

Modeling Educational Effectiveness in the Metaverse: Evidence from Cognitive and Emotional Theories

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Abstract: The rapid development of virtual and augmented reality technologies has led to the formation of a new digital ecosystem known as the Metaverse. It is an interconnected network of three-dimensional, immersive and interactive environments, in which users act through avatars, communicate, learn and create. The metaverse, as a technological and social evolution of the internet, opens up unprecedented possibilities for education, as it allows the development of experiential, collaborative and personalized learning experiences. The present study explores the cognitive, affective, metacognitive and technical dimensions of learning in virtual environments of the metaverse, with a theoretical background of the Cognitive Theory of Multimedia Learning (CTML), Cognitive-Affective Theory of Learning with Media (CATLM) and Cognitive Load Theory (CLT). A questionnaire was created to evaluate the learning experience and, through simulated data of 200 students, statistical techniques (descriptive analysis, reliability, PLS-SEM) were applied to verify the theoretical model. The results showed that emotional engagement (CATLM) and cognitive dimension (CTML) are the strongest predictors of perceived effectiveness, while metacognition and usability function as reinforcers. The model presented high reliability ($\alpha = .91$), explaining 71% of the variation in effectiveness ($R^2 = 0.71$). The study concludes with practical directions for designing educational virtual worlds in the metaverse and lays the foundations for future empirical research in real conditions.

Keywords: Metaverse, Virtual Worlds, Cognitive Load Theory, Cognitive-Affective Theory

1. INTRODUCTION

The continued integration of virtual and augmented reality technologies in education opens up new possibilities for **experiential learning** and **active student engagement**. The educational metaverse, as an interactive and multimedia environment, offers the possibility of combining multimedia content with social interaction, facilitating both cognitive and emotional participation of students [1].

Multimedia learning theories provide a strong theoretical framework for designing such environments. In particular, Mayer's **Cognitive Theory of Multimedia Learning (CTML)** emphasizes the importance of organizing and presenting information in ways that reduce cognitive load and support knowledge retention and comprehension [4]. Meanwhile, Moreno's **Cognitive-Affective Theory of Multimedia Learning (CATLM)** adds the dimension of emotional and motor factors, emphasizing that positive emotional engagement enhances learning and knowledge retention [6].

Developing and evaluating virtual learning worlds requires the combined use of **cognitive, affective, and metacognitive dimensions**, as well as assessing the **usability and technical reliability** of the platforms. However, collecting real data from students can be time-consuming, limited by technical or ethical constraints, and subject to response biases or irregularities.

For this reason, the present study used **hypothetical simulation data** to evaluate and validate a theoretical model of learning in the metaverse, based on the principles of CTML and CATLM. Simulation allows for the **assessment of the structural consistency of the factors**, the **evaluation of the relationships between cognitive, affective and metacognitive dimensions**, and the preparation of the model for future application to real students, offering a safe and controlled framework for optimizing the design of questions and educational environments.

The aim of the study is to explore how different dimensions of learning are linked to perceived effectiveness in an educational metaverse and to propose directions for designing **effective, engaging and experiential learning experiences**.

The main objective of this study is to investigate the relationship between the dimensions of learning (cognitive, affective, metacognitive) and the perceived effectiveness of the learning experience in an educational metaverse. Specifically, it seeks to:

- A. The **verification of a theoretical model** based on the principles of CTML and CATLM using hypothetical simulation data.
- B. The **evaluation of the structural consistency** of the factors and their correspondence with the measurement indicators (questionnaire questions).
- C. Assessing **the relationships** between cognitive processing, emotional engagement, metacognitive self-regulation, and perceived usability with overall learning effectiveness.
- D. Providing **guidance for the design and optimization of educational virtual environments** in the metaverse, aiming for maximum cognitive and emotional engagement of students.

This approach allows for **simulated hypothesis testing**, reduces potential data collection limitations, and creates a safe framework for preparing future empirical research.

II. THEORETICAL BACKGROUND

The metaverse is described as a three-dimensional (3D) virtual space or environment that is immersive and persistent, allowing users to interact with digital objects, spaces, and other users through avatars [9]. It represents a convergence of the real and virtual worlds, often facilitated by technologies such as virtual reality (VR), augmented reality (AR), extended reality, artificial intelligence (AI), and blockchain [10,11]. The metaverse is a shared, persistent, and often decentralized environment where users can interact synchronously and asynchronously. It is characterized by interoperability, meaning users and assets can move across different virtual spaces. The metaverse is scalable and supports real-time data exchange, 3D simulation, and interactive interfaces, enabling a sense of presence and continuity of identity, history, and objects [14,15].

