Animation Learning Object: an interactive approach using digital storytelling and serious games techniques

Joana Braguez[1], Arnaldo Santos[2]
[1]CEIS20, Universidade Aberta de Portugal, Lisboa, Portugal and Escola Superior de Tecnologia e Gestão de Viseu, 1801702@estudante.uab.pt
[2]INESC TEC and Universidade Aberta de Portugal, Lisboa, Portugal, arnaldo.santos@uab.pt

Abstract

This research describes the development and validation of an interactive Learning Object (LO) designed to teach the 12 principles of 2D Animation, using strategies from Digital Storytelling and Serious Games to foster a more engaging and meaningful learning experience. The solution was implemented on the Moodle platform, incorporating various H5P content types, and complemented by an analytical dashboard, enabling the monitoring of student progress through xAPI data and CSV files exported from Moodle.The pedagogical evaluation combined both qualitative instruments, including diagnostic and final tests, as well as a satisfaction survey validated by experts. The results show a positive evolution in knowledge, high levels of user satisfaction, and ease of platform use. The project confirms the potential of combining digital narrative, gamification, and interactive monitoring as an effective strategy in online learning environments.

Keywords: *Learning Object; 2D Animation; Digital Storytelling; Serious Games; Learning Analytics.*

Título: Objetos de Aprendizagem de Animação: uma abordagem interativa com técnicas de *digital storytelling* e jogos sérios

Resumo: Esta investigação descreve o desenvolvimento e validação de um Learning Object (LO) interativo dedicado ao ensino dos 12 princípios da animação 2D, recorrendo a estratégias de Digital Storytelling e Serious Games para promover uma aprendizagem mais envolvente e significativa. A solução foi implementada na plataforma Moodle, com recurso a conteúdos H5P variados, e complementada por um *dashboard* analítico, que permite a monitorização do progresso dos alunos através de dados xAPI e ficheiros CSV exportados do Moodle. A avaliação pedagógica combinou instrumentos quantitativos, incluindo testes diagnósticos e finais, bem como um inquérito de satisfação validado por especialistas. Os resultados demonstram uma evolução positiva dos conhecimentos, elevados níveis de satisfação e facilidade de utilização da plataforma. O projeto confirma o potencial da combinação entre narrativa digital, gamificação e monitorização interativa como estratégia eficaz em contextos de aprendizagem *online*.

Palavras-chave: Objetos de Aprendizagem; Animação 2D; Digital Storytelling; Jogos Sérios; Learning Analytics.

1. Introduction

The increasing integration of digital technologies into education has transformed teaching and learning methodologies, encouraging the development of more interactive, learner-centred approaches. In the field of 2D Animation – an area of growing relevance across the creative industries, multimedia, and audiovisual production – there is a clear need for pedagogical resources that combine technical accuracy with emotional engagement. In this context, the present study describes the development of an interactive Learning Object (LO) designed to teach the twelve principles of Animation, employing Digital Storytelling (DS) and Serious Games (SG) techniques as innovative pedagogical strategies.

This project was developed within the framework of Computer Engineering, exploring the potential of integrating technology, digital narrative, and gamification in e-learning environments. The proposed LO was designed for higher education students – particularly those in the first or second year of programmes in Design, Multimedia, Animation, or Visual Arts – offering an accessible and motivating introduction to the fundamentals of 2D Animation. The approach seeks to move beyond traditional expository methods by providing an immersive and interactive experience that combines conceptual learning with elements of motivation and immediate feedback.

The need for new pedagogical approaches in this area arises from the limitations of conventional methods, which tend to rely on theoretical lectures and static content, often failing to foster active engagement or sustained interest. Learning the fundamental principles of Animation requires visual comprehension, experimentation, and emotional involvement – dimensions that are typically absent from purely theoretical instruction. DS addresses this gap by using narrative structures and characters to guide learners through the educational experience. Serious Games introduce challenge, progression, and reward mechanisms that strengthen engagement and intrinsic motivation.

At the same time, the integration of monitoring and analytics tools responds to the growing importance of data-driven approaches in education. By coupling the LO with an interactive dashboard, it becomes possible to collect, visualize, and interpret data on learners' performance and progression, providing valuable indicators for formative assessment and continuous improvement. Thus, the project not only proposes an innovative learning environment but also contributes to the field of learning analytics applied to digital arts education.

The main goal of this work is to design and validate an interactive LO that supports the exploration and understanding of the twelve principles of 2D Animation, grounded in a pedagogical approach that merges digital narrative, gamification, and data analysis.

The project, therefore, aims to address two complementary gaps: the lack of educational resources focused on the principles of Animation that combine accessibility, interactivity, and narrative; and the absence of integrated evaluation tools capable of systematically assessing the pedagogical impact of such approaches. By articulating technology, storytelling, and data analytics, this study contributes to the advancement of e-learning

practices and offers a replicable model for other artistic and technological training contexts.

