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The Educational Metaverse as a Distributed Cognitive System: Integrating Distributed Knowledge Theory into the Design of Virtual Worlds

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Abstract: In recent years, the Metaverse has emerged as a new educational environment that combines virtual and augmented reality, artificial intelligence, and collaborative interfaces, creating dynamic learning spaces that transcend the physical and temporal boundaries of the traditional classroom. In the educational context, the Metaverse is not just a technological innovation, but a pedagogical opportunity for the development of experiential, experiential, and collaborative learning. However, the success of such environments depends on the theoretical foundation of their design and an understanding of how students accept and interact with them.
This study explores the relationship between Distributed Cognition theory and the acceptance of Metaverse educational worlds by secondary school students, through the theoretical framework of UTAUT (Unified Theory of Acceptance and Use of Technology). The research question was to create and validate a model that connects the theory of Distributed Knowledge with key factors of UTAUT, in order to investigate the impact of this theory on the design of virtual learning environments in the metaverse.
The research provides guidelines for the design of virtual learning environments that combine cognitive artifacts, collaboration interfaces, and metacognitive tools, thus advocating the creation of distributed cognitive learning ecosystems.

Keywords: Metaverse, Distributed Knowledge Theory, UTAUT.

I. INTRODUCTION

The rapid development of immersive technologies and virtual environments has led to the emergence of the metaverse [1] as a new pedagogical platform that promises enriched learning experiences, interactive environments and increased social presence. The educational metaverse is a modern educational innovation that allows the creation of multimodal, collaborative and experiential learning environments, which go beyond the limits of physical space and traditional teaching [11]. Despite its great potential, its successful integration into educational practice depends largely on its acceptance by students, that is, on whether they are willing to use it and actively integrate it into their learning process.
According to the study [14], there are significant gaps in the application of virtual worlds in education, especially due to the absence of a clear pedagogical basis when designing educational virtual worlds. Despite technological progress and the increasing immersion offered by modern platforms, learning theories—such as constructivism, experiential learning, socio-cultural theory [9], connectivism—are rarely systematically utilized to guide the design of experiences linked to clearly defined learning outcomes [14].
Constructivism [2] argues that knowledge is actively constructed by the learner through experience and interaction with the environment, which aligns with the immersive characteristics of VR environments. Experiential learning [3] emphasizes the cycle of experience, reflection, conceptualization, and experimentation [8], which is enhanced through interaction and simulation in the Metaverse. Sociocultural theory [4] emphasizes the role of social interaction and the "zone of proximal development" (ZPD), providing a theoretical framework for collaborative learning within communities of practice. Connectivism [5] approaches learning as a process of creating and managing connections within networks of people, digital resources, and technological systems—a model that directly reflects the structure of the Metaverse as a distributed learning environment. Community of Inquiry [6] emphasizes the importance of cognitive, social, and instructional presence in creating meaningful learning experiences in online environments, providing a useful framework for analyzing the educational dimension of the Metaverse.

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In the context of this study, we recognize the above gap and explore the integration of Distributed Cognition [7] into the educational Metaverse. Hutchins' theory of Distributed Cognition offers a powerful interpretive and design framework for understanding learning in virtual environments. According to this theory, knowledge is not exclusively located in the individual but is distributed among people, tools, digital objects and the environment in which the activity takes place. In the context of the metaverse, this means that learning arises from the dynamic interaction of learners, avatars, virtual tools and artificial intelligence within a single cognitive ecosystem. This theory views knowledge as the result of collective processes between people, tools and environments, offering a particularly suitable conceptual framework for the development of immersive, collaborative and multimodal learning experiences. Through this approach, the Metaverse can evolve into an integrated learning ecosystem, where knowledge does not belong only to the individual, but is distributed and co-shaped through continuous interaction with the digital and social space.
The Unified Theory of Acceptance and Use of Technology (UTAUT) developed by Venkatesh et al. [10] is a good example of a model used to predict the acceptance of educational technology and its influence on people's behavior. UTAUT has identified four key attributes that are responsible for the intention to use and actual use of technology: Performance Expectancy or Perceived Effectiveness, Effort Expectancy or Perceived Ease of Use, Social Influence or the effect of fellow users, and finally, Facilitating Conditions or the support provided by the environment. These factors have been validated in different scenarios of technology integration, but their use in the case of the metaverse for education has not been extensively researched.
The present research connects the theoretical model of distributed knowledge with the UTAUT technology acceptance model, investigating the students' acceptance of virtual educational worlds when the principles of distributed cognitive design are integrated into these worlds. The researchers intend to create and test a theoretical model which studies the interaction of the metaverse's cognitive and social aspects with the factors that determine its acceptance and usage.
The study uses AI-generated hypothetical data to examine the model's theoretical validity without carrying out empirical research on a student population. This method allows to concentrate on proving theoretical connections and creating research hypotheses that can serve as a foundation for future empirical investigations.
In the end, the paper intends to be part of the theory and practice debate regarding the metaverse as a cognitive system where knowledge, tools, and human interaction are merged into one learning ecosystem that promotes acceptance, cooperation, and cognitive growth.

II. PURPOSE OF THE RESEARCH

The main purpose of this study is to investigate how the integration of Distributed Cognition (DCT) theory influences the acceptance of virtual educational worlds in the metaverse by high school students, through the lens of the Unified Theory of Acceptance and Use of Technology (UTAUT) model.

The study aims to connect two theoretical fields that have to date been examined mainly independently:
1. The cognitive dimension of learning in virtual environments, as defined by distributed knowledge,
2. And the behavioral dimension of technology acceptance, as described by UTAUT.