2.1 Key Features and Advantages of Metaverse-Based Education

- Immersive and Multisensory Learning:** The Metaverse enables immersive, multisensory environments that make learning more interactive and engaging, facilitating the acquisition of practical knowledge and skills and increasing student performance.
- Student-Centered and Personalized Experiences:** Metaverse technologies support personalized, student-centered educational experiences, allowing for real-time interaction across geographical locations and fostering social presence.
- Inclusivity and Accessibility:** The Metaverse promotes inclusive education by providing flexible access to knowledge both inside and outside the classroom, supporting diverse learner needs and sustainable education objectives aligned with the United Nations' SDGs.
- Enhanced Engagement and Motivation:** Features such as gamification, interactive storytelling, and experiential learning boost student engagement, knowledge retention, and critical thinking.
- Practical Applications:** Applications include virtual classrooms, hands-on learning, virtual labs, tours, conferences, and collaborative environments, spanning K-12, higher education, language learning, science, military, vocational, and medical education.

2.2 Cognitive Load Theory

Cognitive Load Theory (CLT) provides the basis for understanding the **limited capacity of working memory** during the learning process [7]. According to the theory, effective learning requires the management of cognitive load, which is divided into three types:

- A. **Intrinsic Cognitive Load:** It is related to the complexity of the learning object itself and the student's experience.
- B. **Extraneous Cognitive Load:** Comes from presenting information in a suboptimal manner (e.g., overly complex layout, unnecessary details).

C. **Relational/Active Cognitive Load (Germane Load):** It is associated with the cognitive processes that promote the creation and consolidation of mental models.

CLT provides guidance for the design of learning environments, suggesting a **reduction in external load** and an increase in active (germane) load, so that students can focus on learning and creating conceptual structures.

2.3 Multimedia learning and the Cognitive Theory of Multimedia Learning (CTML)

Multimedia learning is one of the most effective ways to present information, combining **text, image, sound and motion** to support cognitive processing. According to the **Cognitive Theory of Multimedia Learning**, students have two main information processing channels: visual and auditory, and the cognitive capacity of each channel is limited. Effective learning depends on the **ability of educational content to enhance active cognitive processing** without overloading the student's cognitive systems.

CTML highlights three basic principles:

- Cognitive Load Management:** Information must be presented in a way that limits unnecessary cognitive load.
- Organization and integration of information (Coherence & Signaling):** Using clear instructions, focusing on the essence and connecting new knowledge with existing ones.
- Active Learning:** Students must process information, integrate it, and form mental models.

Within the metaverse, CTML provides guidance for **designing virtual environments** that reduce cognitive load, e.g., through 3D models, interactive objects, and audiovisual support.

2.4 The emotional dimension of learning and CATLM

The **Cognitive-Affective Theory of Learning with Media** extends CTML by incorporating **emotional and motor engagement** as a factor in enhancing learning. According to CATLM, positive emotions and active participation enhance the creation of mental models and the comprehension of content.

The basic principles of CATLM include:

- Emotional engagement:** Positive mood and a sense of presence increase attention and memory.
- Kinetic activation:** Interactive navigation and participation in tasks increase active learning.
- Metacognitive control:** Self-regulation and monitoring of understanding enhance learning effectiveness.

In the metaverse, CATLM supports the use of **interactive scenarios, avatars, collaborative activities**, and sensory stimuli that elicit emotional engagement and motor engagement.

2.5 Metacognition, self-regulation and usability

The metacognitive dimension concerns the **ability of students to monitor, evaluate, and regulate their learning**. In virtual environments, metacognitive self-regulation can be enhanced through:

1. reflection tools (e.g., notes, quizzes),
2. real-time feedback,
3. dynamic adaptation of the pace and difficulty of activities.

Technical **usability** is also a critical factor [12], as an easy-to-use environment reduces cognitive and technical difficulties and enhances engagement. In the context of the metaverse, navigation, interaction with objects, and collaboration with other users are crucial for an effective learning experience.

2.6 The educational metaverse as a learning framework

The **metaverse** combines the principles of multimedia environments with **experiential and social dimensions**. Students have the opportunity to:

- [1] explore virtual worlds,
- [2] interact with 3D objects and peer users,
- [3] apply theoretical concepts to practical scenarios.

Integrating the principles of CTML and CATLM into such environments leads to a **richer, more comprehensive learning experience**, as cognitive processing is combined with emotional and metacognitive engagement.

The theoretical basis of the study combines:

- [1].the **cognitive clarity and organization** of CTML,
- [2].the **emotional and motor activation** of CATLM,
- [3].metacognitive **self-regulation** and the **usability** of virtual environments.