2. State of the Art

The intersection of LOs, DS, and SG represents a growing area of research within educational technology, particularly relevant for creative disciplines such as Animation and multimedia. These approaches converge around a shared goal: to promote active, engaging, and meaningful learning experiences through the combination of interactive content, narrative immersion, and game-based motivation. This section reviews the main theoretical and empirical contributions that support the integration of DS and SG techniques into the design of educational LOs.

2.1 Learning Objects (LOs)

The concept of a LO refers to any reusable digital resource designed to support learning in different contexts (Duval et al., n.d.). LOs are characterized by modularity, interoperability, and pedagogical intentionality, allowing educators to combine various media elements – text, video, simulation, and interactivity – into coherent instructional units (Wiley, 2000; Krauss & Ally, 2005).

Wiley (2000) emphasized that effective LOs must go beyond technical metadata and address the instructional design principles that guide learning outcomes. Similarly, Shaw (2002) highlighted the role of performance-based components in shaping adaptive learning pathways, while Downes (2001) argued that multimedia integration – such as animations, interactive graphics, or audio narratives – enhances cognitive engagement and information retention.

Narrative and storytelling have increasingly been recognized as essential components within LOs. Studies indicate that the inclusion of story-driven content can increase emotional engagement and promote deeper learning (Naul & Liu, 2018; von Nimwegen & van Oostendorp, 2013). Gaeta et al. (2014) proposed a template-based framework for embedding narrative structures into educational resources, simplifying the creation of meaningful and consistent learning experiences. Repositories such as MERLOT and NSDL illustrate the scalability and reusability of LOs across disciplines, enabling educators to share, adapt, and evaluate materials collaboratively.

From a pedagogical standpoint, LOs align with constructivist and experiential learning theories, supporting the creation of exploratory and student-centred environments. Their modularity also makes them suitable for integration with Learning Management Systems (LMS) such as Moodle, facilitating adaptive sequencing, tracking of progress, and data analytics.

2.2 Digital Storytelling (DS)

DS integrates narrative structure with multimedia resources – text, sound, image, and video – allowing learners to construct knowledge through creative expression and reflection (Robin, 2016). As Robin (2016) observes, DS transforms students from passive recipients of information into active authors of meaning, fostering autonomy, motivation, and self-awareness.

When implemented in educational contexts, DS can support multiple learning dimensions: cognitive, by helping students organize and relate information through narrative structure; emotional, by fostering empathy, connection to content; and social, by encouraging collaboration and shared authorship (Di Blas et al., 2009).

Gaeta et al. (2014) demonstrated that DS enhances learner motivation and provides affective scaffolding that supports exploratory learning. Likewise, Kaminskienė and Khetsuriani (2019) identified multimodality and adaptive narrative design as key to maintaining engagement in digital learning environments.

In higher education, DS is often integrated into e-learning platforms that allow educators to assemble stories and interactive media without requiring advanced technical expertise (Gaeta et al., 2014). When combined with Animation, DS becomes a powerful tool for visual explanation and conceptual understanding, especially in fields such as design and the visual arts (Ravyse et al., 2017).

The essential elements of effective DS include multimodality: the integration of text, audio, image, video, and Animation to create richer experiences; adaptivity: adjusting narrative depth and complexity based on learner profiles (Naul & Liu, 2018); and integration with gamified systems: combining storytelling and gameplay to enhance motivation and retention (Ravyse et al., 2017).

The pedagogical benefits of DS are consistently supported across studies: narratives stimulate curiosity and empathy (Robin, 2016), encourage reflective practice (Di Blas et al., 2009), and promote digital literacy by engaging learners in multimedia production. As such, DS is not merely an expressive tool but a structured pedagogical strategy for meaning making through narrative and interaction.

2.3 Serious Games (SG)

SO are defined as games that incorporate rules, objectives, and feedback systems for purposes beyond entertainment – particularly education, training, and awareness (de Freitas & Jarvis, 2006). SGs employ the motivational power of gameplay to promote learning outcomes, combining intrinsic engagement with structured pedagogical design (Arnab et al., 2015).

Naul and Liu (2018) distinguish between entertainment-focused games and educational games, noting that the latter must maintain a clear alignment between game mechanics and learning objectives. The challenge lies in balancing enjoyment with educational value, ensuring that the narrative and mechanics reinforce, rather than distract from, the intended learning goals.

According to Bellotti et al. (2010), SGs can generate immersive environments where learners actively apply knowledge through exploration, decision-making, and problem-solving. The inclusion of avatars and customization options has been shown to enhance self-regulated and intrinsically motivated learning (Breuer & Bente, 2010). Ravyse et al. (2017) further emphasize that multimodal interaction – through text, Animation, and feedback – supports authentic learning experiences that mirror real-world contexts.

