Salud, Ciencia y Tecnología. 2025; 5:1895
doi: 10.56294/saludcyt20251895

AG EDITOR

ORIGINAL

Virtual Economies in Motion: Integrating Animated Simulations and Blockchain for Immersive Economic Decision-Making

Economías Virtuales en Movimiento: Integración de Simulaciones Animadas y Blockchain para Una Toma de Decisiones Económicas Inmersiva

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Cite as: RE RY, Yahya N, Buan A, Lofandri W. Virtual Economies in Motion: Integrating Animated Simulations and Blockchain for Immersive Economic Decision-Making. Salud, Ciencia y Tecnología. 2025; 5:1895. https://doi.org/10.56294/saludcyt20251895

Submitted: 03-02-2025 **Revised:** 19-05-2025 **Accepted:** 11-08-2025 **Published:** 12-08-2025

Editor: Prof. Dr. William Castillo-González

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ABSTRACT

The growing impact of digital transformation in economic education highlights the need for immersive, interactive, and transparent learning environments. Traditional teaching models often lack real-time simulations and verifiability, which limits learners' ability to develop strategic thinking. This study addresses that gap by developing a blockchain-integrated animated simulation within a metaverse environment to enhance economic decision-making. A quantitative-exploratory design was employed, involving 45 postgraduate students in economics and information systems. The system used animated 3D simulations and blockchain transactions powered by smart contracts. Data collection instruments included a pre- and post-decision-making test and the System Usability Scale (SUS), with results analyzed using descriptive statistics and paired-sample t-tests. Findings revealed that 86,7 % of participants improved their decision accuracy, with an average SUS score of 83,1, indicating high usability. A paired-sample t-test showed a statistically significant improvement in decision accuracy from the pre-test ($M = 62,5$, $SD = 9,4$) to the post-test ($M = 87,9$, $SD = 6,8$), $t(44) = 13,21$, $p < 0,001$. These results confirm that immersive, blockchain-based simulations can enhance both economic understanding and learner engagement. The study suggests scalable applications in economic education, business training, and policy modeling.

Keywords: Blockchain; Metaverse; Economic Decision; Economic Simulation; Animated Visualization; Usability.

RESUMEN

El creciente impacto de la transformación digital en la educación económica resalta la necesidad de entornos de aprendizaje inmersivos, interactivos y transparentes. Los modelos de enseñanza tradicionales a menudo carecen de simulaciones en tiempo real y verificabilidad, lo que limita la capacidad de los estudiantes para desarrollar pensamiento estratégico. Este estudio aborda esa brecha desarrollando una simulación animada integrada en blockchain dentro de un entorno de metaverso para mejorar la toma de decisiones económicas. Se empleó un diseño cuantitativo-exploratorio, involucrando a 45 estudiantes de posgrado en economía y sistemas de información. El sistema utilizó simulaciones 3D animadas y transacciones de blockchain impulsadas por contratos inteligentes. Los instrumentos de recolección de datos incluyeron una prueba previa y posterior a la toma de decisiones y la Escala de Usabilidad del Sistema (SUS), con resultados analizados utilizando estadísticas descriptivas y pruebas t de muestras pareadas. Los hallazgos revelaron que el 86,7 % de los participantes mejoraron su precisión de decisión, con una puntuación SUS promedio de 83,1, lo que indica una alta usabilidad. Una prueba t de muestras pareadas mostró una mejora estadísticamente significativa en la precisión de las decisiones entre la prueba previa (M = 62,5, DE = 9,4) y la prueba posterior (M = 87,9, DE = 6,8), t(44) = 13,21, p < 0,001. Estos resultados confirman que las simulaciones inmersivas basadas en blockchain pueden mejorar tanto la comprensión económica como la participación del alumnado. El estudio sugiere aplicaciones escalables en la educación económica, la formación empresarial y el modelado de políticas.

Palabras clave: Blockchain; Metaverso; Decisión Económica; Simulación Económica; Visualización Animada; Usabilidad.