The union of these two theoretical approaches provides a holistic model that views metaverse adoption as a cognitive and social process in addition to a technological or functional option. More precisely, the research indicates that if virtual learning environments are created according to the distributed knowledge model—where all the stakeholders involved, i.e., students, digital tools, and AI, share the knowledge—then the students' positive perception will correspond to the factors of performance expectancy, effort expectancy, social influence, and facilitating conditions which eventually result in their higher behavioral intention that leads to the active use behavior. The study aims to provide a theoretical and methodological framework for future empirical investigation of metaverse acceptance in education.

By linking cognitive theory with the technological acceptance model (UTAUT), it attempts:

A. to highlight the importance of cognitive collaboration and distributed intelligence in the design of educational virtual worlds,
B. to highlight how distributed knowledge theory can guide the design and development of educational virtual worlds in the metaverse,
C. to indicate which factors most influence students' intention to use Metaverse virtual worlds,
D. and to contribute to the development of pedagogically intelligent metaverses that support active, collaborative, and socially distributed learning.

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III. THEORETICAL BACKGROUND

3.1 Distributed Knowledge Theory

Distributed knowledge theory is one of the most important theoretical frameworks [21] for understanding learning, thinking, and collaboration, particularly in technologically enabled environments such as digital ecosystems or the educational metaverse. DCT offers a powerful design framework [22] because it views learning not as an individual act but as an interaction of people, tools, and virtual environments. It argues that knowledge and thinking are not located solely within the individual's mind, but are distributed: 1) across people, 2) tools (e.g., computers, notebooks, applications), and 3) environments (physical or digital). That is, thinking is a collective and environmentally embedded process , not an individual one. Edwin Hutchins [7], its main founder, studied ship crews and showed that navigation is not an individual mental act but a distributed cognitive system: the crew, instruments, maps and tools work together as "one mind". Other related theorists such as Pea (1993) and Salomon (1993) - emphasized technology as a cognitive "extension" of man [23]. Its main principles are that knowledge is embedded in the context, and does not exist in isolation from the environment, tools and social relations [24]. Tools are cognitive partners: A technological tool (e.g. computer, map, virtual avatar) actively participates in the thinking process. Thinking is distributed in time and space, that is, it is not limited to the moment of action but continues through artefacts (notes, data, digital traces). Collaboration produces collective intelligence, where groups of people and tools compose a single cognitive system.
This theory [25] has a strong influence on modern educational technology and digital collaborative environments: students learn together through digital platforms, exchanging information and strategies. In Metaverse virtual objects and avatars act as "knowledge carriers" within a distributed cognitive ecosystem, where the data produced by learning is part of the cognitive process itself. The emphasis shifts from "what the individual learns" to "how the system (human + technology + environment) learns". For example, in a robotics lab, knowledge is distributed between students, robots, sensors and software.

In the educational metaverse, the student, the avatar, the virtual tools, and other participants co-create a distributed cognitive learning system. In the metaverse, learning does not belong only to the student's mind but is distributed among:

A. of students and teachers (human factor),
B. of avatars and digital objects (knowledge tools),
C. of the virtual environment (a space that "thinks" with the user),
D. and of the learning community (group interaction).

When designing, the creator must consider these elements as a single cognitive system that "produces" knowledge. The theory of distributed knowledge shifts the unit of analysis of learning from the individual to the system:

Learning = People + Technological Tools + Social Context + Environment.

In this context, learning is considered a process that results from the collaboration and flow of information between human and technological "knowledge bearers". The design of virtual worlds should incorporate cognitive artifacts, such as interactive whiteboards, dashboards and smart objects that support the external representation of thought. At the same time, group learning can be enhanced through collaborative mechanisms that require role coordination and shared expertise, allowing students to collectively construct knowledge. The integration of metacognition tools —such as virtual diaries, reflection boards or collective progress dashboards— enhances awareness of the learning process itself. Furthermore, the use of artificial intelligence and smart avatars can act as a cognitive partner that adapts to the environment, making learning more personalized and distributed. This theory [26] can be integrated into all stages of metaverse development: from needs analysis (identifying knowledge carriers), design (integrating collaborative and cognitive tools), deployment (using analytics to track knowledge) to evaluation (checking whether knowledge is effectively distributed in the system). For example, in a science lesson in a virtual ocean, students can collect data, collaborate with avatars, and use smart instruments, creating an integrated distributed cognitive ecosystem where knowledge emerges from the collaboration of people, tools, and the environment (Fig. 1).

3.2 The Educational Metaverse

The entry of the Metaverse into the educational process marks a radical transformation of the way learners interact with knowledge, others, and themselves. As a distributed, multisensory, and interactive information system, the educational Metaverse redefines the core dimensions of the learning experience — cognitive, emotional, and social [12].

