Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/

GJETA

Global Journal of Engineering and Technology Advances

Global Scholar Press, INDIA

(Research Article)

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Using multimedia learning theory in physics teaching and learning: Work methodology

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Global Journal of Engineering and Technology Advances, 2024, 21(03), 091-096

Publication history: Received on 01 October 2024; revised on 14 December 2024; accepted on 16 December 2024

Article DOI: https://doi.org/10.30574/gjeta.2024.21.3.0230

Abstract

Teaching physics is essential for developing students' analytical skills, but the discipline is often perceived as complex and difficult. Mayer's Multimedia Learning Theory (MLT) proposes integrating visual and auditory elements to make concepts more accessible. This study explores the application of TAM in physics teaching, integrating augmented reality (AR) to make phenomena more concrete. The aim is to design a multimedia model to improve student understanding and engagement, while reducing cognitive overload and enhancing knowledge retention. The methodology includes the creation of multimedia modules, followed by experimental evaluation with a control group. Expected results show that TAM can improve student performance, reduce cognitive overload and increase motivation.

Keywords: Multimedia learning theory; Physics teaching methods; Digital pedagogy; Cognitive Theory of Multimedia Learning; Physics Education

1. Introduction

Science teaching, and physics teaching in particular, plays a central role in developing learners' analytical and problem-solving skills. However, physics is often perceived as an abstract discipline, complex and difficult to master, not least because of its demanding mathematical and theoretical concepts. This negative perception is exacerbated by traditional teaching methods, which sometimes struggle to stimulate students' active engagement or to make physical phenomena tangible and accessible.

Faced with these challenges, the integration of multimedia technologies into physics teaching opens up new pedagogical perspectives. By taking advantage of digital tools, interactive animations and simulations, teachers can make abstract concepts more concrete and comprehensible. Multimedia Learning Theory (MLT), developed by Richard E. Mayer, provides a scientific framework for optimizing these practices by combining visual and auditory elements to maximize learner comprehension and retention [5].

TAM is based on key principles, such as the management of cognitive overload, the simultaneous use of visual and auditory sensory channels, and the structured organization of information to facilitate its integration into long-term memory. These principles are particularly relevant in physics education, where learners must not only acquire new knowledge but also relate it to real-world experiences and theoretical models - so-called augmented reality [1].

"The application of augmented reality (AR) in physics can improve student understanding, engagement and inspiration [1].

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This research is part of this context, with the aim of applying TAM principles to the design of teaching aids adapted to physics learning. It aims to explore how these tools can reduce barriers to understanding, stimulate cognitive engagement and improve learner performance. By proposing a pedagogical model based on the latest advances in multimedia learning, this study aims to transform pedagogical practices and contribute to a better understanding of the physical sciences in a rapidly evolving educational context.

1.1. Issues

How can we design a pedagogical model that builds on TAM and enables physics learners to overcome the barriers associated with cognitive overload while stimulating their engagement and active understanding?

2. Assumptions

Applying Mayer's TAM principles in a multimedia pedagogical model will reduce learners' cognitive overload, facilitating their ability to process and understand complex physics information [6].

"According to cognitive load theory, the integration of augmented reality reduces students' cognitive load by providing additional sensory input synchronized with learning materials, thus facilitating the assimilation of knowledge."[2].

The combined use of visual (diagrams, animations) and auditory (narratives, explanatory sounds) elements in a TAM-based pedagogical model will improve knowledge retention and deepen physics learners' conceptual understanding. [7].

"In physics, AR facilitates the direct visualization and manipulation of phenomena such as gravity, forces and electromagnetic fields in a tangible environment, thus improving the practical understanding of complex concepts." [2].

A pedagogical model that combines interactivity, multimodality and clear organization will increase learner engagement, motivating them to participate actively and improving their retention of physics concepts over the long term. [3].

3. Theoretical framework

To develop a theoretical framework for the use of multimedia learning theory (MLT) in physics education, it is essential to integrate key concepts from learning theories, multimedia pedagogy and physics education.

Here are the main elements to include in this framework:

3.1. Basic theories of multimedia learning

3.1.1. Cognitive theory of multimedia learning (Richard E. Mayer)

- **Multimodality principle**: Learners learn best when information is presented in a combination of verbal (text/voice) and visual (images/diagrams) forms. [9].

"The integration of learning objects into hypermedia adaptive systems has demonstrated a significant improvement in learner motivation and performance, by tailoring educational pathways to their specific needs and preferences." [14].

- **Principle of spatial and temporal contiguity**: Effectiveness is enhanced when text and corresponding images are spatially close and appear simultaneously. [10]
- **Personalization principle**: A conversational style of storytelling promotes better understanding. [9].
- **Cognitive load principle**: Avoid cognitive overload by limiting superfluous information. [6].

3.2. Cognitive load theory (Sweller)

The role of intrinsic (subject complexity), extrinsic (poor design) and germane (effort to learn) cognitive load in multimedia media design.

3.3. Double encoding theory (Paivio)

Importance of combining visual and verbal codes to reinforce learning. [9].

4. Learning in physics

4.1. Particularities of learning in physics

Abstract, mathematical nature of concepts (e.g. kinematics, dynamics, electromagnetism). Need to visualize phenomena (simulations, animations).

Importance of interactive experiences to promote understanding.

"Designing teaching activities following an inductive approach, moving from the concrete to the abstract, enables learners to gradually build general knowledge from concrete experiences, thus strengthening their critical thinking and conceptual understanding."(Hassane Kemouss et al., 2023)

4.2. Specific teaching methods

Use of constructivist approaches where learners build their own understanding through hands-on activities and discussions.

Integration of simulations and animations (e.g. with PhET or GeoGebra) to make concepts dynamic and interactive.

