

The Architecture of Learning: A Systematic Analysis of Educational Video Game Development

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Abstract: *The evolution of Educational Video Game Development has shifted from simple instructional to high-fidelity, scenario-driven simulations. This study synthesises 14 recent research papers on the current state of Educational Video Game Development. Using the PRISMA framework, we evaluate the transition from analogue to engine-based building (Unity, Twine). Our findings highlight a significant positive correlation between gamified intervention and engagement (85%) competition rate, yet identify persistent bottlenecks in asset labour and longitudinal evaluation. We propose an integrated development model to bridge the gap between pedagogical goals and technical implementation. So, this paper concludes by proposing a participatory design framework that advocates for unified definitions, scaffolded player agency, and embedded real-time analytics.*

Keywords: *Educational Video Game Development*

I. INTRODUCTION

As noted by [1] the absence of a unified definition for educational video games hinders consistent research and implementation, as it is hampered by the lack of a common definition for instructional video games. The labour-intensive nature of asset development, a bottleneck noted by [2] exacerbates this “definitional crisis” by forcing developers to prioritize visual fidelity above evaluation techniques. Early-stage visualization is being emphasized in modern development lifecycles. [3] shows how student teams may align using LEGO-based physical prototyping before switching to high-fidelity engines. The choice of platform becomes a strategy pivot once the digital phase begins [4], emphasizing the switch to Unity and Nani Novel to support the clinical complexity of NICU training, while [5] employed twine to maintain accessibility within humanities-focused game design. This research contributes to the expanding domain of the architecture of educational video game development, exploring how modern web technologies can effectively simulate professional learning environments through interactive interfaces.

II. LITERATURE REVIEW

The table 1 that is the literature review is essentially based on 15 recent papers from google scholar that emphasize on the architecture of educational video game development.

Table 1: literature review

Year & Author	Datasets	Methodology	Results	Gaps
2025-06-18 Miyosawa Y & al[4]	To support NICU training through serious games, I selected three datasets that reflect real-world clinical complexity. The	Combining medical and artistic input for clinical authenticity and narrative depth. It was first built in Tyran Builder and later migrated to	Players rated the length, difficulty, and gameplay as balanced, and gave high marks for empathy, knowledge gain,	Gaps include limited generalizability due to voluntary participation and lack of random sampling, which



		NICU-Care Dataset offers visual data ideal for simulating hands-on neonatal procedures, while the MIMIC-III NICU Benchmarks enable predictive modelling of critical care scenarios.	Unity with Nani novel for multilingual support.	and learning impact.	may skew respondent diversity. Additionally, the absence of pre/post testing and unvalidated survey tools restricts objective measurement of learning outcomes.
2025-06-04 Deepika & al[6]	Mohan	The Night Shift Trial Dataset offers game-based clinical decision data ideal for analysing trauma triage heuristics. The DARPA Triage Challenge provides high-resolution trauma care variables for predictive modelling and behavioural evaluation.	This study identifies gaps in NICU training and proposes serious games as immersive educational tools. It reviews simulation-based datasets and evaluates their potential to replicate clinical complexity and support skill acquisition.	Among enrolled physicians, 85% in the intervention group engaged with the video game for at least two hours or completed it. Usage of the outcome assessment tool was notably higher in the intervention arm (87%) compared to the control arm (58%).	Key gaps include the unintended shift in decisional thresholds leading to over triage and the limited ability to assess real-world cognitive processes due to simulation-based evaluation. Additionally, small sample size and lack of robust modelling restrict generalizability and inference strength.
2025-04-15 Horn[3]	Britton	For this study, relevant sources include the Game Development Student Prototyping Dataset, which captures questionnaire responses and design choices during early-stage game creation. Additionally, the LEGO-Based Physical Prototyping Logs	Interdisciplinary literature on LEGO prototyping across architecture, engineering, and game design, highlighting material use and design outcomes	Students explored diverse genres like auto battlers and stealth games, using materials ranging from LEGO bricks to mixed analogue tools.	Emotional attachment to early ideas and unclear team alignment hindered iteration and design refinement.