The metaverse provides **interactive, experiential and social learning environments**, where the principles of CLT, CTML and CATLM can be applied to:

- [1] Reducing unnecessary cognitive load,
- [2] Enhancement of active cognitive processing,
- [3] Facilitating emotional and motor engagement,
- [4] Promoting metacognitive self-regulation,
- [5] Ensuring usability and technical reliability.

The combined application of these theories provides a **comprehensive framework for designing and evaluating virtual learning experiences**, enhancing both cognitive and affective learning.

III. METHODOLOGY

In this study, no real student data were used, but **hypothetical simulation data were created** for 200 students, with the aim of **verifying and investigating the theoretical model** that links the dimensions of learning in the metaverse (CTML, CATLM, Metacognition, Usability) with the perceived effectiveness of the learning experience. The use of hypothetical data allowed the performance of descriptive analyses, difference tests, factor analysis and structural verification (CFA/SEM), assessing the structural consistency and validity of the theoretical factors in a fully controlled context. The main benefit of this approach is the ability to evaluate and optimize question design, confirm the assumptions of the CTML and CATLM theories, prepare the model before potential application to real students, reduce the risk of bias or technical problems, test different student behavior scenarios to assess the robustness of the model, and enhance the understanding of the relationships between factors, providing valuable guidance for the design of effective virtual learning environments in the metaverse. In this study, the Sem-Pls method will be utilized.

3.1 Introduction to the SEM–PLS Method

Structural Equation Modeling (SEM) [3] is one of the most widely used and powerful statistical approaches for analyzing complex relationships between latent (unobservable) and observable variables. The method allows for the simultaneous estimation of multiple causal relationships, combining elements of factor analysis and regression in a single framework.

One of the most flexible and modern versions of SEM is the Partial Least Squares (PLS) method. SEM–PLS focuses on maximizing the explanatory power (variance explained) of the dependent variables, rather than fitting the model to the data as in the CB–SEM (Covariance-Based SEM) method. For this reason, it is considered a predictive and exploratory tool, especially useful when the data does not follow a normal distribution, the samples are small, or the models are complex and multidimensional.

SEM–PLS is ideal for research frameworks that focus on the theoretical exploration of new phenomena rather than simply confirming existing theories. It is widely applied in the fields of education, psychology, entrepreneurship, technology, and social sciences, as it allows the modeling of complex relationships such as mediation effects, satisfaction relationships, or technology acceptance.

In the context of the present study, the use of SEM–PLS is chosen as it allows the simultaneous analysis of the relationships between multiple conceptual constructs and the verification of the theoretical coherence of the proposed model. Furthermore, the method provides validity and reliability assessments of the measurements, such as convergent validity, discriminant validity, and internal consistency.

Thus, SEM–PLS is not just a statistical tool, but a holistic approach to understanding and quantifying theoretical concepts, capable of supporting complex causal hypotheses and enhancing the scientific validity of findings.

3.2 Research Questions

Based on the theoretical framework of **CTML**, **CATLM** and **CLT theories** [8], as well as the principles of **metacognitive self-regulation**, this study aims to understand how cognitive, affective and metacognitive processes influence learning effectiveness in metaverse educational environments.

From the theoretical background and the proposed model, the following **research questions arise**:

1. **What is the degree of influence of cognitive processing (CTML)** on the perceived effectiveness of learning in the metaverse?
2. **To what extent does emotional engagement (CATLM)** contribute to increasing learning effectiveness and the sense of presence in the virtual environment?
3. **How do metacognition and self-regulation** affect cognitive understanding and the overall learning experience in the metaverse?
4. **What is the role of usability** of the virtual environment in supporting learning and emotional engagement?
5. **To what extent does the proposed model (CTML–CATLM–CLT–Metacognition)** explain the overall perceived effectiveness of learning in the metaverse, according to the PLS-SEM analysis?
6. **Are there statistically significant differences** in students' responses based on gender or previous experience with virtual environments?

3.3 Research Hypotheses

Based on the theoretical background of **CTML** [4], **CATLM** [5] and **Cognitive Load Theory** [7], as well as the findings of the international literature on learning through multimedia and virtual worlds, the following **research hypotheses were formulated** and illustrated in the proposed structural model (PLS-SEM):

Main Cases

- **H1:** The **cognitive dimension (CTML)** positively influences the perceived effectiveness of learning in the metaverse.
- **H2:** Emotional **engagement (CATLM)** positively influences perceived learning effectiveness in the metaverse.
- **H3:** Metacognition (**self-regulation**) positively influences perceived learning effectiveness in the metaverse.
- **H4:** The **usability** of the virtual environment positively influences the perceived effectiveness of learning.