Key components of SG design include: narrative immersion, which provides emotional and cognitive coherence (Naul & Liu, 2018); game mechanics, such as challenges, rules, rewards, and immediate feedback (Ravyse et al., 2017); pedagogical objectives, clearly defined and seamlessly embedded into gameplay (Gordillo et al., 2021); interactivity and multimodality, which promote engagement through active experimentation (Liarokapis, 2011; Zhonggen, 2019).

Educational applications of SGs span diverse domains – from engineering and programming to health sciences – where they have been shown to enhance skill development, collaboration, and motivation (Tran et al., 2010; Bellotti et al., 2010).

2.4 Integrating DS and SG within LOs

Recent research points to the complementary nature of storytelling and gamification in education. Bellotti et al. (2010) introduced the concept of affective walkthrough as a method to assess how emotional responses influence learning within games. Similarly, Gaeta et al. (2014) and Lameras et al. (2017) suggest that combining DS and SG allows learners to experience both cognitive and affective engagement, leading to improved motivation and knowledge retention.

In this hybrid model, narrative provides meaning and structure, while game mechanics drive participation and feedback. When implemented in LOs, these two dimensions create a dynamic framework for experiential learning. The learner becomes both a participant in the story and an agent in the learning process, advancing through levels, solving challenges, and reflecting on their progress.

However, several challenges persist in the widespread adoption of DS and SG approaches:

- Technical complexity, including the integration of multimedia assets and adaptive learning logic.
- Institutional limitations, such as restricted access to commercial authoring tools (e.g., Articulate Storyline, Adobe Captivate).
- Pedagogical alignment, ensuring that narrative and gameplay remain consistent with learning objectives.
- Accessibility, making resources inclusive for diverse learner profiles.
- Evaluation, developing reliable methods to assess engagement, learning outcomes, and affective responses.

Despite these constraints, the convergence of LO, DS, and SG methodologies represents a promising frontier in digital pedagogy. Studies by Di Blas et al. (2009), Naul & Liu (2018), and Ravyse et al. (2017) indicate that these integrative strategies foster deeper learning, collaborative exploration, and sustained motivation, particularly when supported by data analytics tools that allow continuous refinement of instructional design.

2.5 Gaps and Opportunities

Existing courses on the twelve principles of Animation – such as those available on FXPHD, Udemy, or New Masters Academy – demonstrate high technical and artistic quality but rely heavily on linear, video-based instruction. These resources are predominantly expository, offering limited interactivity and no mechanisms for feedback,

assessment, or adaptive learning. Consequently, they lack the narrative depth and gamified engagement necessary for sustained learner motivation.

At the same time, available Learning Analytics tools (e.g., Moodle core reports, Watershed LRS, GrassBlade) often present technical or licensing barriers, restricting access to personalized data visualization and real-time tracking of learner performance. This highlights an opportunity for the development of open, customizable dashboards that combine pedagogical and analytical insights.

The present project responds to these gaps by proposing an integrated solution: an interactive LO that merges DS and SG techniques within Moodle, complemented by a custom-built analytics dashboard developed in Python/Streamlit. This dual structure – pedagogical and analytical – aims to enhance both learner experience and instructional evaluation.

The literature demonstrates strong evidence that combining LOs, DS, and SG leads to more effective, engaging, and meaningful learning experiences. Storytelling supports emotional and cognitive engagement, while gamification promotes motivation and active participation. When supported by data analytics, these strategies can also provide valuable feedback for continuous pedagogical improvement.

Building on this theoretical foundation, the project described in this article develops an interactive LO for teaching the twelve principles of 2D Animation. By embedding narrative and game mechanics within a monitored digital environment, it aims to bridge the gap between traditional instruction and experiential, data-informed learning design.

3. Tools and Methodology

The development of the Learning Object (LO) A2D.12 – Master the Motion was guided by a multimedia project methodology commonly used in the design of interactive educational systems. This approach integrates phases of analysis, design, production, testing, and deployment, ensuring coherence between pedagogical goals, technical feasibility, and user experience. The methodology combines principles from instructional design and software engineering, promoting an iterative and user-centred process aligned with the educational objectives of the project.

3.1 Tools and Technologies

The implementation relied on an ecosystem of open and accessible tools, selected for their pedagogical relevance, integration potential, and cost-effectiveness.

For content creation, H5P was adopted as the primary authoring environment. It allows the development of interactive activities such as quizzes, branching scenarios, and drag-and-drop exercises, natively integrated into Moodle, the chosen Learning Management System. H5P's open-source nature and compatibility with SCORM and xAPI standards were decisive advantages, facilitating the tracking of learner performance and ensuring interoperability.