5. Design of a multimedia pedagogical model

5.1. Design stages

- Pedagogical needs analysis: Identify the difficulties encountered by physics students.
- Design based on multimedia principles: Apply Mayer's principles and avoid cognitive overload errors.
- Prototyping and validation: iterating between design and practical testing.

5.2. Model validation

Quantitative and qualitative research methods to assess effectiveness: standardized tests (to understand learning gains), questionnaires and interviews to measure commitment and perceptions.

5.3. Evaluation of results

- Quantitative measures: Improvement in scores, reduction in conceptual errors.
- Qualitative measures: learner satisfaction, sense of self-efficacy.

5.4. Integrating technology into multimedia learning

- Use of digital platforms: online course platforms, interactive videos. Simulation and animation tools: PhET, Matlab, Python.
- Virtual and augmented reality: Immersion in laboratory environments.

5.5. Perspectives and implications

The importance of training teachers to use multimedia tools.

Integration of models in hybrid learning environments (face-to-face and distance learning). Customize materials to meet individual student needs.

This theoretical framework highlights the importance of combining the principles of multimedia learning with the specificities of physics education. The design, validation and evaluation of an effective pedagogical model require an iterative, learner-centered approach.

6. Methodology

To answer the problem and test the hypotheses formulated, the methodology is based on three key stages: pedagogical design, experimental validation and data analysis. Each of these is detailed below to ensure scientific rigor and pedagogical relevance, after of course the realization of a literature review, particularly suited to identifying recent trends and conceptual work in the field of multimedia in physics teaching and learning. This approach enables us to understand the current landscape and future research directions.

6.1. Educational design

Objective: Design a multimedia learning model following an instructional design process, from needs analysis to content design and development, while integrating the principles of Mayer's multimedia learning theory. This approach makes it possible to structure learning materials by optimizing the use of visual and auditory elements, thus reducing cognitive overload and promoting better knowledge retention among learners.

- Consistency: Remove distracting elements, such as irrelevant images or animations.
- Spatial and temporal contiguity: aligning text and diagrams to synchronize visual and verbal learning.
- Segmentation: dividing content into logical, progressive units (for example, breaking Newton's laws down into forces, acceleration and mass).
- Modality: Use of a combination of auditory narratives and visual representations to promote double coding

6.2. Experimental validation

Objective: Evaluate the impact of the modules developed on learner understanding and engagement.

6.2.1. Preliminary studies:

- Pilot testing with a small sample to identify any design flaws and measure perceived cognitive load.
- Collection of learners' impressions via qualitative questionnaires.

6.3. Controlled experiment:

Participants are divided into two groups:

- Experimental group: Using the multimedia modules developed.
- Control group: Traditional teaching methods (lectures, textbooks).
- Duration of experiment: 4 to 6 weeks, covering specific chapters such as forces or the principles of conservation in physics.

6.4. Data analysis

Objective: Measure module effectiveness in terms of academic performance, commitment and satisfaction.

6.4.1. Measuring learning performance

- Comparison of the two groups' scores on standardized tests before, during and after use of the modules.
- Analysis of results to assess improvement in understanding of complex concepts.

6.5. Evaluating commitment and satisfaction

- Use of post-test questionnaires to gather learners' impressions of the interactivity, clarity and effectiveness of the modules.
- Measuring engagement through indicators such as active participation in simulations and frequency of interaction with modules.

6.6. Statistical analysis

- Application of statistical tests (e.g. t-test to compare means between groups) to validate hypotheses with a predefined level of significance.

7. Expected results

- The multimedia modules should show a significant improvement in the performance of learners in the experimental group compared with the control group.
- Learners using the modules should report a reduction in perceived cognitive overload.

- Engagement questionnaires should indicate increased satisfaction and motivation to learn physical concepts.

This rigorous methodology will guarantee a comprehensive evaluation of the effectiveness of the TAM-based pedagogical model.

8. Conclusion

The application of multimedia learning theory (MLT) to the teaching of physics represents a major advance in scientific pedagogy. By exploiting multimedia technologies, such as interactive animations and augmented reality (AR), this approach makes complex concepts more accessible, while providing an interactive and engaging learning experience. Learners benefit from a learning environment that promotes knowledge retention, stimulates motivation and active engagement.

However, the success of this integration depends on the rigorous design of the teaching modules. This must be based on Mayer's principles of coherence, contiguity, segmentation and multimodality, while taking account of learners' cognitive limitations.Particular attention needs to be paid to evaluating the effectiveness of these tools, using experimental methodologies to measure academic performance, engagement and student satisfaction.

In future articles, it will be essential to further evaluate the impact of multimedia learning theory (MLT) in other scientific disciplines, such as chemistry, biology and mathematics, in order to understand how to adapt MLT to the pedagogical specificities of each field. In addition, the integration of immersive technologies, such as virtual reality (VR) and mixed reality (MR), could enrich learning environments, particularly for distance learning and the inclusion of learners with learning difficulties. Another avenue is to develop adaptive models for personalizing multimedia learning, tailored to skill levels and learning styles, using artificial intelligence to design individualized learning paths. Longitudinal studies will assess the long-term impact of TAM on learners' academic performance, analytical skills and career choices. Finally, it will be crucial to create training programs to help teachers master these multimedia tools and principles, while measuring the effect of this mastery on student success. These perspectives aim to enrich and diversify research on multimedia learning, while maximizing its effectiveness in a variety of contexts.

Multimedia learning theory offers a solid basis for transforming science education, but further research is needed to refine methodologies, maximize impact and broaden the application of these approaches to other educational fields. These initiatives will help shape an education system that is more inclusive, interactive and adapted to the challenges of the 21st century.

Compliance with ethical standards

Disclosure of conflict of interest

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