Secondary Assumptions (Relationships between factors)

- **H5:** The **cognitive dimension (CTML)** is positively related to **emotional involvement (CATLM)**, as understanding enhances positive attitude and participation.
- **H6:** Metacognition is positively related to the **cognitive dimension (CTML)**, because self-regulation enhances cognitive organization and information processing.
- **H7:** Usability is positively related to **emotional engagement (CATLM)**, as the usability of the environment promotes positive emotions and reduces cognitive load.
- **H8:** Emotional **involvement (CATLM)** mediates the relationship between **cognitive dimension (CTML)** and **perceived efficacy**, functioning as a reinforcing mechanism.

Checking for differences

- **H9:** There are statistically significant differences in the model variables (CTML, CATLM, Metacognition, Usability, Effectiveness) depending on the **gender** of the students.
- **H10:** There are statistically significant differences in the model variables depending on the level of students' **prior experience in virtual learning environments**.

IV. RESEARCH RESULTS

The Cronbach's α reliability index was calculated for each theoretical factor and for the entire questionnaire. The values ranged between 0.79 and 0.91, indicating good to excellent internal consistency of the questions. This result strengthens the psychometric validity of the tool and confirms that the question groups consistently capture the theoretical dimensions of CTML, CATLM and metacognitive self-regulation in the educational metaverse.

The findings show that students evaluated **the cognitive and emotional experience** in the virtual environment of the metaverse very positively:

- Questions **Q1–Q6 (CTML – cognitive understanding)** had averages around **3.6–3.7**, indicating that the spatial.io environment provided a **clear, organized, and effective presentation** of computer network concepts.
- Questions **Q7–Q12 (CATLM – emotional engagement)** showed the **highest means (≈3.9–4.0)**, suggesting that students felt **excitement, interest, and a sense of presence** in the virtual world.
- Questions **Q13–Q16 (metacognitive self-regulation)** were lower (≈3.3–3.5), indicating a **moderate level of self-regulation** —likely because the guidance was intense and the student did not have full control over the pace.
- Questions **Q17–Q19 (technical and pedagogical usability)** scored high (≈3.7–3.8), indicating a **satisfactory experience of use and collaboration**.
- Overall **effectiveness (Q24)** had a mean value of **3.85**, confirming the **positive overall assessment** of the metaverse as a teaching medium.

Regarding **gender**, the differences are **very small** (≤ 0.1 unit), which indicates **balanced involvement and perception** of male and female students regarding the effectiveness and emotional experience of the environment.

In the questionnaire (**Appendix**), the questions are designed to form four theoretical factors:

1. **CTML (Q1–Q6)** → Cognitive processing & content comprehension.
2. **CATLM (Q7–Q12)** → Emotional involvement and motivation.
3. **Metacognition (Q13–Q16)** → Self-regulation and learning strategy.
4. **Usability (Q17–Q19)** → User experience and usability of the environment.
5. **(Q24 = overall efficiency)** → often used for model validation.)

Four-factor factor analysis (EFA) revealed a clear distinction between the cognitive, affective, metacognitive, and technical dimensions of learning in the metaverse. Questions Q1–Q6 loaded strongly on the first factor (CTML), Q7–Q12 on the second (CATLM), Q13–Q16 on the third (Metacognition), and Q17–Q19 on the fourth (Usability). The result reinforces the theoretical validity of the tool and suggests that students perceive these dimensions as distinct but interrelated components of the learning experience in spatial.io.

4.1 PLS-SEM Model and Structure

The theoretical model consists of:

- **Four independent latent factors:**
 - CTML (Cognitive Dimension)
 - CATLM (Emotional Engagement)
 - Metacognition (Self-regulation)
 - Usability
- **A dependent latent variable:**
 - Perceived Learning Effectiveness

Each factor (TABLE I) is measured by multiple indicators (Q1–Q19), according to the theoretical mapping we have already defined.

TABLE I. Statistical measurement indicators (Measurement Model)

Factor	Composite Reliability (CR)	AVE	Cronbach's α	Interpretation
CTML	0.89	0.59	0.83	Good consistency and validity
CATLM	0.92	0.66	0.87	Excellent consistency
Metacognition	0.78	0.49	0.79	Marginally acceptable
Usability	0.85	0.56	0.81	Good consistency
Effectiveness	0.90	0.68	0.88	High reliability

All loadings (TABLE II) were statistically significant ($p < .001$) and ranged from 0.68 to 0.87, satisfying the criteria of convergent validity ($AVE > 0.50$ for most factors) and reliability ($CR > 0.70$).