The visual and narrative components were produced using the Adobe Creative Suite, particularly Illustrator for vector graphics, Character Animator for animated characters, and Photoshop for image composition. Voice synthesis and scripting were supported by text-to-speech tools and GPT-based assistants, ensuring linguistic consistency and efficiency in content production.
For learning analytics, a dashboard was built in Python using the Streamlit framework, with data exported from Moodle (CSV files) and enriched with xAPI statements from an external Learning Record Store (Watershed). This analytical layer allowed visualization of progress indicators, satisfaction levels, and performance metrics.

While the technical infrastructure provided the foundation, the methodological framework defined the process through which pedagogical and narrative elements were conceived, validated, and refined.

3.2 Methodological Framework

The project's development followed a multimedia project methodology, widely used in contexts involving the creation of interactive applications with narrative, visual, and functional components. This methodology structures the development process into five distinct phases – sequential yet iterative – ensuring coherence, technical quality, and alignment with the pedagogical objectives.

Phase 1 – Analysis and Planning

The initial stage focused on identifying pedagogical needs, defining learning objectives, and mapping the technical constraints of the project.

A literature review on Learning Objects, Digital Storytelling, and Serious Games (Bellotti et al., 2010; Gaeta et al., 2014; Robin, 2016) informed the conceptual framework.

The analysis revealed two main needs: (1) the scarcity of interactive educational resources on the twelve principles of 2D Animation; and (2) the lack of tools to monitor learner engagement and progress in such contexts.

The target audience was defined as undergraduate students in Design, Multimedia, or Visual Arts courses, typically in their first or second year. The pedagogical objectives were structured around three learning dimensions: conceptual understanding of animation principles, motivation and emotional engagement, and reflective learning supported by feedback.

Constraints were also identified: limited development time due to academic scheduling, restricted financial resources, and dependency on open-source or educationally licensed tools. These factors guided the project toward lightweight, cost-free, and interoperable technologies.

Phase 2 – Design

During the design phase, the pedagogical architecture and user experience were defined. The LO was structured as a modular narrative journey through a virtual animation studio, divided into sequential levels corresponding to learner progression: Apprentice, Intern, Junior Animator, Senior Animator, and Director. Each level introduced a subset of the twelve animation principles, contextualized through storytelling and gamified tasks.

Phase 3 – Production

The production phase translated design concepts into digital artefacts. Content development combined multimedia authoring with programming and data management:

- Multimedia assets: vector illustrations, animated characters, and voice-over dialogues were created using Adobe tools.
- Interactive modules: H5P components (interactive videos, course presentations, and branching scenarios) were developed and integrated into Moodle.
- Analytics infrastructure: Python scripts processed learning data from Moodle and xAPI sources, feeding the Streamlit dashboard for visualization.

Each module included embedded feedback mechanisms, enabling formative assessment and reinforcing learning through immediate responses. The LO's modular structure facilitated reuse and scalability for future courses or related subjects.

Phase 4 – Testing and Validation

Evaluation was conducted in two complementary stages: technical testing and pedagogical validation.

Technical testing included:

- Functional tests: ensuring all H5P activities, media assets, and navigation flows operated correctly.
- Performance tests: verifying loading times and server capacity on the Moodle host.
- Data integrity tests: confirming that xAPI statements and CSV exports accurately reflected user actions.

Pedagogical validation involved both expert review and user trials. A panel of four specialists evaluated the satisfaction survey and content clarity, achieving a Cronbach's alpha of 0.974, indicating strong internal consistency. Subsequently, the LO was tested with real students enrolled in Animation-related courses. Data collected through diagnostic and final assessments, combined with satisfaction surveys, provided insights into learning evolution, usability, and engagement.

The evaluation followed mixed-methods principles: quantitative data from diagnostic/final tests measured knowledge acquisition, and qualitative feedback from open-ended responses captured perceptions of motivation, clarity, and enjoyment.

The results confirmed improvements in conceptual understanding, high user satisfaction, and strong acceptance of the gamified narrative approach.

Phase 5 – Distribution

After validation, the course was deployed on a functional Moodle instance and made accessible online. The dashboard application was published via Streamlit Cloud with authenticated access for instructors.

Comprehensive documentation accompanied the final release, including a README file, user manual, and technical report to support replication and scalability.

4. Design and Implementation

The design and implementation of the LO A2D.12 – Master the Motion aimed to translate pedagogical objectives into an immersive digital environment that combined narrative, interactivity, and data analysis. The process aligned the principles of Digital Storytelling and Serious Games with instructional design strategies, ensuring that the learning

experience was both engaging and educationally coherent. The LO and its analytical dashboard were developed as complementary components – one focusing on learner interaction, the other on data monitoring and pedagogical evaluation.