INTRODUCTION

Economic education today is undergoing a paradigm shift, driven by the urgent need to equip learners with strategic thinking and adaptable decision-making skills essential for navigating complex and dynamic economic systems. Traditional pedagogical approaches, while foundational, often fall short in offering the kind of experiential and system-level understanding required in today's interconnected economies. A key scientific problem emerges: how to effectively bridge the gap between abstract economic theory and its real-world application through innovative, technology-enhanced learning environments.

This problem is particularly pressing given that conventional educational models struggle to replicate the real-time behavior and operational complexity of economic systems. As a result, learners may develop a theoretical understanding without the practical competence needed for high-stakes decision-making. To address this gap, there is a growing call for the development of interactive, simulation-based instructional tools that foster active learning and mirror real-world economic environments.

The rise of digital technologies offers a transformative pathway forward. Emerging tools—particularly blockchain and immersive technologies—are redefining the structure of economic education by introducing greater transparency, traceability, and interactivity.[1] These innovations offer the potential to not only modernize teaching methods but also to simulate economic systems in ways that are both dynamic and pedagogically effective. As global economies become increasingly data-driven and decentralized, the demand for real-time, trustworthy educational tools has never been more urgent.[2] One promising strategy is the integration of economic decision-making within immersive virtual environments, where users can interact with complex variables in realistic simulations.[3] Moreover, gamification and animation have been shown to enhance engagement and improve retention in educational contexts.[4] further justifying their use in economic learning environments.

Among these emerging tools, blockchain technology stands out due to its capacity to ensure transparency and data integrity. By employing a decentralized ledger system, blockchain minimizes opportunities for data manipulation and enhances confidence in transaction validity.[5] It promotes accountability through immutability and auditability, which are crucial in building trust in educational simulations. Furthermore, the integration of smart contracts in blockchain systems allows for automated and unbiased execution of predefined rules—enhancing operational efficiency and reducing manual oversight.

Therefore, the objective of this study is to investigate the feasibility and effectiveness of a blockchain-integrated, animated metaverse simulation in enhancing users' economic decision-making and usability perceptions. This interdisciplinary research aims to empirically evaluate the proposed model through a quantitative-exploratory study, thereby providing insights into its potential for revolutionizing economic education and simulation-based training. Beyond academic implications, this work has broader significance for business education, policy experimentation, and future workforce development—particularly in light of the growing importance of decentralized finance (DeFi), digital assets, and tokenized economies.[6,7,8,9,10]

In summary, this study seeks to address a crucial question: *Can immersive, blockchain-enabled animated simulations improve learners' economic decision-making processes and their perception of system usability?* By doing so, it aims to bridge the gap between emerging technologies and educational innovation, contributing to a robust foundation for future-ready economic education.[11,12,13,14,15,16]

Table 1 illustrates the differences between traditional economic models and blockchain-based simulations. This table highlights core differences in traceability, decentralization, and interactivity, helping readers grasp the innovative features of the proposed system.

Table 1. Comparative Analysis of Traditional vs. Blockchain-Based Economic Models

Feature	Traditional Economic Model	Blockchain-Based Virtual Economy
Transparency	Often opaque; data centralized and restricted	Fully transparent; public ledger accessible to all
Control Structure	Centralized (government or institution-based)	Decentralized via consensus mechanisms
Security	Vulnerable to single-point failures	Cryptographically secured and distributed
Transaction Speed	Slower; requires intermediaries	Near-instantaneous; peer-to-peer validation
Trust Mechanism	Based on third-party institutions	Based on code (smart contracts) and protocol rules
User Participation	Limited to passive roles	Interactive and participatory (voting, DAO, etc.)
Data Integrity	Prone to manipulation or loss	Immutable and verifiable ledger
Adaptability to Change	Requires policy revisions	Programmable and scalable via smart contracts

METHOD

This research employs a mixed-method simulation approach to develop a prototype for a decentralized virtual economic environment. It combines agent-based modeling (ABM), animated visual simulations, and blockchain smart contract integration to design and test the prototype. By definition, smart contracts are programs that automatically follow economic rules, enabling collaboration without requiring mutual trust. The research methodology is divided into four main phases: conceptual framework design, simulation model development, blockchain integration, and performance analysis. The following section provides a detailed discussion of these phases.