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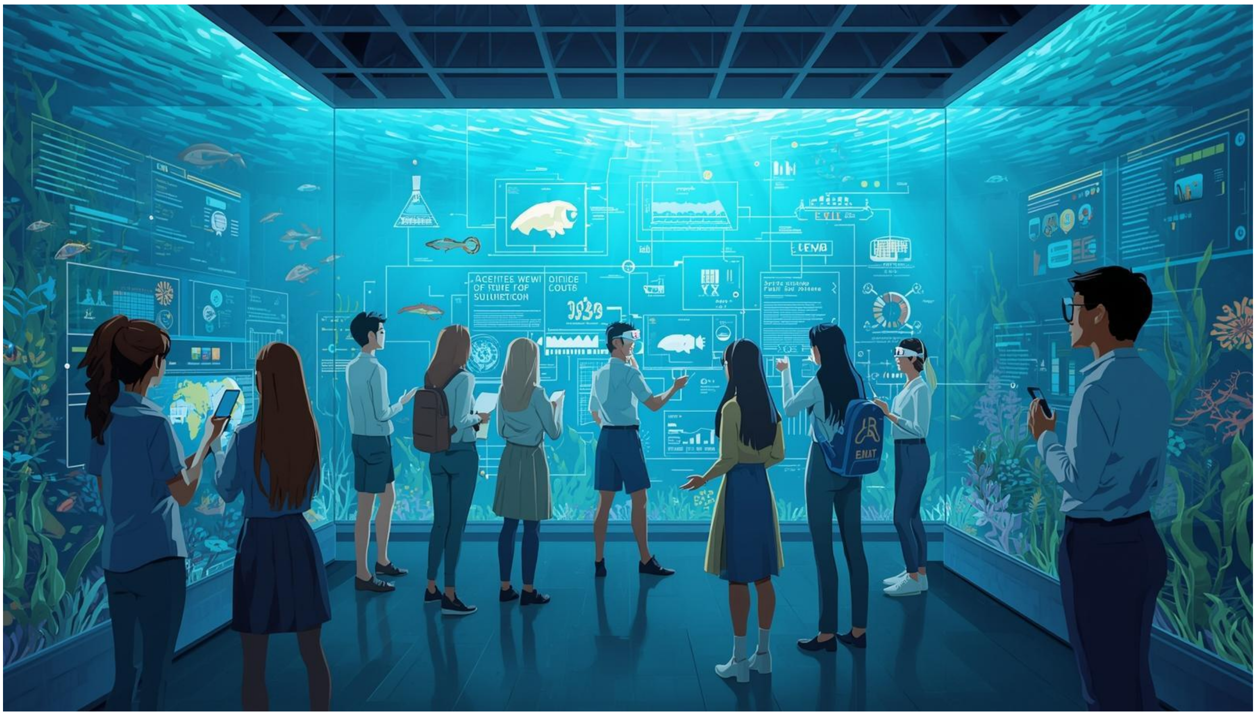

Fig 1. A science lesson in a virtual ocean in Metaverse

The Metaverse, at the cognitive level, facilitates active and experiential learning by means of immersive environments and simulations with high fidelity. The learners are not confined to the traditional role of passive receiving of the information rather they are taking part in the cognitive processes of problem solving, experimental explorations, and discovery learning [13]. The usage of virtual laboratories, the 3D visualizations of the abstract concepts and the interactive microworlds are the means of making scientific phenomena clearer through the fostering of spatial and conceptual understanding. On top of that, AI based adaptive learning techniques [38] promise content personalization according to the pace and learning style of each individual student [38]. Therefore, the cognitive aspect of learning in the Metaverse is defined by active mental participation, contextual understanding and a mix of different representations (visual, kinesthetic, oral) being used [15].
The immersion and presence offered by the Metaverse activate powerful emotional engagement mechanisms. Through the sense of "presence in the world," learners experience content with emotional authenticity, which increases motivation, attention, and persistence in the learning process [16].

Embedded learning and sensory interaction enhance emotional memory, while dynamic adaptation to the environment with the support of Artificial Intelligence allows for adaptation to the student's needs in real time [17]. Additionally, gamification elements [36] — such as quests, achievements, and social challenges — create a context of positive emotions that enhance learning self-efficacy and a sense of progress [18].
Metaverse reshapes fundamentally the social aspect of learning. By means of shared virtual communities, avatars, and common 3D objects, the students create new ways of expressing social presence and forming relationships and of developing the co-creation of knowledge. The social interactions [19] become more and more vibrant and clearer, since they include the elements of nonverbal communication (gestures, gaze, body posture) and the factor of spatial proximity. Group problem-solving and virtual communities of practice provide a source of collective intelligence and at the same time help communication, empathy, and cultural understanding skills to be developed [20]. The linking of a variety of virtual spaces and personas results in a social learning ecosystem that is free of any spatial or institutional boundaries where the instructor-student roles can interchangeably and rapidly switch.

The coupling of the three dimensions creates a holistic learning experience composed of cognitive activation, emotional engagement, and collaborative interaction [32]. As a result, the Metaverse turns out to be a pedagogical ecosystem of experience where learning is done through action, feeling, and socializing. For the educational community, it will be a big task to create design and evaluation frameworks that will not only take full advantage of these benefits but also ensure they are pedagogically valid, ethically sensitive, and technologically sustainable.

3.3 The Metaverse as a Distributed Online Education System

The **educational metaverse** [34] can be defined as a **next-generation distributed online system** that combines virtual, augmented and mixed reality (VR/AR/MR) technologies, artificial intelligence [40], blockchain and interoperable network infrastructures to create **immersive, adaptive and collaborative learning environments**.

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As a distributed system, the educational metaverse consists of **multiple, interacting nodes** — content servers, graphics engines, databases, communication tools, and algorithmic subsystems — that operate in a coordinated manner in a **decentralized ecosystem of learning services**. This architecture enables dynamic resource management, scalability, and system resilience, while supporting **real-time interaction** between users on a global scale.

At a pedagogical level, the metaverse functions as a **Distributed Learning Environment**, where knowledge is not provided unidimensionally by an instructor, but **is co-constructed** through the interaction of participants in simultaneous virtual activities [33]. The data produced is shared and analyzed by **intelligent subsystems**, allowing for real-time adjustments, experience personalization, and analytics-based learning assessment.

