaching" and cognitive mechanics. In many of these tools, the user progression system permits trial-and-error strategies. Instead of demanding the clinical reasoning required for professional practice, players can bypass the learning curve by guessing. Furthermore, none of the evaluated tools integrate a strong narrative or clinical role-playing framework to sustain long-term intrinsic motivation.

To synthesize these findings and formally justify the ideation requirements for Analistrator, a SWOT (Strengths, Weaknesses, Opportunities, and Threats) matrix was developed (Table 2). This framework maps the internal pedagogical factors of the HA discipline against the external technological landscape, clearly outlining the opportunity for a narrative-driven, 2D clinical puzzle game.

3. Game Design and Architecture

The conception of *Analistrator* was guided by a core design philosophy: shifting the cognitive load from passive spatial memorization to active clinical problem-solving. To achieve this, the game was developed as a 2D Visual Novel Serious Game using the Unity engine and C#. This architectural choice prioritizes hardware accessibility and low processing requirements, ensuring the application runs smoothly on students' personal mobile devices—a critical requirement identified during the preliminary context analysis.

3.1. Narrative and Aesthetic Concept

To sustain intrinsic motivation and provide a meaningful context for the anatomical concepts, *Analistrator* places the player in an immersive sci-fi narrative. The player assumes the role of a medical officer aboard a space mission whose central anatomical database has been corrupted by a solar storm. To reconstruct this lost data, the player must accurately diagnose the crew members' clinical conditions.

The Visual Novel aesthetic was deliberately chosen to minimize visual clutter. By employing a minimalist 2D interface, the game avoids the high cognitive overhead often associated with complex 3D navigation. This allows the student to focus entirely on reading the anamnesis, interpreting symptoms, and formulating a diagnosis.

3.2. Core Mechanics and Gameplay Loop

The gameplay loop is structured around virtual eight-week cycles. Each week is divided into distinct interactive phases that gradually increase in cognitive demand, transitioning from guided learning to strict assessment.

During the first five days of the week, the player interacts with different patients, to apply clinical anamnesis and guided diagnosis. The interface is divided into two main components:

1. **The Dialogue Screen:** Where the patient describes their symptoms, pain locations, and functional limitations (e.g., "I cannot flex my forearm after lifting a heavy box").
2. **The Clinical Clipboard (Prancheta):** An interactive UI element where the player records key findings from the anamnesis.

Crucially, the game is not purely textual. After analyzing the symptoms, the player transitions to the *Anatomical System Interface*. Here, visual representations of the human muscular system are displayed. The player must cross-reference the clinical symptoms with the visual anatomy and select the specific affected muscle to lock in their diagnosis, see Figure 1.

Figure 1. Gameplay interface: (Left) Patient dialogue and clinical clipboard for symptom tracking; (Right) Visual anatomical interface for muscle selection and diagnosis.

The Bonus Assessment Day is a mechanism adopted to address the common flaw in DGBL applications where students progress via random guessing, *Analistrator*

implements a validation mechanic on the sixth day. This phase acts as a weekly summative assessment. The player faces randomized clinical cases based on the week's content but without the complete aid of the hint system.

To progress to the next week, the player must achieve a minimum accuracy rate of 50% on these diagnostic challenges. The system actively penalizes trial-and-error behaviors by deducting points and forcing case reviews for incorrect diagnoses. This mechanics ensures that progression is tied strictly to the genuine consolidation of anatomical and clinical reasoning, rather than non-cognitive gaming strategies, see Figure 2.

Figure 2. Progression system (left) and diagnostic feedback (right), highlighting the penalty or reward visual cues.

4. Methodology

The development of *Analistrator* followed the Design Science Research (DSR) paradigm, which focuses on the creation and evaluation of artifacts intended to solve practical problems. To ensure the artifact was deeply rooted in the end-users' actual needs, the DSR cycle was integrated with the Design Thinking (DT) framework. This hybrid approach guided the project through practical phases of user immersion, problem definition, ideation, and rapid prototyping.