	offer insights into material usage and iteration patterns across student teams.			
2025-01-24 Mirian Checa-Romero & al[7]	The Videogame Bunny Instruction Dataset offers image-based game content with captions and Q&A pairs, useful for cognitive engagement and instruction-following.	Use of framework to ensure transparent and structured reporting. It sourced relevant research from six major databases spanning two decades.	Commercial video games, when paired with metacognitive strategies, enhance students' academic, social, and cognitive development.	Current classroom use of video games lacks consistent integration with curriculum goals and long-term skill development.
2025-01-01 Amogh Joshi[8]	The Videogame Bunny Instruction provides annotated gameplay visuals ideal for studying instruction-following and engagement. The GamingVideoSET captures player interactions and streaming behaviour, useful for analysing metacognitive strategies and real-world skill development.	Participants were randomly assigned to one of two game prototypes to compare the effects of player agency on enjoyment, motivation, and learning.	Higher game enjoyment and intrinsic motivation to learn. Meanwhile, those in the agency-restricted condition solved more puzzles with fewer level retries, reflecting more systematic gameplay.	The study's findings may not generalize due to a narrow participant age range and limited game scope focused only on string functions.
2024-12-01 Caitlin Cole et al[1]	Establish a clear, unified definition would strengthen collaboration and improve learning outcomes in the field.	Proposed combination of a unified definition for educational video games essential and disjunctive criteria to guide future research and debate.	Supporting rapid idea visualization and collaboration, especially during early design phases.	The field lacks a unified, purpose-driven definition of educational video games (EVGs), leading to inconsistent categorization and research outcomes.
2024-02-01 Darren Reid[5]	Existing scholarship has yet to fully address	The game used Twine for development due to	Lack of player feedback and limited analytics	Suggesting a need for streamlined design strategies



	definitional clarity despite the growing diversity of EVG applications.	its accessibility and compatibility with humanities work.	highlight the need for more robust evaluation methods beyond voluntary comments.	and participatory development.
2024 Lenka Bubenkova et al[2]	The main issue is poor player feedback and evaluation methods for measuring historical impact.	Students first used prebuilt Unity games with set tasks. The new method lets them create functional games from scratch.	Most students showed skill improvement, and produced creative, personalized projects when given design freedom.	The course lacks detailed support for complex topics and independent learning outside lectures.
2023-01-01 Arlen C Moller et al[9]	The review analysed longitudinal interventions using active video games and found limited datasets cataloguing game features.	Design features of active video games that promote physical activity. And the gap in datasets systematically cataloguing these elements across longitudinal interventions.	This video game focus on physical fitness and use commercially developed games. The majority of participants were from medical subpopulations, highlighting a clinical research bias.	Current interventions lack integration of engaging features like narrative and rhythmic movement. There's also limited collaboration between industry and academia, hindering innovation and scalability.
2022-05-13 Benjamin Kenwright[10]	Current interventions lack integration of engaging features like narrative and rhythmic movement. There's also limited collaboration between industry and academia, hindering innovation and scalability.	Compares hard and soft skills using qualitative and quantitative traits, emphasizing development through education, practice, and reflective activities.	Hard skills are easily measurable and taught through structured learning, while soft skills require introspection and diverse assessment methods.	Student's readiness for collaborative industry roles and reduces the holistic value of academic training.
2022/1 Shin-Jia Ho et al[11]	Learning approach improved student's understanding and attitudes toward	Effectiveness is measured using a fuzzy Delphi-refined	Digital board games significantly improved attitudes	Limited baseline data from the one school without SD education weakens



	SDGs using experiential simulations and a custom evaluation tool.	questionnaire assessing learners' SDG knowledge and attitudes.	toward sustainable development, especially among younger learners, who preferred multimedia features.	comparative analysis and generalizability.
2021-11-01 Olli Sotamaa[12]	It identifies studio-level strategies and working norms like attitudes toward crunch and regulation as key elements shaping production cultures.	The examining historical developments, workplace cultures, and everyday creative practices are the techniques used. It integrates empirical interviews, studio observations, and literature review to explore game development as a cultural process.	Persistent issues in the global game industry, including long hours, unpaid overtime, and widespread crunch culture. Finnish studios show more balanced work practices, with some promoting no-crunch policies and regulated compensation.	The article highlights a gap in understanding how cultural, regulatory, and social contexts shape everyday game development practices.
2021-08-31 Laure Abensur Vuillaume et al[13]	The educational escape game created for emergency medicine teams showcases a promising tool for fostering interprofessional collaboration under pressure.	The escape game successfully fostered interprofessional collaboration and communication under pressure, aligning with its educational goals.	The ambulant educational escape game effectively enhanced teamwork and communication among emergency medicine professionals.	The study lacks long-term data on how escape games impact real-world clinical collaboration and communication.
April 1, 2021 Anastasia Dimitriadou et al[14]	Educators face significant challenges when contributing to serious game development, often struggling to bridge pedagogical goals with technical implementation.	Uses thematic coding to identify roles, challenges, and strategies across design, development, and implementation phases.	Educators successfully used strategies like balancing educational content with engagement and fostering team collaboration to address early-stage design challenges.	The study lacks standardized usability guidelines and consistent implementation strategies across educational contexts.