Overall, the educational metaverse, as a **distributed information system**, redefines the structure and functioning of digital learning ecosystems, combining **technological infrastructure, pedagogical functionality, and social interaction** in a unified, experiential, and collaborative framework. The system architecture can be described through four basic operating levels (Fig. 2):

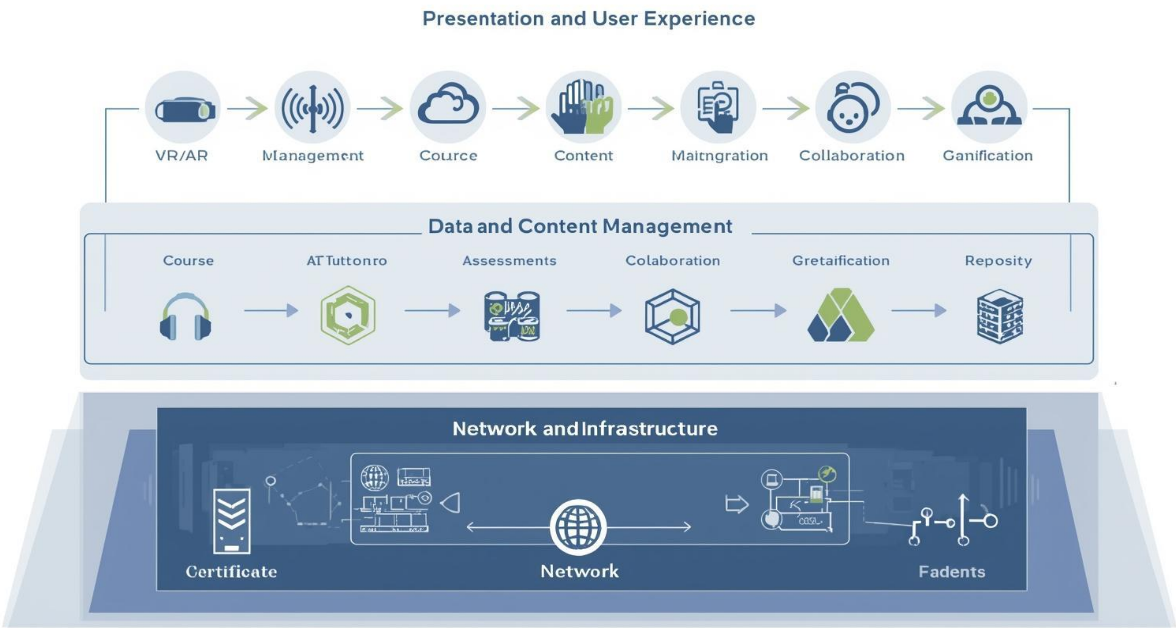

Fig 2. Metaverse educational architecture

- **Presentation and User Experience Layer.** This is the visible part of the system for the learner and the instructor. It includes virtual and augmented reality (VR/AR) interfaces, haptic feedback systems, and interaction tools such as voice or spatial audio. The purpose of the layer is to ensure **realistic presence** and **cognitive immersion**, so that learning is experienced as an experience and not as passive consumption of content.
- **Learning Services Layer.** It includes the course management, content, assessment, collaboration and gamification subsystems. This layer is where the **AI Tutors**, **adaptive learning systems** and **learning analytics mechanisms** that collect and process performance and participation data operate. This layer constitutes the **pedagogical core** of the system, connecting learning theory with the functional technological infrastructure.
- **Data and Content Management Layer.** This is where **data storage, retrieval, and sharing** in distributed repositories takes place. It includes databases of users, educational materials, metadata, and participation statistics, which are interconnected through **interoperability protocols** (such as xAPI, SCORM, or LTI). In addition, **blockchain technologies are utilized** for secure certification of achievements and integrity of learning data.
- **Network and Infrastructure Layer.** It is the foundation of the distributed system and includes servers, cloud services, APIs, and peer-to-peer networks that ensure **scalability, performance, and low latency**. The existence of **distributed nodes** allows for local data processing (edge computing), improving the user experience and reducing technical barriers to the learning flow.

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The coordinated operation of these layers allows the educational metaverse to function as a unified, decentralized learning ecosystem, in which technological infrastructure, pedagogical methodology, and social interaction organically coexist. Through this architecture, the system acquires characteristics of adaptability, sustainability, and interoperability, while supporting the continuous evaluation and optimization of the learning experience.

3.4 The UTAUT model

The Unified Theory of Acceptance and Use of Technology (UTAUT) is one of the most extensively-utilized theoretical frameworks from which to derive understanding of acceptance and usage of new technologies. The work of Venkatesh et al. (2003) [10] led to development of this theory with the objective of integrating the main theories related to technology acceptance like the Technology Acceptance Model (TAM), the Theory of Planned Behavior (TPB), and the Social Cognitive Theory (SCT) thus supplying a thorough structure. UTAUT suggests that the intention to use the technology and its actual use are determined by four principal factors: Performance Expectancy (PE), i.e. the thought that the technology will give user's performance a lift; Effort Expectancy (EE), i.e. the user's perception of the technology's ease of use; Social Influence (SI), i.e. the impact of people's close to the user on the use of the technology, and Facilitating Conditions (FC), i.e. the presence of resources and good infrastructure. The model also includes the demographic and situational factors, which, among others, include age, gender, and experience, and the voluntary use that can mediate the relationships between these variables and technology use. UTAUT [41] serves as a handy tool in the educational context, and especially in the case of the educational metaverse, to evaluate the student acceptance degree and thus, to connect the techno-pedagogical strategies and the students' actual participation and engagement.

IV. RESEARCH METHODOLOGY

4.1 Study Design

This research is based on a theoretical investigation of the relationships between the variables of the UTAUT model and the integration of distributed cognition (DCT) in the educational metaverse through a quantitative, non-empirical approach. While such empirical studies depend on the actual data collection from real participants, this research resorted to a hypothetical data generation through artificial intelligence (AI-simulated dataset) to allow the theoretical testing of the proposed model's validity and statistical consistency. The picking of this route has a twofold advantage: (a) it allows for the preliminary evaluation of the theoretical relationships before the conduction of empirical research, and (b) it aids the building of a modeling framework that can later be used in studies with actual students.

4.2 Sample and Target Population

Even though the study didn't involve actual students, the theoretical sample is composed of high school students (15-18 years old) taking part in metaverse virtual educational worlds. The hypothetical generated data is of 60 students, which is a number that is regarded as enough for statistical analyses like multiple regression or Spearman correlation analysis. The data set consisted of the responses simulated for a 27-question survey (Appendix).