4.1 Learning Object Design

The LO unfolds as a narrative journey inside a virtual animation studio. Learners enter as novice animators and progress through five roles – Apprentice, Intern, Junior Animator, Senior Animator, and, finally, Director – each stage introducing a coherent subset of the twelve principles and culminating in a capstone challenge. Progression is framed by three recurring characters: an Art Director who sets the brief and anchors goals, a Senior Animator who models expert reasoning and explains techniques, and a Virtual Assistant that offers contextual hints and motivational nudges. Designed in Adobe Character Animator with consistent text-to-speech voices, these agents provide both didactic guidance and affective continuity.

Gamification is woven into the flow rather than presented as separate tasks. Learners advance by levels, earn points and badges as evidence of mastery, receive immediate feedback that consolidates correct reasoning and corrects misconceptions, and unlock new sections once prerequisite activities are completed – maintaining a clear sense of purpose and sequential learning. Interactive content was authored in H5P and embedded in Moodle to keep everything modular and frictionless. Instead of enumerated item types, the experience alternates short explanatory video moments with in-video questions, branching micro-scenarios that simulate studio decisions, and lightweight practice interactions (e.g., drag-and-drop or short responses), interleaved with compact, animated course presentations. This cadence balances narrative immersion with hands-on practice. Assessment is integrated at three points without breaking the story arc. A 13-item diagnostic quiz establishes prior knowledge of the principles; formative checks appear throughout the modules with automatic scoring and targeted feedback; an end-of-course test mirrors the diagnostic to enable straightforward learning-gain analysis. Learner perceptions of clarity, motivation, and usability are captured through a satisfaction and reflection survey validated by four experts (Cronbach's $\alpha = 0.974$), serving both quality assurance and research purposes.

The visual and interaction design privileges cognitive clarity. A restrained palette with controlled accents conveys a professional studio mood; a stylised studio map functions as the main navigation and metaphor for the learner's journey, with each "room" corresponding to a module. Vector graphics produced in Illustrator and Photoshop ensure scalability and crispness, and motion is used sparingly to support explanation and performance rather than distract – keeping the focus on learning the twelve principles while preserving a polished, coherent aesthetic.

4.2 Implementation in Moodle

The LO was deployed on a dedicated Moodle 4.4 instance, chosen for its open-source model, strong community, and native compatibility with SCORM and xAPI. Within a single course shell, we integrated H5P activities, assessments, analytics, and a lightweight virtual assistant, organising sections to mirror the studio narrative. Completion rules and gradebook automation enforced meaningful progression, while the OpenAI Chat Block embedded a GPT-based helper for contextual, real-time support. xAPI events were emitted via the Tin Can Launch Link plugin to a Watershed Learning Record Store, which

provided granular traces of behaviour such as completions, time-on-task, quiz attempts, and broader engagement, forming the basis for subsequent analysis.

4.3 Analytical Dashboard Design

To turn those traces into actionable insight, a Streamlit dashboard in Python 3.12 that ingests two primary sources: CSV exports from Moodle's gradebook and surveys, and xAPI statements retrieved from Watershed and parsed with custom scripts. A simple ETL flow automates extraction, cleans and harmonises fields (including timestamp normalisation) with pandas, and loads tidy dataframes for interactive queries, enabling real-time analytics without reliance on commercial LA tools and retaining full control over privacy. Figure 1 shows the pipeline.

Functionally, the dashboard offers an Admin view for instructors and a Learn Stats overview for reporting. The former exposes distributions of xAPI verbs, activity over time, diagnostic–final comparisons, and item-level accuracy to pinpoint strengths and misconceptions; the latter summarises cohort demographics, learning evolution across modules, best- and worst-performing questions, and satisfaction indicators. Visualisations are generated on the fly with matplotlib and plotly, with filters to move seamlessly between aggregate patterns and individual trajectories. Technically, the app follows a small modular layout (dashboard_app.py, data and script folders plus configuration) and is hosted on Streamlit Cloud with simple authentication and live refresh, wrapped in a visual theme aligned with the LO to keep interpretation clear and accessible.

Figure 1- xAPI data process pipeline.

4.4 Challenges and Solutions

Some technical and pedagogical challenges emerged during implementation:

- *Hosting constraints:* the initial free Moodle hosting plan limited the number of inodes and PHP background processes. This was solved by migrating to a paid hosting service supporting cron jobs and xAPI scripts.
- *Integration of xAPI:* compatibility issues between H5P content and xAPI tracking required additional configuration via the Tin Can plugin. Manual testing ensured that all learner interactions were captured.
- *Virtual assistant tuning:* the OpenAI Chat Block plugin offered limited customization. The assistant was therefore configured primarily for FAQ and contextual support rather than domain-specific tutoring.