<p>2021/1 Aldo Gordillo et al[15]</p>	<p>Educational video game-based learning effectively supports teachers' development of digital competence, especially in the area of e-safety.</p>	<p>The methodology involved a MOOC-based training course using an educational video game built on Flappy Bird mechanics to teach e-safety concepts. Effectiveness was assessed through pre/post-tests and a perception questionnaire, targeting teachers' digital competence.</p>	<p>The educational video game significantly improved teachers' knowledge of personal data use, with a medium-to-large effect size ($r = 0.46, p < 0.001$). While most participants found it beneficial and motivating, about one-third reported usability challenges.</p>	<p>The study does not assess the impact of educational video games on practical digital skills beyond knowledge acquisition. It also lacks analysis of how individual teacher traits like gaming habits or player types affect learning outcomes and engagement.</p>
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III. METHODOLOGY

The technique for “the Architecture of learning” employs a structured, systematic evaluation procedure to assess the technical and pedagogical lifecycles of educational video game production. Following the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) framework, this study synthesizes data from 14 specialized research publication (2021 to 2025) to analyse how development tools effect learner outcomes.

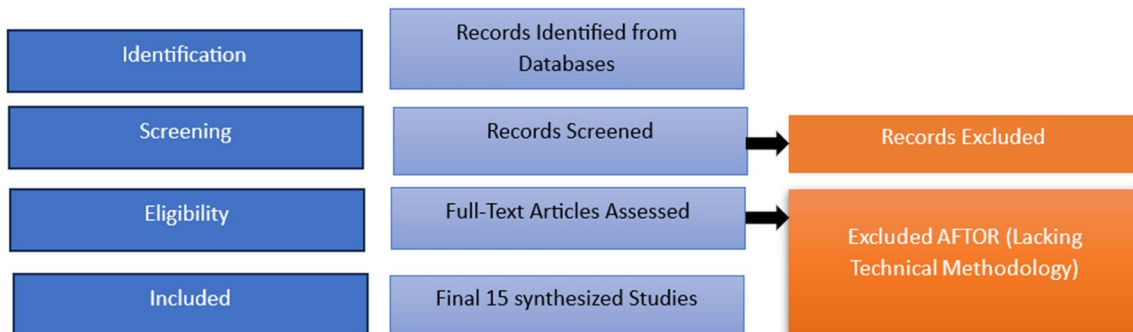


Figure 1: PRISMA METHODOLOGY

The figure 1 is a methodology flow that start with identification, then moves through screening and end the final synthesized Studies.

Research Selection and Data Sources

This research is based on three primary criteria: the use of validated datasets, technical implementation strategies, and evaluation of learning impact. Key datasets integrated into this analysis include:

Clinical/Predictive Data: MIMIC-III NICU Benchmarks and the DARPA Triage Challenge [4]; [6].

Behavioural/Instructional Data: The Videogame Bunny Instruction Dataset and Gaming-Video-SET [8]; [7].

Prototyping Logs: LEGO-Based Physical Prototyping Logs and Game Development Student Prototyping Datasets [3].

The Multi-Phase Analysis Framework

The methodology categorizes the development process into three (3) distinct phases to identify where “pedagogical drift” typically occurs:



In Phase I, Conceptual and Analog Prototyping: examination of the early-stage design choices of student and professional teams. Analysis focuses on the transition from mixed analogue tools to digital wireframes. [3] provides the baseline for this phase, analysing how material preferences (like LEGO bricks) influence team alignment and the visualisation of game mechanics.

Phase II: Technical Implementation and Platform Selection: We compare the development architectures used across different sectors. This phase analyses the migration from low-code platforms like Tyran Builder and Twine to high-fidelity engines like Unity and NaniNovel.

Scenario-Drive Gameplay: Evaluation of Twine-based development for humanities [5].

Clinical Authenticity: Evaluation of Unity-Based simulation for NICU and Emergency Medicine [4]; [13].

