

# Enhancing Learner Engagement and Retention in STEM MOOCs Through Interactive 3D Simulations Developed in Game Engines

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DOI: <https://doi.org/10.51244/IJRSI.2026.13020030>

Received: 29 January 2026; Accepted: 04 February 2026; Published: 25 February 2026

## ABSTRACT

Massive Open Online Courses (MOOCs) in STEM fields continue to face low engagement and completion rates, often below 15% in open/free formats despite platform growth and innovations. This study examines the integration of interactive 3D simulations built with Unreal Engine and Unity into STEM MOOCs to boost learner engagement and retention. A prototype virtual physics laboratory was developed using Unreal Engine and Unity, incorporating real-time physics, Niagara visual effects, Blueprint scripting, and features for experiments such as projectile motion and circuit simulations. The module was deployed in a Coursera-style MOOC platform with 248 participants (control group: traditional video lectures, n=124; experimental group: 3D interactive group, n=124). Quantitative results indicated a 42% increase in average module completion rate (from 38% to 80%) and a 31% improvement in post-test scores in the experimental group. Engagement metrics (time-on-task, interaction logs) increased by 57%. Qualitative feedback emphasized enhanced immersion and reduced cognitive load. Findings demonstrate that game engines like Unreal Engine and Unity provide scalable, cost-effective tools for experiential learning in online STEM education. Limitations include device compatibility, bandwidth demands, and lack of long-term retention data. Future directions should prioritize long-term follow-up studies, optimization/cloud-based streaming for accessibility, multi-user VR/AR extensions, cost-benefit analyses, and broader demographic sampling.

**Keywords:** MOOCs, STEM Education, Unreal Engine and Unity, Interactive 3D Simulations, Learner Engagement, Retention Rates, Virtual Laboratories, Game-Based Learning

## INTRODUCTION

Massive Open Online Courses (MOOCs) have democratized access to higher education, with millions enrolling in STEM subjects annually and the global MOOC market expanding significantly in recent years. However, challenges persist, particularly low learner engagement and retention. Completion rates in open MOOCs typically range from 5–15%, though structured or paid programs can achieve higher rates (up to 80–85% in some cases). Passive formats like video lectures and static quizzes often fail to support the hands-on, experiential demands of STEM disciplines, where practical application is essential for deep conceptual understanding.

Game engines such as Unreal Engine (by Epic Games) and Unity offer robust tools for real-time 3D interactive environments, featuring accurate physics simulation, high-fidelity rendering, and cross-platform deployment—including WebGL/HTML5 for MOOC integration. Their visual scripting systems (e.g., Blueprints in Unreal) and particle/effects tools (e.g., Niagara) allow educators with limited coding expertise to create sophisticated simulations. This paper investigates whether embedding such Unreal Engine- and Unity-based interactive 3D simulations in STEM MOOCs can improve engagement (via behavioral metrics) and retention (completion and knowledge outcomes).

### Research Questions:

1. Does exposure to interactive 3D simulations increase module completion rates in STEM MOOCs?
2. How do such simulations affect learner performance and perceived engagement compared to traditional formats?

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## LITERATURE REVIEW

Prior research on MOOC engagement highlights gamification, personalization, and interactivity as key levers for improvement. Virtual laboratories have demonstrated benefits for practical skills in science education. Game engines like Unity and Unreal have been used in educational simulations, with Unreal noted for photorealistic rendering and physics fidelity. However, large-scale integration into MOOCs specifically for STEM retention remains underexplored, particularly with empirical data from platforms like Coursera or edX. This study addresses that gap through a controlled quasi-experimental design.

## METHODOLOGY

**Simulation Development** A virtual physics lab prototype was built in Unreal Engine and Unity (modern versions leveraging ongoing updates). Features included:

- Projectile motion simulator with adjustable parameters (angle, velocity, gravity).
- Electric circuit builder with real-time current and component visualization.
- First-person navigation, interactive UI widgets, immediate feedback, Chaos Physics (Unreal), and WebGL/HTML5 packaging for MOOC compatibility.

**Participants and Design** Quasi-experimental design involving 248 undergraduate students (aged 18–24) in an introductory physics MOOC. Random assignment to:

- Control group (n=124): Standard video lectures + quizzes.
- Experimental group (n=124): Same content + embedded 3D interactive module. Duration: 6 weeks.

### Data Collection

- Engagement: Time-on-task (platform analytics), interaction counts (manipulations/clicks).
- Retention: Module completion percentage.
- Learning Outcomes: Pre/post-tests (20 multiple-choice questions on projectile motion and circuits).
- Qualitative: Post-study survey (Likert-scale + open-ended responses on immersion and usability).

**Data Analysis** Independent t-tests for group differences ( $p < 0.05$ ). Cohen's  $d$  for effect sizes. Thematic analysis of qualitative data.

## RESULTS

### Quantitative Findings

- Completion Rate: Experimental group 80% vs. Control 38% ( $t(246) = 8.42, p < 0.001, d = 1.07$ ).
- Post-Test Scores: Experimental  $M = 82.4\%$  ( $SD = 11.2$ ) vs. Control  $M = 62.7\%$  ( $SD = 14.5$ ) ( $t(246) = 11.3, p < 0.001, d = 1.52$ ).
- Engagement: Average session time 24.6 min (experimental) vs. 14.1 min (control); interaction count 3.2x higher.

**Qualitative Insights** Participants frequently noted: "The 3D simulation made abstract concepts tangible" (68% positive comments on immersion). Drawbacks included initial loading delays on low-end devices (22% of responses).

## DISCUSSION

Interactive 3D simulations markedly improved engagement and retention, consistent with constructivist theories emphasizing active, experiential learning. Unreal Engine and Unity facilitated rapid, low-cost prototyping accessible to non-programmers. Effects were strongest for conceptually challenging topics like physics mechanics.

Limitations include the single-institution sample (potential self-selection bias), absence of long-term retention assessment (e.g., 6–12 months post-intervention), hardware/bandwidth barriers for low-end devices, and lack of diverse demographics (age, professional background). No direct cost comparison was conducted between game-engine development and traditional video production.

## CONCLUSION

Unreal Engine- and Unity-based 3D simulations represent a promising, innovative solution to STEM MOOC challenges, enabling scalable experiential learning with substantial gains in completion, performance, and engagement. Educational institutions and platforms should explore adoption of these tools.

To strengthen future impact, the following enhancements are recommended:

- Conduct long-term follow-up studies measuring knowledge retention 6–12 months after the intervention.
- Investigate optimization techniques (e.g., reduced polygon counts, level-of-detail systems) and cloud-based streaming solutions (leveraging services that render simulations remotely and stream video to low-end devices) to improve accessibility and mitigate hardware/bandwidth limitations.
- Develop and test multi-user VR/AR extensions for collaborative, immersive experiences.
- Perform a comparative cost-benefit analysis of game-engine development versus traditional video production to guide institutional investment decisions.
- Expand participant demographics to include diverse age groups, professional learners, and global cohorts to better support claims of scalability across MOOC platforms.

## ACKNOWLEDGMENTS

The author thanks Gujarat University for platform access and Epic Games for educational licenses to Unreal Engine and Unity.

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