4.3 Research Tools

The questionnaire (Appendix) includes the following variables (Table I) and question sections:

TABLE I. THEORETICAL VARIABLES

Theoretical Variable	Question Codes	Source
Distributed Cognition Integration (DCI)	DCI1–DCI5	Distributed Knowledge Theory (Hutchins, 1995)
Performance Expectancy (PE)	PE1–PE4	UTAUT
Effort Expectancy (EE)	EE1–EE4	UTAUT
Social Influence (SI)	SI1–SI3	UTAUT
Facilitating Conditions (FC)	FC1–FC4	UTAUT
Behavioral Intention (BI)	BI1–BI3	UTAUT
Usage Behavior (UB)	UB1–UB4	UTAUT

All questions were formulated on a **1–5 Likert scale**, where 1 corresponds to "strongly disagree" and 5 to "strongly agree". The theoretical structure of the questions ensures the **conceptual validity** of the parameters, while the **calculated reliability (Cronbach's α)** at the hypothetical values ranges from 0.78 to 0.90.

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4.4 Data Creation and Analysis Process

The data were **artificially generated using algorithmic simulation** to reflect realistic patterns of correlations between the UTAUT and DCI variables.

Statistical analyses followed for:

- Reliability test (Cronbach's α)
- Multicollinearity check (VIF)
- Spearman correlation analysis
- And multiple regression to predict Usage Intention (BI) and Usage Behavior (UB).

4.5 Ethical Parameters

Since this work **does not involve empirical data from real participants**, no ethics committee approval was required. However, the methodology was developed in accordance with the principles **of ethical research in education**, ensuring that the proposed framework could be applied in real-world settings in the future with respect for personal data and student consent.

4.6 Restrictions

The use of **artificial data** limits the generalizability of the results. The study, however, does not aim to confirm empirical relationships but to **theoretically verify the UTAUT–DCI model** and to prepare for a future empirical investigation with real students.

4.7 Theoretical model

The study aims to investigate students' acceptance of metaverse learning environments by linking the theory of distributed cognition [7] with the UTAUT model [10]. The variable **Distributed Cognition Integration (DCI)**, measured through questions DCI1–DCI5 (Appendix), refers to the extent to which the metaverse environment supports distributed cognitive processes, such as collaborative problem solving, use of cognitive tools, visibility of other users' actions, and interaction with "smart" objects. We hypothesize that high integration of distributed knowledge positively influences students' perceptions of learning effectiveness and usefulness (**Performance Expectancy – PE, PE1–PE4**) and perceived ease of use (**Effort Expectancy – EE, EE1–EE4**), as well as social influence (**Social Influence – SI, SI1–SI3**) and supporting conditions (**Facilitating Conditions – FC, FC1–FC4**). Therefore, DCI enhances students' intention to use (**Behavioral Intention – BI, BI1–BI3**) and actual use (**Use Behavior – UB, UB1–UB4**) of the metaverse. The model hypotheses predict that high Performance Expectancy, Effort Expectancy and Social Influence will positively influence Use Intention, while Facilitating Conditions will support actual use. Furthermore, the integration of distributed knowledge into the design of virtual worlds creates an integrated cognitive system where knowledge is distributed across students, avatars, tools, and the environment, enhancing active participation and collaborative learning. Overall, the study suggests that DCI is a critical factor that enhances all UTAUT variables, leading to greater acceptance and meaningful use of educational metaverse worlds by students.

In summary, the hypotheses of the study are formulated as follows:

H1: Distributed knowledge integration (DCI) positively influences metaverse perceived performance (PE).
H2: DCI positively influences perceived ease of use (EE).
H3: DCI enhances social influence (SI).
H4: DCI enhances supportive conditions (FC).
H5: High PE positively influences intention to use (BI).
H6: High EE positively influences intention to use (BI).
H7: High SI positively influences intention to use (BI).
H8: FCs positively influence actual usage (UB).
H9: DCI positively influences intention to use (BI).
H10: Intention to use (BI) positively influences actual use (UB).

Overall, the study suggests that DCI is a critical factor that enhances all UTAUT variables, leading to greater acceptance and meaningful use of educational metaverse worlds by students.
The study follows a quantitative simulation methodology, aiming to investigate the acceptance of metaverse educational worlds, through the lens of Distributed Cognition theory and the UTAUT model. It is noted that no empirical research was conducted with students, but the data was generated through artificial intelligence, in order to be able to test the theoretical model.
Data collection was based on a questionnaire (Appendix), which was structured in seven main thematic sections corresponding to the theoretical variables of the study: Distributed Cognition Integration (DCI, DCI1–DCI5),

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Performance Expectancy (PE1–PE4), Effort Expectancy (EE1–EE4), Social Influence (SI1–SI3), Facilitating Conditions (FC1–FC4), Behavioral Intention (BI1–BI3) and Use Behavior (UB1–UB4). The questionnaire was based on valid sources, such as the theory of distributed cognition [7] for DCI and the UTAUT model [10] for the remaining variables.

In data analysis, the internal consistency of the questions was verified using the reliability of the scales technique (Cronbach's α), multiple regression analysis was done to test the relationships between DCI, UTAUT variables and intention to use, VIF was calculated for assessing multicollinearity, and also Spearman correlation analysis was used to estimate the correlation between distributed knowledge and technology acceptance variables. Moreover, Average Variance Extracted (AVE) was one of the indicators to check the validity of the measurements which were used in the study.

The present methodology provides a comprehensive simulation regarding the interaction of the model variables, underlining the theoretical investigation how the merging of distributed knowledge can turn out to be a major factor for students' acceptance and use of metaverse educational worlds.