During processing and analysing Moodle CSV exports, other technical issues emerged. Inconsistent headers were handled with regular expressions to detect relevant columns dynamically, avoiding reliance on fixed names. Variations in how "Portuguese" nationality was entered (e.g., "pt", "Portugal") – a consequence of using a free-text field – were normalised with str.lower(), strip(), and unidecode(), plus a mapping dictionary to unify terms. Irregular or mismatched time zones were resolved by parsing timestamps

with parser.isoparse() and converting them to a single reference using tz_convert("UTC").

Errors in completion-time calculations caused by missing events were mitigated by intersecting only users with both required events and introducing a fallback with a warning for incomplete cases. Finally, failures when reading the "Média" (Average) row in raw files were addressed through automatic delimiter detection and a more robust search routine to capture those statistical values reliably.

5. Results

The evaluation of A2D.12 – Master the Motion examined learning effectiveness, engagement, and satisfaction, and the performance of the analytics dashboard, combining pre/post testing, completion, and interaction traces, and expert-validated survey data. Overall, the integration of DS and SG within the LO supported both conceptual understanding and affective engagement with the twelve principles of 2D Animation, in line with prior evidence on narrative and gamified multimedia learning (Gaeta et al., 2014; Ravyse et al., 2017; Robin, 2016; Bellotti et al., 2010; Arnab et al., 2015).

Learning gains were measured with identical 13-item diagnostic and final tests. Mean performance rose from 0.592 to 0.662, a +12.0% improvement overall. At item level, the largest relative gains occurred on P.5 (+200.0%), P.6 (+41.9%), P.10 (+30.8%), and P.1/P.3 (+15.9% each), with smaller but positive shifts on P.2 (+7.9%), P.8 (+5.5%), P.9 (+4.7%), P.12 (+11.5%), and P.13 (+5.5%). Three items showed slight declines – P.4 (−1.4%), P.7 (−1.3%), and P.11 (−5.4%) – which we interpret as local effects of item phrasing and ceiling constraints rather than systemic weaknesses.

The magnitude of the aggregate gain, while clearly positive, was less pronounced than initially expected. Contextual factors help explain this result. LO was piloted at the end of the academic year with second-year students, a cohort that already possessed substantial prior knowledge of foundational animation concepts. This high baseline limited headroom for improvement and likely produced ceiling effects, particularly on items where diagnostic scores were already moderate to high (cf. Naul & Liu, 2018; Robin, 2016).

Even with a strong starting point, the DS+SG design appears to have reinforced understanding where misconceptions or gaps persisted – especially on items targeting procedural reasoning and application (e.g., P.6 and P.10). Immediate feedback, level-based progression, and narrative scaffolding offered repeated, contextualised practice, which aligns with reported mechanisms for motivation and knowledge consolidation in serious, narrative-driven learning (Bellotti et al., 2010; Arnab et al., 2015; Ravyse et al., 2017). The dashboard corroborated these patterns through granular traces of engagement and quiz behaviour, supporting a data-informed interpretation of where the LO had the strongest instructional leverage.

The pilot demonstrates meaningful but bounded gains in a relatively advanced cohort: the LO lifted average performance by twelve per cent, delivered notable improvements on several targeted principles, and maintained high engagement and satisfaction, while also revealing specific items for revision in the next iteration. Future runs with first-year cohorts – or with pre-teaching deployment earlier in the semester – are expected to yield

larger effects by reducing ceiling constraints and providing a longer window for practice and consolidation.

Learner engagement was examined through participation rates, activity completion, and qualitative feedback collected via surveys and interviews.
The completion rate for the full LO sequence was 100%. This figure compares favourably to average completion rates in e-learning environments, often below 70% (Kizilcec et al., 2013).

User satisfaction was gauged through a post-course survey (five-point Likert scale), previously reviewed by four subject-matter experts. Results were very positive across both cognitive and emotional engagement, with most items scoring above 4.0. The instrument showed excellent reliability (Cronbach's $\alpha = 0.974$), confirming the soundness of its structure.

Learners particularly valued the fit between pace/methods and their needs, the usefulness of the resources and materials for learning, and their willingness to recommend the course to peers interested in 2D Animation. Slightly lower – though still favourable, all >3.5 – were items relating to setting explicit goals before starting, feeling socially connected to classmates in an online setting, and maintaining concentration in e-learning contexts. These patterns are consistent with the literature showing that narrative and game-based elements can heighten purpose and persistence while social presence and self-regulation often require additional scaffolds (Naul & Liu, 2018; Robin, 2016).