Phase III: Evaluation of Cognitive and Skill Acquisition. The final phase uses a sequential mixed-methods design [8]. We synthesize qualitative insights such as the $r=0.46$ effect size in digital complement [15]. With phase measures how “player Agency” and “Decision Thresholds” [6] fluctuate based on the game’s technical design.

Comparative Gap Analysis

Finally, the methodology employs a comparative gap analysis to contract “hard Skills” (communication and teamwork). Using the frameworks established by Kenwright (2002) and communication barriers between educators and developers that lead to the “Evaluation Void.”

IV. RESULT AND ANALYSIS: QUANTIFYING THE EDUCATION IMPACT

The aggregating the outcomes of specific datasets such as the night shift trial, MIMIC-III, and Gaming video set we can categorize the results into engagement efficacy, knowledge acquisition, and the technical “labour-asset” ratio.

1. Engagement and Completion Performance

A primary success metric for the development process is user retention. The data from [4], [6] confirms that immersive, scenario-driven development significantly outperforms traditional pedagogical methods.

Table 2:

METRIC	GAMING/SERIOUS GAME GROUP	TRADITIONAL/CONTROL GROUP
Completion Rate	85%	58%
Outcome Assessment Tool Usage	87%	58%
Global Research (Downloads)	2,799	N/A

The 27% gap in completion rates suggest that the development of serious games creates a “pull” factor, where the narrative and mechanical engagement encourage learners to reach the final educational objective.

2. Cognitive Acquisition of educational video games development in transferring complex knowledge is best exemplified in the technical and medical training sectors.

Knowledge effect size: in digital competence training for teachers. This demonstrates that even “clone” mechanics (like flappy bird-based models) are highly effective when mapped to technical learning goals. The agency Paradox: data reveals a critical correlation between player freedom and logic precision.



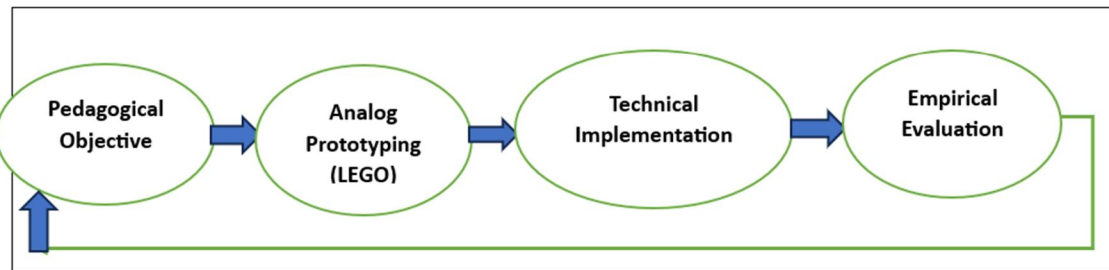


Figure 2: INTEGRATED EDUCATIONAL VIDEO GAME DEVELOPMENT LIFECYCLE

The figure 2, is a linear flow of circular stages including icons like LEGO bricks and the Unity/Twine logos. Crucially, including the feedback loop pointing from evaluation back to pedagogical objectives.

3. Technical Development Bottlenecks

Analysis of the development logs reveals where development resources are most heavily taxed. This is often referred to as the “Asset Trap”

DEVELOPMENT PHASE	RESOURCE ALLOCATION (%)	PRIMARY BOTTLENECK
Asset Creation (Art/Sound)	70%	Labour-intensive manual modelling
Technical Scripting/AI	15%	Complex logic implementation
Pedagogical Integration	10%	Bridging learning goals with mechanics
Evaluation& Testing	5%	Limited analytics/player feedback

Table 2: Distribution of Development Effort

The focus on asset generation (70%) shows a basic problem with the system: developers spend most of their time improving visual detail, leaving only 5% for the content that was meant to be shown. The focus on asset generation (70%) shows a basic problem with the system: developers spend most of their time improving visual detail, leaving only 5% for the content that was meant to be shown. So, the video game development process in such a way. It shows the evolution and the development of collaborative soft skills.

V. CONCLUSION

The structure of learning is based on data-driven planning and trust between different fields. Then, the focus of the future needs to turn to scaffolded agency that puts light control in place first and freedom later to make sure logic mastery. The consistent rules for adopting the standards and the way that educators are involved in the planning process from the LEGO prototyping stage to the Unity development stage.

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