Learning Physics through Elastic Storytelling in Virtual Reality: A Museum-Like Educational Experience

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Figure 1: Virtual learning space with information boards about the Millikan experiment, arranged like an exhibition in a museum.

Abstract

This study explores the conceptual and technical foundation for studying the effects of elastic storytelling in virtual reality (VR) on learning outcomes in physics education, using the Millikan experiment as use case. For investigation, a VR-based learning environment was developed, placing the Millikan experiment within a virtual museum context. Based on the user's decisions, the narrative gradually unfolds deeper content and enables self-directed exploration in the elastic narrative variant. Only fundamental content is displayed in the linear narrative variant in which the user has no decision-making power. A between-subjects study is planned to compare a linear and an elastic narrative variant of the application. Planned data collection includes pre- and post-tests on conceptual understanding, different questionnaires like the NASA-Task Load Index and the Player Experience Needs of Satisfaction. This poster presents the design concept, implementation details, and study plan for future empirical evaluations.

Index Terms: Virtual Reality, Edutainment, STEM.

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1 Introduction

In recent years, virtual reality (VR) has emerged as a powerful medium in science education, offering immersive and interactive environments that have the potential to enhance learners' engagement, motivation, and conceptual understanding [4, 2]. This fact is particularly emphasised in the context of physics education through the understanding of complex and abstract concepts. The literature indicates that student engagement in science lessons is often difficult. Moreover, the inherent complexity of science education makes it particularly challenging to spark interest among all students [5, 3]. The role of narrative in educational VR environments has gained increasing attention in recent years [1]. In this context, the concept of elastic storytelling, defined as a narrative framework that dynamically adapts to users' decisions, prior knowledge, and interaction paths, offers the potential to individualise learning experiences while ensuring educational focus [6]. Despite the theoretical potential, there are still unanswered questions regarding how such narrative structures influence learning processes and outcomes, particularly in connection with complex experimental procedures and their theoretical foundations. This study aims to address this gap in the literature. The present case study involves the development of a VR learning application that focuses on the Millikan experiment (see Figure 1). The following research question will be considered:

How does the elasticity of storytelling in comparison to linear storytelling in virtual reality affect learning outcomes in physics education, as demonstrated by the Millikan experiment?

2 Millikan Experiment as a Virtual Museum Exhibit

The VR application presents the Millikan oil-drop experiment as a museum-like exhibit within a virtual classroom environment (see Figure 2).

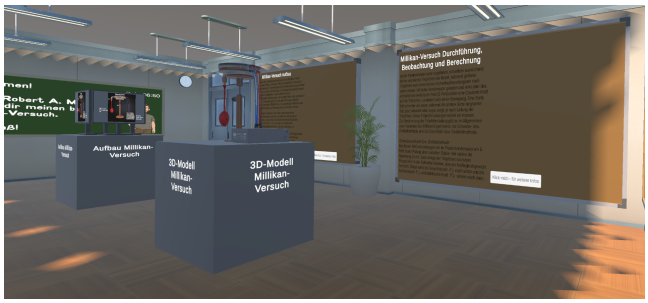

Figure 2: Overview of the exhibit on the Millikan experiment with information boards, the experimental setup and measure instructions including calculation formulas.

Users move through a structured path consisting of informational stations that shed light on the historical context, theoretical background, and experimental setup of electrical charge quantization. Content is conveyed primarily through virtual boards placed along the route (see Figure 3).

Figure 3: Visualisation of the information board with the elastic option to delve deeper into the topic.

In the elastic narrative version, users can choose at certain points whether they want to access additional, in-depth information. In contrast, the linear version presents the same core content without any user-driven branching. The learning content displayed on the information boards was developed in collaboration with a teacher from a secondary school. The application was developed in Unity 6000.0.44f1 using the Meta All-in-One SDK [1] with the Building Blocks system, tailored for Meta Quest 3 and designed for intuitive controller-based navigation. Classroom assets were also used to create a realistic learning environment [2].

3 Planned Study Procedure

To investigate the impact of elastic storytelling on learning in VR physics education, a between-subjects study will be conducted using a custom-developed VR application illustrating the Millikan oil-drop experiment as virtual museum exhibit. The study involves upper secondary school students and is being conducted in a controlled school setting. At the beginning of the study, they are asked about their interest in physics and whether they are already familiar with the Millikan experiment. The participants then receive a pre-knowledge test, the results of it are logged for the evaluation but not shown. They will experience one of two variants of the narrative storytelling: either linear or elastic. After each VR experience, participants will complete the Player Experience Needs of Satisfaction Questionnaire, the NASA-TLX questionnaire to evaluate perceived cognitive load and a post-test assessing knowledge acquisition. All user decisions and time stamps are logged to enable detailed interaction analyses afterwards. This is necessary to check whether users have clicked through the information quickly without reading or whether it was intentional. This information can help if there are discrepancies in the evaluation of the knowledge test.

4 Conclusion

This study explores how elastic storytelling in virtual reality can enhance learning outcomes in physics education. It aims to determine which parts of the learning process benefit most from narrative design by comparing linear with elastic storytelling in a VR Millikan experiment. The findings are expected to enhance the development of more engaging and effective learning experiences in immersive educational environments.

[1] https://assetstore.unity.com/packages/tools/integration/meta-xr-all-in-one-sdk-269657

[2] https://assetstore.unity.com/packages/3d/environments/assets-classroom-98134

References

[1] J. Calvert and M. Hume. Immersing learners in stories: A systematic literature review of educational narratives in virtual reality. *Australasian Journal of Educational Technology*, 38(5):45–61, 2022. 1

[2] Y. Georgiou, O. Tsivitanidou, and A. Ioannou. Learning experience design with immersive virtual reality in physics education. *Educational Technology Research and Development*, 69(6):3051–3080, 2021. 1

[3] Y. Hadzigeorgiou and R. M. Schulz. What really makes secondary school students "want" to study physics? *Education Sciences*, 7(4), 2017. doi: 10.3390/educsci7040084 1

[4] H. Matovu, D. A. K. Ungu, M. Won, C.-C. Tsai, D. F. Treagust, M. Mocerino, and R. Tasker. Immersive virtual reality for science learning: Design, implementation, and evaluation. *Studies in Science Education*, 59(2):205–244, 2023. 1

[5] K. J. Pugh, C. M. Bergstrom, and B. Spencer. Profiles of transformative engagement: Identification, description, and relation to learning and instruction. *Science Education*, 101(3):369–398, 2017. 1

[6] D. Seyser and M. Zeiller. Scrollytelling – an analysis of visual storytelling in online journalism. In *International Conference Information Visualisation (IV)*, pp. 401–406, 2018. doi: 10.1109/iV.2018.00075 1