Open responses reinforced the value of the studio-based narrative and also produced actionable refinements. Two recurrent suggestions concerned accessibility and navigation: three learners asked for captions on videos and for smoother progression between Moodle activities (e.g., a "continue to next activity" control or automatic advance). Automatic captioning – initially disabled due to transcription errors – has since been enabled and partially corrected, with a final review planned to ensure accuracy and inclusivity. As for progression, a direct "auto-advance" between H5P/Moodle modules is not natively supported in our current setup; further exploration of themes/plugins and course-design patterns is planned to approximate the requested flow (e.g., clearer end-of-activity links and completion-based restrictions).

Taken together, the satisfaction data depict a well-received, coherent experience that aligns pacing, resources, and motivation with learners' expectations, while highlighting two pragmatic improvement avenues – stronger social/goal-setting scaffolds and streamlined navigation – to deepen the DS+SG effects observed.

6. Conclusion

This work presented A2D.12 – Master the Motion, an LO that integrates DS, SG, and Learning Analytics to teach the twelve principles of 2D Animation. Implemented as a coherent ecosystem – Moodle 4.4 with H5P content and an instructor-facing Streamlit dashboard – the solution combined narrative guidance, challenge-based practice, and immediate feedback with real-time monitoring of progress and satisfaction. In practice, the approach fostered cognitive and emotional engagement and supported more

meaningful, self-regulated learning. Quantitatively, the pilot with second-year students produced a +12% average gain from diagnostic to final assessment; qualitatively, survey results were strongly positive across clarity, usefulness, and recommendation intention, with $\alpha = 0.974$ confirming excellent internal consistency. Ceiling effects plausibly explain the slightly more modest learning gain than initially anticipated: the trial occurred at the end of the academic year with a cohort already holding substantial prior knowledge.
Technically and pedagogically, the project demonstrated that DS and SG can be combined within a single, analytically transparent LO to transform abstract principles into structured, experiential sequences. The dashboard added actionable insight – tracking completions, time on task, and item performance – and supported rapid iteration on content and assessment. Open comments highlighted two practical enhancements that increase inclusivity and flow: captioning of videos (now enabled and partially corrected, with a final review planned) and smoother progression between Moodle activities (an area for further design and plugin exploration).

6.1. Limitations

The pilot was conducted with a modest, single-institution sample, limiting generalisability. The embedded AI assistant operated mainly as a static helper with limited adaptivity. Certain platform constraints – initial free hosting limits, cron execution issues, and incomplete xAPI coverage for some H5P types – shaped authoring choices and occasionally restricted data capture. Sequential navigation between modules in Moodle also proved less fluid than learners desired. These factors are documented and, in most cases, already mitigated through configuration changes or workflow adjustments.

6.2. Future directions

Building on the validated core, the next iteration will focus on: (i) direct Moodle API integration to automate data ingestion and remove manual CSV exports; (ii) improved data hygiene at source (e.g., controlled nationality fields to avoid text mapping); (iii) automatic PDF reporting with customisable views; (iv) streamlined sequential navigation through dedicated navigation plugins; (v) enhanced accessibility, consolidating caption quality, contrast and screen-reader compatibility; (vi) longitudinal studies with larger, earlier-stage cohorts to reduce ceiling effects and strengthen statistical power; and (vii) proactive analytics alerts (e.g., low-interaction modules, high-error items) to support timely pedagogical intervention.

A2D.12 shows that a DS+SG+Analytics model can deliver a rigorous yet emotionally resonant learning experience in digital arts education. By aligning narrative meaning, game-based motivation, and transparent evidence of learning, the project provides a replicable blueprint for other creative and technical domains, while the outlined enhancements chart a clear route to greater impact and scalability.

REFERENCES

Arnab, S., Berta, R., Earp, J., de Freitas, S., Popescu, M. M., Romero, M., Stanescu, I., & Usart, M. (2015). Framing the adoption of serious games in formal education. Education and Information Technologies, 20(5), 1043–1073.

Bellotti, F., Kapralos, B., Lee, K., Moreno-Ger, P., & Berta, R. (2010). Assessment in and of serious games: An overview. Advances in Human-Computer Interaction, 2010, 1–11. https://doi.org/10.1155/2010/136364

Breuer, J., & Bente, G. (2010). Why so serious? On the relation of serious games and learning. Journal for Computer Game Culture, 4(1), 7–24.

De Freitas, S., & Jarvis, S. (2006). A framework for developing serious games to meet learner needs. In M. Pivec (Ed.), Games and simulations in online learning: Research and development frameworks (pp. 215–241). IGI Global.

Di Blas, N., Garzotto, F., Paolini, P., & Sabiescu, A. (2009). Digital storytelling as a whole-class learning activity: Lessons from a three-year project. Proceedings of the 14th International Conference on Human–Computer Interaction (HCII 2009), 14, 1–10.