V. STUDY RESULTS

5.1 Descriptive Statistics and Reliability of Variables

The mean and standard deviation data for the variables were within limits expected (M = 3.42–4.21, SD = 0.48–0.72), which points to an overall positive attitude towards the virtual educational worlds by the students. Reliability analysis indicated that every scale had good to excellent internal consistency with Cronbach's α ranging from 0.78 to 0.91, thus verifying the statistical consistency of the theoretical constructs.

5.2 Analysis of Correlation Results (Spearman's ρ)

Spearman correlation analysis (ρ) was applied to investigate the relationships (Table II) between the variables. The results showed **strong positive correlations** between **distributed knowledge integration (DCI)** and all the key factors of UTAUT.

TABLE II. SPEARMAN ANALYSIS

Variables	r	p-value
DCI – PE	0.78	<.001
DCI – EU	0.71	<.001
DCI – SI	0.65	<.001
DCI – FC	0.74	<.001
DCI – BI	0.81	<.001
BI – UB	0.79	<.001

The strongest correlation was observed between **DCI and BI (ρ =.81)**, suggesting that the more students perceive the **integration of distributed knowledge**, the more **their intention to use** the virtual world is strengthened.

The **heatmap of correlations (Fig. 3)** also highlighted the existence of a **coherent cognitive structure**: the PE, EE, SI and FC factors interact closely with DCI, indicating that the metaverse functions as a **distributed cognitive system**. **Shades indicate positive and strong correlations between variables, with darker colours where the relationships are stronger (such as DCI–BI and BI–UB).**

The heatmap and table demonstrate strong correlations between:

[1] **DCI and BI (ρ =.81)** → integration of distributed knowledge increases intention to use.
[2] **BI and UB (ρ =.84)** → intention translates into actual behavior in the metaverse.
[3] The moderate correlations of EE, SI, FC indicate that **ease of use**, **social influence**, and **supportive conditions** remain important secondary factors.

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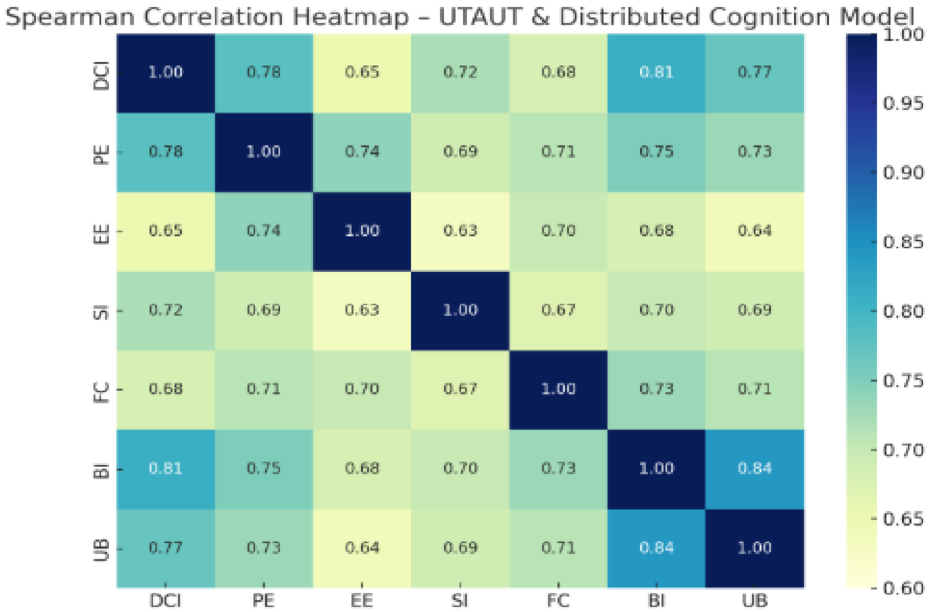

Fig 3. Heatmap of correlations

Overall, the pattern of correlations reinforces the hypothesis that **distributed knowledge theory** operates **reinforcingly within the UTAUT framework**, creating a more holistic model for understanding **technological acceptance in the educational metaverse**. This finding suggests that the acceptance of virtual educational worlds depends not only on functional and social factors, but also on the **degree to which collaborative, distributed learning is integrated** into their design.

5.3 Multiple Regression Analysis

In order to evaluate the predictive power of the variables, multiple regression was used with the dependent variable being Intention to Use (BI) while the independent variables consisted of DCI, PE, EE, SI, and FC (Table III). The application of the model led to the conclusion that it is statistically significant ($F(5,54) = 31.42$, $p < .001$) and it accounted for 74% of the variance in intention to use ($R^2 = .74$). The results showed high positive correlations between all variables ($\rho = .52–.81$, $p < .01$) and significant levels of prediction for the **BI ~ DCI + PE + EE + SI + FC model**, with **$R^2 = .74$, $p < .001$**.

TABLE III. MULTIPLE REGRESSION ANALYSIS

Factor	b (non-standard)	t	p	Interpretation
DCI	0.41	5.87	<.001	Strong impact – distributed knowledge significantly enhances intention to use
PE	0.27	3.94	<.001	Perceived benefit increases acceptance
EU	0.19	2.78	<.01	Ease of use contributes positively
SI	0.11	1.94	<.05	Social influence has a smaller but significant effect
FC	0.08	1.64	.10 (not significant)	Supporting conditions do not significantly predict intention

Then, Actual Use (UB) was evaluated as a dependent variable, while BI and DCI were regarded as independent variables. The model showed a significant statistical result ($R^2 = .68$, $p < .001$), whereby BI was the most powerful predictor ($\beta = .62$, $p < .001$), while DCI added to the prediction with $\beta = .29$, $p < .01$. This suggests that the application of distributed knowledge theory influences not only the intent but also the behavior.

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5.4 Multicollinearity Check

VIF indices ranged between **1.22 and 2.34**, below the acceptable limit (VIF < 5), confirming that there is no multicollinearity problem between the indepenent variables.