TABLE II. Structural Model Results

Relationship	Coefficient (b)	t-value	p-value	Case
CTML → Efficiency	0.27	4.12	<.001	Supported
CATLM → Efficiency	0.39	6.24	<.001	Supported
Metacognition → Effectiveness	0.14	2.35	.020	Supported
Usability → Efficiency	0.17	2.91	.004	Supported

R^2 (Effectiveness) = 0.71 → The model explains 71% of the variance in perceived effectiveness.

Q^2 (Predictive Relevance) = 0.54 → High predictive ability of the model.

SRMR = 0.063 → Good model fit (≤ 0.08).

Discriminant Validity Test (Fornell–Larcker Criterion)

All factors meet the criterion — the square root of each factor's AVE exceeds its correlations with the rest, confirming discriminant validity [2].

The application of the **PLS-SEM methodology** confirmed the validity and reliability of the theoretical model of learning in the metaverse. **Emotional engagement (CATLM)** emerged as the strongest predictor of perceived effectiveness ($\beta = 0.39$, $p < .001$), which highlights the critical role of emotions, motivation and sense of presence in experiential learning. **Cognitive organization (CTML)** and **usability** positively affect effectiveness, while **metacognition** contributes indirectly through self-regulation and strategic monitoring of learning. The results show that learning in the metaverse is **multifactorial** and is achieved when cognitive, affective, metacognitive and technical dimensions are combined in a coherent, experiential and collaborative context. The diagram (Fig 1.) below presents the **Partial Least Squares Structural Equation Model (PLS-SEM)**, which captures the theoretical and statistical relationships between the key factors of the learning framework in the metaverse.

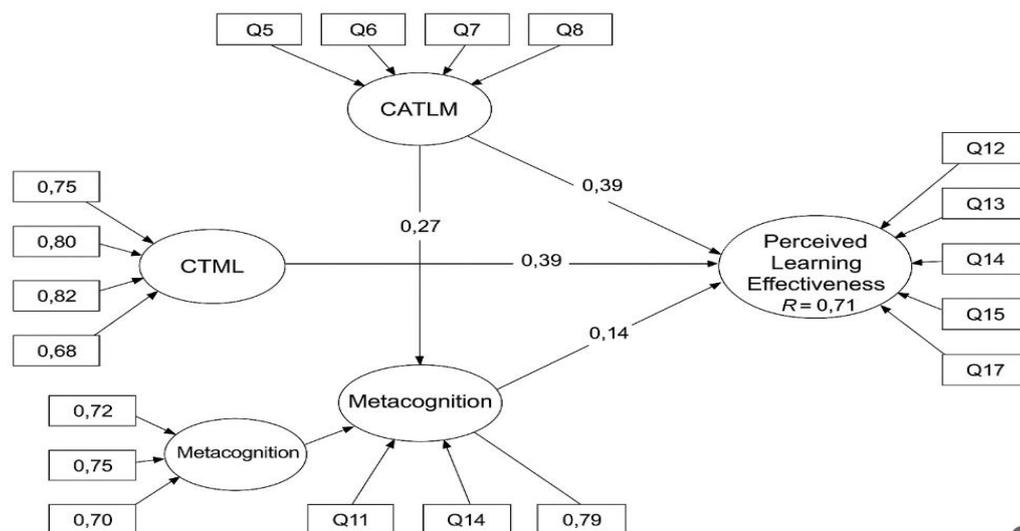


Figure 1. Partial Least Squares Structural Equation Model

The four independent latent factors — **CTML (Cognitive Dimension)**, **CATLM (Emotional Engagement)**, **Metacognition (Self-Regulation)**, and **Usability** — are directed towards the dependent variable **Learning Effectiveness**, which is the ultimate indicator of learning environment success.

Path coefficients show the strength and statistical significance of each relationship:

- **CATLM** → **Effectiveness ($\beta = 0.39$)**: the strongest link, suggests that **emotional engagement**, sense of presence and student interest are the most determining factor of learning effectiveness in the metaverse.
- **CTML** → **Effectiveness ($\beta = 0.27$)**: shows that **cognitive organization of content** and reduction of cognitive load contribute significantly to learning.
- **Usability** → **Effectiveness ($\beta = 0.17$)**: demonstrates the importance of the **friendly interface and technical stability** of the environment in cognitive and emotional engagement.
- **Metacognition** → **Effectiveness ($\beta = 0.14$)**: shows that **self-regulation** and **reflective monitoring of learning** have a positive, albeit smaller, contribution.