Simulation Design

The system is designed as an animated economic simulation integrated with blockchain smart contracts. Users interact within a 3D virtual environment where each economic transaction is executed through smart contracts, visualized in real time, and immutably recorded on the blockchain.

To better illustrate the system design and data interaction, figure 1 presents the conceptual framework, user interaction flow, and system architecture of the blockchain-based metaverse simulation.

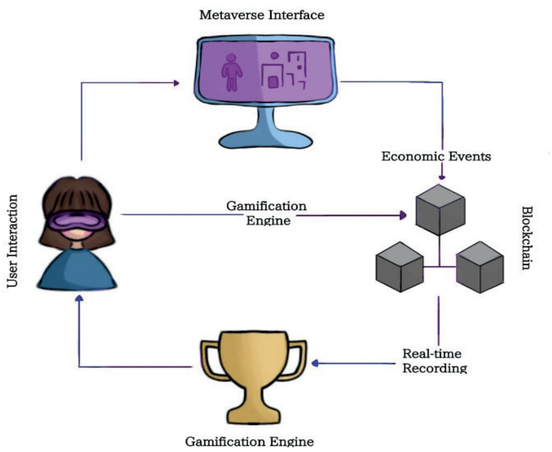

Figure 1. Conceptual Framework of the Simulation System

Figure 1 illustrates user interaction within the metaverse interface, which drives the educational experience of economic events securely recorded and permanently stored on the blockchain. The diagram shows the interaction between smart contracts, animation engines, and user inputs within the blockchain-based metaverse simulation. The figure also highlights the critical role of the gamification engine in enhancing user interaction and participation within the learning simulation. Blockchain technology supports this process by enabling instant data recording. Using this real-time information, the gamification engine continuously fine-tunes learning activities and provides immediate feedback to learners. Consequently, the gamification engine plays a key role in shaping user interactions, encouraging active involvement, celebrating progress, and fostering ongoing engagement. This creates a flexible and dynamic learning environment.

Figure 2 illustrates how users interact within a virtual world that simulates an economy. This flowchart outlines how users engage with animated economic tasks and trigger blockchain transactions in the metaverse environment. The process begins when a user logs into the animated metaverse environment, where dynamic virtual activities take place. These key actions are immediately transmitted to a dedicated system component that records the transactions, ensuring every important interaction is captured. The recorded transactions are then permanently stored on the blockchain, which serves as a secure and transparent digital ledger, guaranteeing the accuracy and immutability of the data. This blockchain information is subsequently used to generate an economic dashboard, providing users with a comprehensive view of their progress and activities within the virtual economy. Crucially, the dashboard delivers valuable feedback to users through a continuous feedback loop, effectively guiding and enhancing their learning experience.