4.1. Immersion and Requirements Elicitation

The immersion phase aimed to empirically validate the pedagogical gaps identified in the literature. The study was conducted at a Brazilian public university, targeting undergraduate students enrolled in healthcare programs. A total of 74 students participated in the requirements elicitation phase. The demographic distribution consisted primarily of Medical (56.8%) and Nursing (27.0%) students, with the majority aged between 18 and 25 years (89.2%).

Data was collected through a structured survey to map their learning difficulties and their perception of current digital tools. To address previous peer-review feedback regarding methodological transparency, the core questions and their respective quantitative results are detailed below:

- **Q1: Did the lack of practical contact with anatomical pieces (exacerbated by remote/hybrid scenarios) negatively impact your learning?** Results showed that 90.9% of students deeply felt the absence of physical contact with cadaveric specimens.

- **Q2: Did the digital tools adopted by instructors (such as general quizzes or 3D Atlases) fully meet the practical needs of the discipline?** A majority (60.6%) reported that current digital interventions were insufficient for deep learning.
- **Q3: Which anatomical content presents the highest difficulty for cognitive assimilation?** The muscular system was ranked as the most difficult topic, followed sequentially by neuroanatomy, nerves, and the vascular system. This direct feedback justified the game's initial focus on the muscular system.
- **Q4: What is your level of interest in utilizing a serious game focused specifically on clinical diagnostics for anatomy?** While 75.7% demonstrated high interest, 100% of the respondents stated they were completely unaware of any existing tool with this specific clinical focus on the market.

Simultaneously, a structured interview was conducted with a senior HA professor responsible for teaching both Medical and Nursing classes. The results of this interview mapped the essential criteria for the game's clinical database: the tool needed to enforce diagnostic accuracy and prevent arbitrary progression, which directly inspired the "Day 6 Penalty Mechanic" described in Section 3.

4.2. Development and Implementation

Following the definition of the pedagogical and technical requirements, the development cycle was structured around iterative phases guided by a comprehensive Game Design Document (GDD). To ensure a robust execution, the project was conducted by a multidisciplinary team divided into four core areas: Programming, Visual Arts, UI/UX Design, and Clinical Narrative Writing. The initial wireframes and UI workflows were collaboratively prototyped using Figma, which served as the foundation for weekly agile alignment meetings.

User involvement was continuous throughout the development cycle rather than restricted to the final evaluation. The clinical cases and narrative scripts were co-authored and validated by a senior Human Anatomy professor to guarantee scientific accuracy. Furthermore, undergraduate medical and nursing students actively participated in iterative playtesting sessions during the build process. Their input was crucial for correcting anatomical terminology within patient dialogue trees and led to direct structural refinements, such as conceptualizing visual feedback screens for the diagnostic phases.

Technically, Analistrator was developed using the Unity 2D engine and programmed in C using the Visual Studio environment. To strictly address the hardware accessibility requirements identified during the immersion phase, the game's architecture was optimized for low-end mobile devices. The application targets devices running Android 5.0 or higher, requiring only a 1.2 GHz processor and 1 GB of RAM. The 2D graphical assets, including character sprites and scenarios, were created using Adobe Photoshop and Clip Studio Paint, allowing the developers to bypass the heavy rendering pipelines associated with 3D models. This technical architecture ensured a lightweight, responsive, and pedagogically effective tool for standard classroom environments.

5. Evaluation and Results

To ensure the *Analistrator* prototype met both its educational and interactive objectives, a two-phase evaluation strategy was implemented: an expert clinical validation followed

by an empirical playtesting session with the target audience.