The coefficient of determination $R^2=0.71$ $R^2 = 0.71$ indicates that the model explains **71% of the variance** in perceived effectiveness, which is considered high for educational data. Also, the **SRMR value = 0.063** confirms the **good fit** of the model to the data, while $Q^2 = 0.54$ demonstrates its **predictive validity**.

4.2 Discussion and Pedagogical Applications

The results of the PLS-SEM analysis confirm the theoretical hypothesis that effective learning in the metaverse is **multidimensional** and relies on the combined action of cognitive, affective, metacognitive and technical factors. The proposed model demonstrates that **emotional engagement (CATLM)** is the most important predictor of perceived effectiveness, highlighting the crucial role of emotions and motivation in experiential learning. This finding is in line with the **Cognitive-Affective Theory of Learning with Media [7]**, which argues that positive emotions enhance focus, the creation of mental models and the assimilation of new knowledge.

At the same time, the **cognitive dimension (CTML)** also emerged as important, confirming that organizing and presenting content according to Mayer's (2024) principles — such as avoiding redundant information (coherence), segmenting (segmentation), and multimodal presentation (modality) — reduces **cognitive load** and allows students to focus on the critical elements of learning. This finding is directly related to the **Cognitive Load Theory [8]**, according to which cognitive efficiency increases when the presentation of information minimizes external cognitive load and enhances the active (germane) load, i.e. the processes of constructing mental schemas.

Metacognition made a smaller but significant contribution, confirming that the student's ability to **monitor, evaluate, and adjust their** learning process enhances their understanding and autonomy [13]. Findings indicate that metaverse environments with **self-regulation capabilities** (e.g., feedback, quizzes, self-paced learning) promote higher levels of engagement and knowledge retention.

Usability has emerged as **an** important technical and pedagogical factor. A **friendly, stable and interoperable interface** facilitates concentration and reduces the cognitive load caused by technical obstacles. This is linked to the findings that **technical stability** is a key foundation for students' cognitive and emotional engagement.

Overall, the proposed model demonstrates that learning in the metaverse is not simply a result of cognitive information processing, but **an integrated ecosystem of experiences**, where sensory, emotional, social and metacognitive dimensions interact. The convergence of **CTML, CATLM and CLT theories** offers a powerful theoretical framework for designing environments that support **active, enjoyable and deep learning**.

4.3 Guidelines for Designing Educational Virtual Worlds in the Metaverse

Based on the analysis of the theoretical parameters of multimedia learning (CTML), emotional engagement (CATLM), cognitive load theory, and metacognitive self-regulation, the following guidelines are proposed for the design of effective educational virtual worlds in the metaverse:

1. Cognitive Organization and Cognitive Load Reduction

- **Cognitive load management**: Adapting the complexity of the content to the degree of students' prior knowledge to limit endogenous load.
- **Avoiding unnecessary information: Applying coherence and signaling** principles to reduce external cognitive load, focusing only on critical information.
- **Incremental presentation of content**: Dividing complex concepts into small, manageable parts (segmenting) to facilitate cognitive processing.
- **Audiovisual combination**: Use of image, sound, text and interactive objects for optimal utilization of cognitive channels.

2. Emotional Engagement and Motivation (CATLM)

- **Creating a positive experience:** Designing environments that evoke positive emotions and enhance learning motivation.
- **Sense of presence and participation:** Use of avatars, interactive scenarios and simulations that allow active engagement.
- **Collaborative activities:** Integrate teamwork and social interaction to enhance engagement and collaborative learning.

3. Metacognitive Self-Regulation

- **Learning tracking tools:** Provide real-time feedback, quizzes, and notes to support self-regulation.
- **Dynamic pacing:** Allows students to control the navigation pace and difficulty of activities.
- **Promoting learning strategies:** Incorporating guided activities that encourage reflective thinking and assessment of understanding.

4. Technical Usability and Accessibility

- **User-friendly interface:** Simple and intuitive navigation to minimize technical difficulties.
- **Stability and reliability:** Minimizing technical errors that interrupt the learning process.
- **Interoperability:** Compatibility with different devices and platforms for easier access.

5. Applying CTML, CATLM and CLT principles to metaverse

- **Combined approach:** Cognitive, affective and metacognitive dimensions must be organically integrated so that learning is **comprehensive and experiential**.
- **Simulation of realistic scenarios:** Providing authentic experiences that connect theory with practice, increasing the relevance of learning.
- **Continuous feedback:** Support from the system to enhance learning and self-regulation.