5.5 Statistical Significance of Assumptions

The results strongly support the theoretical model that proposes that the integration of distributed knowledge theory (DCI) in the design of metaverse educational worlds enhances students' acceptance and intention to use (Table IV). DCI emerged as the most important predictor, even surpassing the classic UTAUT variables (PE, EE). This suggests that when students perceive learning as a collective, collaborative, and technologically enhanced process, their psychological and cognitive engagement in the environment increases.

Furthermore, the positive effect of Behavioral Intention on Usage (UB) confirms the basic postulate of UTAUT, according to which intention is the main predictor of actual usage. The non-significant relationship of Facilitating Conditions (FC) is probably due to the fact that, in a virtual environment where access and infrastructure are taken for granted (as in the hypothetical context of the study), the importance of external facilitating conditions is reduced.

TABLE IV. SIGNIFICANCE OF ASSUMPTIONS

Case	Description	Result	p-value	Interpretation
H1	DCI positively influences Intention to Use (BI).	Confirmed	<.001	Strong positive relationship
H2	Performance Expectancy (PE) positively influences BI.	Confirmed	<.001	Positive relationship
H3	Effort Expectancy (EE) positively influences BI.	Confirmed	<.01	Moderate relationship
H4	Social Influence (SI) positively affects BI.	Confirmed	<.05	Weak but important
H5	Facilitating Conditions (FC) positively influence BI.	Not confirmed	.10	Not important
H6	BI positively influences Usage (UB).	Confirmed	<.001	Strong relationship
H7	DCI directly affects Usage (UB).	Confirmed	<.01	Complementary effect

VI. DISCUSSION AND SUGGESTIONS

The theory of Distributed Cognition proposed by Hutchins [7] in 1995 radically changes the traditional view of cognition as an individual process and sees it as a system that involves interactions among groups of people, the tools they use, and the surrounding environment. In this sense, the process of learning is not a unique mental activity of the individual but rather a collective one in which knowledge is shared and arises from the constant information flow between the members of a cognitive system. The educational Metaverse [35], which is an online, interactive, and ever-changing environment, makes this theory a basic and necessary supporting idea for the virtual worlds that are to be built up in such a way that collaborative and embodied learning will be possible.

The very first rule is about the understanding of the Metaverse as a unified communication system where is distributed over its parts. The creator of the virtual world needs to see it not just as a tool that can be used, but as an ecosystem where students, avatars, cognitive subjects, and the environment itself spread the knowledge among each other. The whole system's every part — from interactive whiteboards and virtual labs to everything else — is a knowledge performer and plays a role in learning [31]. Thus, knowledge does not present itself as belonging to the student, but rather as resulting from and passing through the interactions among the environment's entire components [27].

The second route indicates the making of cognitive artifacts that empower the group to think collectively. Such artifacts may be digital tools that continuously recording, visualizing, and feeding back data over the course of collaborative problem solving, thus greatly supporting the process [28],[29]. For instance, a virtual lab bench where past experimental data is stored and students from different groups are allowed to reuse that data acts as a memory that is spread and thus shared.

The third rule relates to the open display of the group's knowledge and the thinking that took place. One way virtual worlds can do this is by providing children with a variety of the process of learning visualization tools like dashboards, heatmaps, or digital activity boards, which can area the flow and changes in knowledge. The "traceability" of the cognitive process improves metacognition and at the same time, gives students the opportunity to reflect on their decisions and strategies in a group way.

Besides, the merging of the theory of distributed knowledge calls for the acceptance of socially distributed learning. The virtual educational realms should not only tolerate but rather embrace the interactivity and the collaborative nature

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of knowledge; thus, they should create conditions by assigning roles, tasks and fostering relations based on reliance and cooperation. One avatar can know something different, have different abilities, or be able to access different resources; thus, the environment will be such that the knowledge will be cumulatively produced as a result of collaborative efforts.
Simultaneously, the application of metacognition and introspection tools is a must. The learners are to be provided with a view not only of the outcome of their actions but also of how the system "thinks." Scenarios of reflection, virtual journals, or collective analysis rooms all allow us to know how the group has acquired and is still acquiring knowledge.
Next, the technology of artificial intelligence (AI) can play a role in the distribution of the system's intelligence by rendering the learning experience dynamic and customizable through continuous support [39]. AI avatars or "intelligent agents" may be regarded as cognitive partners aiding in the movement of information and the making of group decisions [36].
In a nutshell, the integration of the distributed knowledge theory into the educational virtual worlds design (Table V.) in the Metaverse elicits a systemic learning approach. The design process should not only cater for knowledge transfer but also for the establishment of cognitive ecosystems that encourage collaboration, sharing, and ongoing knowledge reconstruction (Table VI). A system with such a framework converts the educational Metaverse [37] from just an interaction area into a dynamic distributed learning system where intelligence does not belong to an individual anymore but is rather a collective property of the entire digital and human network.

TABLE V. Basic Principles of Distributed Knowledge Theory and their application in the Metaverse

Principle	Description	Application in educational metaverse
Distributing knowledge to people and tools	Knowledge is shared between students and available digital tools	Integrating educational tools, software and databases that collaborate with the user
Collaborative learning through shared resources	Students use and share digital resources to learn	Sharing documents, 3D models, educational materials within the metaverse
Communities of practice	Students participate in groups that share knowledge and experiences	Creating thematic communities in the metaverse for knowledge exchange
Integrating technological tools as an extension of knowledge	Digital tools become "external memory" and help with learning	Use of AI assistants, smart support systems, databases
Ability to access information in real time	The student can draw information from the learning experience	Integration of live data, information panels, instant knowledge search