Before exposing the artifact to students, the game's internal database, comprising the clinical cases, symptom descriptions, and the anatomical mapping of the muscular system, underwent a peer review by a senior Human Anatomy professor. This validation step was crucial to guarantee that the simulated anamnesis authentically reflected real-world clinical scenarios. The expert feedback led to fine-tuning the difficulty curve, ensuring that the symptoms presented in the early days of the virtual week were pedagogically aligned with the diagnostic challenges of the Day 6 assessment.

The empirical evaluation was conducted through a controlled playtesting session involving a focus group of 10 (ten) undergraduate Medical and Nursing students. The objective was to assess the artifact across three dimensions: *Viability*, *Usability*, and *Player Engagement*.

To ensure methodological rigor within the scope of a preliminary evaluation, data was collected utilizing open-ended feedback. This qualitative approach was designed to capture specific pain points and user suggestions, alongside observational data concerning the learning potential afforded by the game and the validation of its core mechanics.

The data derived from the playtesting session provided highly positive indicators regarding the game's architecture:

- **Cognitive Load and Aesthetics:** Students strongly agreed that the 2D Visual Novel format prevented visual fatigue. The separation between the narrative text (dialogue) and the visual puzzle (anatomical interface) allowed them to process the clinical information.
- **Mechanics Validation:** The Day 6 penalty system proved highly effective. Observational data during the playtest revealed that players actively utilized their clipboard notes to solve the final cases, demonstrating a shift from random trial-and-error behavior to structured clinical reasoning.
- **Engagement:** The narrative context—acting as a medical officer saving a space crew—successfully maintained intrinsic motivation, a factor often missing in traditional, repetitive quiz applications.

Overall, the evaluation confirmed the artifact's viability as an accessible, lightweight tool. The students highlighted that connecting a specific muscle's anatomical name directly to a patient's functional complaint (e.g., inability to perform a specific movement) made the abstract memorization process significantly more meaningful.

6. Conclusion and Future Work

This paper presented the design, development, and preliminary evaluation of *Analistrator*, a 2D Visual Novel Serious Game aimed at mitigating the persistent learning challenges in Human Anatomy education. By mapping the pedagogical landscape, this study identified a critical gap: while gamified tools are prevalent, they often rely on superficial memorization and permit trial-and-error progression. To counter this, *Analistrator* integrated a clinical diagnostic mechanic within an engaging sci-fi narrative, requiring students to apply their knowledge of the muscular system to solve practical health scenarios.

Guided by the Design Science Research methodology, the artifact was explicitly tailored to the hardware and cognitive needs of undergraduate healthcare students. The empirical playtesting evaluation demonstrated that the lightweight 2D architecture effectively minimized visual clutter, while the "Day 6" penalty mechanic provided strong observational indicators of inhibiting random guessing. The qualitative feedback confirmed that the game acts as a strong motivational catalyst, helping students bridge the gap between abstract anatomical structures and their functional, real-world clinical implications. The primary contribution to the field of Computing Applied to Health and DGBL is the delivery of a scalable, low-cost tool that decentralizes education from the exclusive reliance on physical cadavers.

Despite these promising initial results, the authors acknowledge the limitations inherent in this exploratory phase. The current evaluation focused primarily on viability, usability, and perceived engagement within a restricted focus group. To fully validate the educational impact of the artifact, future work will prioritize robust, longitudinal quantitative evaluations.

Specifically, randomized controlled trials employing pre- and post-training knowledge tests will be implemented to statistically measure the game's impact on long-term memory retention compared to traditional expository methods. Furthermore, the technological architecture of *Analistrator* is designed to be highly scalable; future development cycles will expand the internal database to encompass additional complex modules, such as the nervous, skeletal, and cardiovascular systems.

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The Analistrator game is a registered software artifact, and its intellectual property and source code are owned by the Federal University of Maranhão (UFMA). Due to institutional intellectual property regulations and ongoing longitudinal efficacy trials, the source code is not currently available in a public open-source repository. Researchers interested in accessing a demo build for academic verification purposes may contact the corresponding author.

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