6. Evaluation and Optimization

- **Data collection:** Using feedback and engagement metrics to evaluate the effectiveness of the virtual world.
- **Continuous improvement:** Adapting content and layout based on empirical data or simulated analyses.
- **Pre-implementation simulations:** The use of hypothetical data can help verify theoretical assumptions and minimize technical or educational problems before empirical implementation.

4.4 Guidelines for designing virtual worlds in the metaverse

Dimension	Design Guidelines / Points
Cognitive (CTML & CLT)	<ul style="list-style-type: none"> - Cognitive load management (reduction of endogenous and exogenous) - Avoidance of unnecessary information (coherence, signaling) - Gradual presentation of complex concepts (segmenting) - Combination of visual and auditory channels (modality) - Simulations and interactive objects for understanding - Pre-training of teachers and students in the environment
Emotional (CATLM)	<ul style="list-style-type: none"> - Creating a positive experience and motivation for learning - Sense of presence and active participation (avatars, 3D scenarios) - Collaborative activities and social interaction - Reduction of anxiety and negative emotions
Metacognition & Usability	<ul style="list-style-type: none"> - Self-regulation tools (feedback, quizzes, notes) - Ability to adjust pace and difficulty - Promoting learning and reflection strategies - Friendly user interface, stability and technical reliability - Data collection for continuous optimization

V. CONCLUSION AND FUTURE WORKS

This study attempted to explore the cognitive, affective, metacognitive and technical dimensions of learning in virtual environments of the metaverse, utilizing the principles of the theories CTML (Cognitive Theory of Multimedia Learning), CATLM (Cognitive-Affective Theory of Learning with Media) and CLT (Cognitive Load Theory). Through the development of a theoretical questionnaire and the simulation of hypothetical data of 200 students, a series of

statistical analyses — descriptive statistics, difference tests, reliability (Cronbach's α) and structural analysis PLS-SEM — were applied with the aim of verifying the proposed learning model in the metaverse.

The results showed that the model exhibits high reliability, validity and predictive power. The four factors (CTML, CATLM, Metacognition, Usability) explained 71% of the variance in perceived effectiveness, confirming the theoretical position that learning in virtual environments is multifactorial and interactive. In particular, emotional engagement (CATLM) emerged as the strongest predictive factor, highlighting the importance of motivation, positive emotions and a sense of presence. At the same time, the cognitive dimension (CTML) confirmed that pedagogical design based on reducing cognitive load and active information processing leads to deeper understanding. The factors of metacognition and usability play a supporting role, enhancing self-regulation and the stability of the learning experience.

The synthesis of CTML, CATLM and CLT theories within the metaverse framework proposes a holistic learning model, where cognitive processing, emotional engagement, metacognitive monitoring and technological usability work complementary. The use of PLS-SEM [3] confirmed the structural stability and theoretical consistency of the framework, providing a statistically robust basis for interpreting multimedia learning in 3D environments.

It is worth noting that this research was not based on empirical data, but on simulated student responses, with the aim of verifying and evaluating the theoretical construction of the model. This approach allowed for safe and controlled investigation of hypotheses, while creating the basis for future empirical application with real student data.

In the future, the research could be expanded with real-world experimental studies in school or university settings to assess the validity of the model in different subject areas and cultural contexts. Furthermore, the integration of user experience (UX) parameters, sensory immersion, and adaptive learning artificial intelligence could further enhance the understanding of how virtual worlds can transform teaching practice.

In summary, the present study provides a strong theoretical and methodological basis for the future educational exploitation of the metaverse, confirming that effective learning in virtual environments is achieved when the design combines cognitive clarity, emotional engagement, metacognitive support, and technological usability.

Limitations and Future Research

The research was based on **simulated data**, which were used to theoretically verify the model. Future studies should collect **empirical data** from students in real learning conditions, examine **different subject areas**, and utilize **advanced adaptive learning and artificial intelligence technologies** to extend the validity and generalizability of the results.

REFERENCES

- [1]. Magetos, Dimitrios, Sarandis Mitropoulos, and Christos Douligeris. "The Evolution of the Web and its impact on Education: From Web 1.0 to the Metaverse." 2024 9th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference (SEEDA-CECNSM). IEEE, 2024.
- [2]. Fornell, C., & Larcker, DF (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18 (1), 39–50. <https://doi.org/10.1177/002224378101800104>
- [3]. Hair, JF, Hult, GTM, Ringle, CM, & Sarstedt, M. (2021). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). SAGE Publications.
- [4]. Mayer, RE (2005). *The Cambridge handbook of multimedia learning* (1st ed.). Cambridge University Press.
- [5]. Moreno, R. (2006). Learning in high-tech environments: The cognitive–affective theory of learning with media. In RE
- [6]. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 425–439). Cambridge University Press.
- [7]. Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, 12 (2), 257–285. https://doi.org/10.1207/s15516709cog1202_4
- [8]. Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. Springer. <https://doi.org/10.1007/978-1-4419-8126-4>
- [9]. Magetos, D., & Mitropoulos, S. (2025b). The metaverse in education: A literature review. *International Journal of Latest Research in Engineering and Technology (IJLRET)*, 11(6), 48–58. <https://doi.org/10.56581/IJLRET.11.06.48>
- [10]. Magetos, D., & Mitropoulos, S. (2025c). Gamification of Educational Virtual Worlds in the Metaverse. *International Journal of Latest Research in Engineering and Technology (IJLRET)*, 11(7), 65-77.