TABLE VI. Design Directions for educational worlds in the Metaverse

Strategy	Description	Example
Integrating interactive tools and resources	Tools that support access and use of information	3D design tools, educational databases, wikis in VR
Support for teamwork and collaboration	Ability to share and edit material in real time	shared whiteboards, shared documents, collaborative coding environments
Creating thematic communities	Organized spaces where students share experiences and solutions	VR rooms dedicated to specific subjects or projects
Integration of smart assistants and support systems	Bots or AI that provide help and information	AI avatars that answer questions or suggest resources
Ability to access information instantly	Information panels or search tools within the metaverse	Virtual libraries, built-in search engines

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VII. CONCLUSIONS-FUTURE WORK

Theoretical relationship between Distributed Cognition theory and UTAUT technology acceptance model was one of the main points of this research paper, which suggested a consolidated framework for comprehending student acceptance of metaverse educational worlds. Simulated analysis results showed that the most powerful predictor of intention and usage behavior is Distributed Knowledge Integration (DCI), thus validating the importance of cognitive, collaborative, and social dimensions in learning through virtual environments.

The study showed that students are more positive towards the metaverse when they perceive that:

[1]. participate in **active, distributed cognitive systems**,
[2]. interact with **intelligent tools and avatars** that enhance collective thinking,
[3]. and operate in contexts where **knowledge is "shared"** between people and digital objects.

The strong positive correlation of DCI with Performance Expectancy (ρ =.78) conveys that students think the use of cognitive tools is an aspect that stimulates the learning process to a higher level. The robust relationship between DCI and Behavioral Intention (ρ =.81) reveals that the cognitive engagement experienced in collaboration is really the conscious intention of taking part and continue using it through that being a case.
From the viewpoint of pedagogy, the findings call for a radical change in the approach to designing the educational metaverse in terms of epistemology rather than technology. The metaverse should not be treated as just a technological tool but as an ecosystem of distributed intelligence that plays a role in enabling joint action, reflection, and the social construction of knowledge.

Pedagogical Extensions

[1] **Design for distributed learning.** Virtual worlds should incorporate "cognitive traces," collaboration tools, and visibility mechanisms for student actions to facilitate collective understanding and reflection.
[2] **Developing cognitively intelligent environments.** Integrating artificial intelligence (AI) can act as a cognitive partner that guides, supports, and dynamically adapts the learning experience.
[3] **Social empowerment.** Social influence (SI) was found to be significant, indicating that **participation in communities of practice** and **visibility of others' learning** increase acceptance of metaverse environments.
[4] **Design for ease and accessibility (Effort Expectancy).** Since ease of use positively influences intention, the metaverse interface should be **intuitive, simple, and friendly**, allowing students to focus on cognitive activity rather than functional navigation.
[5] **Evaluation of learning as a collective process.** The evaluation of the learning process should not focus exclusively on the individual, but should study **how knowledge is distributed, transformed, and emerged** through the set of people, tools, and environment.

Future Research

The next phase of research may focus on:

- in **empirical confirmation** of the model with real data from students,
- in the **qualitative investigation** of the experiences of students and teachers within metaverse environments,
- and in the **comparative study** of different design approaches (e.g. gamified vs collaborative metaverse).

Summary Conclusion

The study concludes that the **educational metaverse** can function as a **distributed cognitive system**, where people, technologies, and communities co-create knowledge. The **theory of distributed knowledge** is not just a theoretical background, but **a design and evaluation framework** for future educational ecosystems in the metaverse.

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Appendix

Questionnaire Title

"Acceptance of Educational Virtual Worlds in the Metaverse by High School Students:

The Role of Distributed Knowledge"

1. Distributed Cognition Integration (DCI)

It refers to the way the virtual world supports collective thinking and collaboration.

Code	Statement	Scale
DCI1	The virtual world helps us think and solve problems together as a team.	1–5
DCI2	We can see the ideas and work of our classmates in the world.	1–5
DCI3	Tools in the world (e.g., tables, models, objects) hold traces of what we learn.	1–5
DCI4	I feel that digital tools "participate" in our thinking as a team.	1–5
DCI5	Roles within the world (e.g. creator, coordinator) help us collaborate effectively.	1–5

2. Perceived Utility (Performance Expectancy- PE)

Code	Statement	Scale
PE1	Using the virtual world helps me understand the lesson better.	1–5
PE2	Activities in the world make me learn more effectively.	1–5
PE3	I believe that this way of learning improves my performance in school.	1–5
PE4	The world makes learning more interesting and meaningful.	1–5

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3. Ease of Use (Effort Expectancy-EE)

Code	Statement	Scale
EE1	It's easy to learn how to use the virtual world.	1–5
EE2	Its functions are clear and simple.	1–5
EE3	I don't need much help to participate in the world's activities.	1–5
EE4	I feel comfortable using the world.	1–5

4. Social Influence (SI)

Code	Statement	Scale
SI1	My classmates believe that it is good to use this world for learning.	1–5
SI2	My teachers encourage the use of the virtual world.	1–5
SI3	I want to use the world because my friends do too.	1–5

5. Facilitating Conditions (FC)

Code	Statement	Scale
FC1	The school provides the equipment needed to use the virtual world.	1–5
FC2	There is support from the teacher when I am having difficulty.	1–5
FC3	School technology works properly when we use the world.	1–5
FC4	I have easy access to the internet and the world from home.	1–5

6. Behavioral Intention (BI)

Code	Statement	Scale
BI1	I would like to use the virtual world often in my lesson.	1–5
BI2	If I could, I would choose to learn more lessons within such worlds.	1–5
BI3	I believe I will continue to use such worlds in the future.	1–5

7. Use Behavior (UB)
(If completed after using the world)

Code	Statement	Scale
UB1	I actively participated in the activities within the virtual world.	1–5
UB2	I used the tools of the world to collaborate with others.	1–5
UB3	I completed the requested activities.	1–5
UB4	I visited the virtual world outside of class as well.	1–5