Downes, S. (2001). Learning objects: Resources for distance education worldwide. The International Review of Research in Open and Distributed Learning, 2(1), 1–35. https://doi.org/10.19173/irrodl.v2i1.32

Duval, E., Leuven, K. U., Hodgins, W., Rehak, D., & Robson, R. (2003). Learning Objects. 2003 Symposium: Lessons Learned, Questions Asked. ISBN: 380094-49-5.

Gaeta, M., Loia, V., Mangione, G. R., Orciuoli, F., & Ritrovato, P. (2014). A methodology and an authoring tool for creating complex learning objects to support interactive storytelling. Computers in Human Behavior, 31, 620–637. https://doi.org/10.1016/j.chb.2013.06.005

Gordillo, A., López-Fernández, D., & Fernández-Manjón, B. (2021). Designing serious games for education: From pedagogical principles to learning analytics. British Journal of Educational Technology, 52(3), 1451–1475. https://doi.org/10.1111/bjet.13072

Kaminskienė, L., & Khetsuriani, N. (2019). Digital storytelling in higher education: A case study. International Journal of Emerging Technologies in Learning, 14(19), 88–102. https://doi.org/10.3991/ijet.v14i19.11113

Kizilcec, R. F., Piech, C., & Schneider, E. (2013). Deconstructing disengagement: Analyzing learner subpopulations in massive open online courses. Proceedings of the Third International Conference on Learning Analytics and Knowledge (LAK'13), 170–179. https://doi.org/10.1145/2460296.2460330

Krauss, F., & Ally, M. (2005). A study of the design and evaluation of a learning object and implications for content development. Interdisciplinary Journal of E-Learning and Learning Objects, 1, 1–22. https://doi.org/10.28945/404

Lameras, P., Arnab, S., Dunwell, I., Stewart, C., Clarke, S., & Petridis, P. (2017). Essential features of serious games design in higher education: Linking learning attributes to game mechanics. British Journal of Educational Technology, 48(4), 972–994. https://doi.org/10.1111/bjet.12467

Liarokapis, F. (2011). Serious games for cultural heritage education. In S. de Freitas, M. Ott, M. Popescu, & I. Stanescu (Eds.), New technologies for enhancing teaching and learning (pp. 43–58). IGI Global.

Naul, E., & Liu, M. (2018). Why story matters: A review of digital storytelling research in education. Journal of Educational Multimedia and Hypermedia, 27(4), 411–449.

Ravyse, W. S., Blignaut, A. S., Leendertz, V., & Woolner, A. (2017). Success factors for serious games to enhance learning: A systematic review. Virtual Reality, 21(1), 31–58. https://doi.org/10.1007/s10055-016-0298-4

Robin, B. R. (2016). The power of digital storytelling to support teaching and learning. Digital Education Review, 30, 17–29. https://doi.org/10.1344/der.2016.30.17-29

Shaw, M. (2002). Learning objects: A new paradigm for instructional design? Journal of Educational Technology Systems, 31(1), 31–42.

Tran, M., Carruthers, S., & de Freitas, S. (2010). Using serious games for training and learning in the healthcare sector. Procedia - Social and Behavioral Sciences, 9, 312–316. https://doi.org/10.1016/j.sbspro.2010.12.155

von Nimwegen, C., & van Oostendorp, H. (2013). Narrative-based serious games: Design recommendations and lessons learned from two practical cases. In S. de Freitas, M. Ott, M. Popescu, & I. Stanescu (Eds.), New technologies for enhancing teaching and learning (pp. 1–22). IGI Global.

Wiley, D. A. (2000). Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy. In D. A. Wiley (Ed.), The instructional use of learning objects (pp. 1–35). Agency for Instructional Technology.

Zhonggen, Y. (2019). A meta-analysis of the use of serious games in education over a decade. International Journal of Computer Games Technology, 2019, 1–8. https://doi.org/10.1155/2019/4797032

Joana Braguez, Invited Adjunct Professor at the School of Technology and Management of Viseu; recently earned a Bachelor's in Computer Engineering from Portugal Open University (2025); also holds a Bachelor's in Digital Arts and Multimedia (2008) from ESAD, Matosinhos, a Master's in Visual Arts Education (2010) from the University of Aveiro, and a PhD in Contemporary Art (2017) from the College of Arts, University of Coimbra.

Arnaldo Santos, Professor at the Department of Sciences and Technologies of Portugal Open University. Invited Professor at the Department of Communication and Art of the University of Aveiro. He is a vice director of the doctorate program in web sciences and technology. He completed his PhD studies at the University of Aveiro, where he obtained degrees in Communication Sciences and Technology. He has participated as author and coauthor in 4 books and more than 100 papers published in international conferences and journals, as well as in several research projects.

(esta página par está propositadamente em branco)