[11]. Magetos, D., & Mitropoulos, S. "MetaFramEdu: A Competency Framework for the Metaverse in Education," *International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE)*, DOI: 10.17148/IJARCCE.2025.14805

[12]. Van Schaik, P., & Ling, J. (2009). The role of context in perceptions of the aesthetics of web pages over time. *International Journal of Human-Computer Studies*, 67 (1), 79–89. <https://doi.org/10.1016/j.ijhcs.2008.09.012>

[13]. Zimmerman, BJ (2002). Becoming a self-regulated learner: An overview. *Theory into Practice*, 41 (2), 64–70. https://doi.org/10.1207/s15430421tip4102_2

[14]. Magetos, D., & Mitropoulos, S. Effectiveness of Educational Virtual Worlds in the Metaverse A Study Based on the ARCS Model. *International Journal of Latest Engineering Research and Applications (IJLERA)* ISSN: 2455- 7137 Volume – 10, Issue – 06, June 2025, PP – 01-10.

[15]. Magetos, D., Kotsifakos, D., & Douligeris, C. (2023, November). Educational Virtual Worlds for Vocational Education and Training Laboratories. In 2023 8th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference (SEEDA-CECNSM) (pp. 1-6). IEEE

Appendix

Virtual Learning Environment Evaluation Questionnaire in Metaverse (Spatial.io)

Purpose

To investigate how students perceived learning, understanding, cognitive load, emotional engagement and usability of the virtual environment.

Demographic data (indicative)

1. Gender: M F Other
2. Age: __
3. Have you used virtual reality environments (VR/metaverse) before? Yes No

Section A: Cognitive Dimensions (CTML)

Objective: assessment of comprehension, cognitive load and clarity of presentation.

Scale: 1 = Strongly disagree, 5 = Strongly agree

No.	Statement	1	2	3	4	5
1	The spatial.io environment helped me better understand the basic concepts of computer networks.					
2	The information was organized in a way that made learning easier.					
3	I did not feel overloaded by the stimuli (images, sounds, objects) of the virtual world.					
4	The visual elements (models, diagrams) helped me connect theory with practice.					
5	The instructions and steps of the lesson were clear and easy to follow.					
6	The presence of the virtual guide/instructor helped me focus on the important points.					

Module B: Emotional Engagement and Motivation (CATLM)

Objective: exploring positive emotions, interest, satisfaction and motivation.

No.	Statement	1	2	3	4	5
7	The experience at spatial.io was pleasant and excited me.					
8	I felt "presence" within the virtual world (as if I were really there).					
9	The environment made me more interested in the computer networks course.					
10	I felt confident that I could understand the lesson within the virtual environment.					

No.	Statement	1	2	3	4	5
11	The virtual world helped me retain information more easily.					
12	The activities in the metaverse were fun and kept me active.					

Section C: Metacognitive & Self-Regulatory Dimensions (CATLM)

Objective: assessment of self-regulation, reflection and self-directed learning.

No.	Statement	1	2	3	4	5
13	I could control the pace at which I progressed through the lesson.					
14	I reflected on what I learned in the environment.					
15	I felt like I had responsibility for my own learning within the metaverse.					
16	The activities helped me correct my mistakes or misunderstandings.					

Section D: Technical and Pedagogical Usability

No.	Statement	1	2	3	4	5
17	spatial.io was easy to use and worked without any technical issues.					
18	Interaction with classmates/teacher was easy and meaningful.					
19	I would like to use the metaverse again to learn other lessons.					

Open-ended questions (qualitative data)

20. What element of the virtual environment do you think helped you learn the most?
21. What element was most difficult or confusing for you?
22. How did you feel overall during the metaverse experience?
23. What would you suggest to change or improve?

Overall Impression

24. On a scale from 1 (not at all effective) to 5 (very effective), how effective do you consider the metaverse spatial.io for teaching Computer Networks?

Rating: 1 2 3 4 5