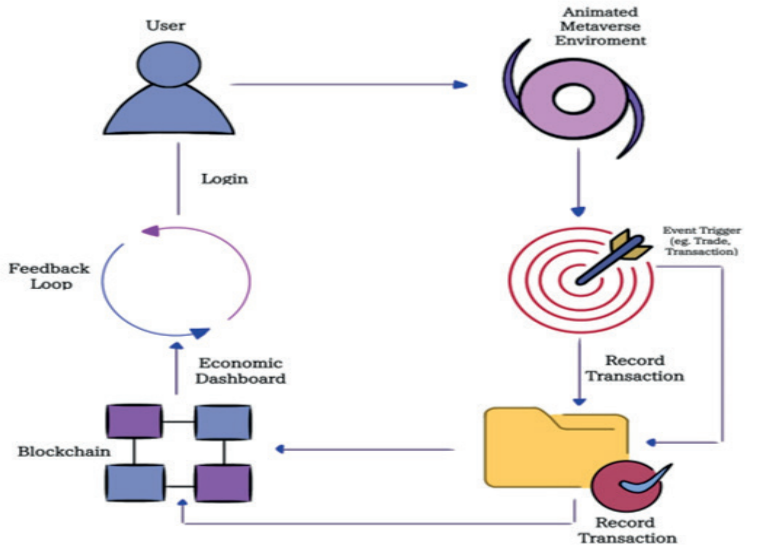

Figure 2. User Interaction Flow in the Metaverse Economy

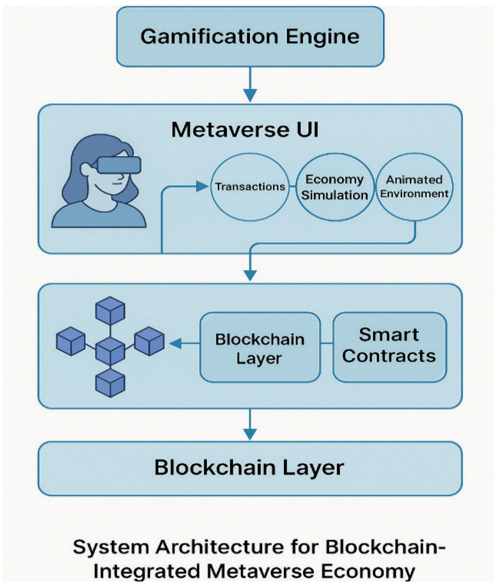

Figure 3. Simulation Architecture Flow

The diagram in figure 3 illustrates the gamified architecture of a simulation based on blockchain technology. This system-level diagram presents data flow between frontend 3D interaction, blockchain layer, and data analytics backend, reinforcing the operational logic of the simulation. As shown, the gamification component initiates game-like elements and challenges for the learner to engage with. This experience is delivered through the metaverse user interface, which consists of three key elements: (1) virtual transactions, (2) economic simulation, and (3) an animated environment. As users interact and progress within this immersive metaverse, their actions and achievements are recorded on the Blockchain Layer. The blockchain, combined with smart contracts, securely and transparently logs all events from virtual interactions to simulation outcomes ensuring that every learning step and accomplishment is verifiable and tamper-proof.

Participants

This study targets a defined universe consisting of postgraduate students enrolled in economics and information systems programs across three major universities. From this population, a sample of 45 participants (27 males and 18 females) aged 23 to 35 was drawn using purposive sampling, based on the inclusion criteria of having foundational knowledge of economic systems and digital technologies. This ensures that the selected sample aligns with the study's objective of evaluating technology-enhanced economic decision-making.

Expert Validation

Validation was conducted by three domain experts specializing in economics, blockchain technology, and instructional design. Each expert evaluated the simulation design for content accuracy, realism, and educational alignment using a rubric-based scoring instrument (annex).

Data Collection Instruments

The System Usability Scale (SUS) was employed to assess the user experience. A decision-making accuracy test comprising 10 economic scenario questions was also administered both before and after participants used the simulation. This method is simple enough to be used with respondents of varying qualifications and can be used in small research samples with accurate results. The System Usability Scale uses ten items rated on a scale from 1 to 5, five of which are negative. The sum of the scores for each question is then multiplied by 2,5 to obtain the SUS score. The average system usability scale score is 68. A score below 68 indicates a problem affecting the system's usability.

Statistical Techniques

Descriptive statistics were used to calculate the mean score of SUS, standard deviation, and level of improvement. Furthermore, inferential statistics used a paired-sample t-test comparing pre- and post-test performance with a critical p-value of 0,05 for correlation analysis to examine the relationship between usability and decision accuracy.

RESULTS

The study involved 45 postgraduate students from economics and information systems programs. Two primary data sets were collected: (1) performance on economic decision-making tests before and after the intervention, and (2) user experience data measured by the System Usability Scale (SUS).

Decision-Making Performance

To evaluate the impact of the blockchain-based animated simulation on decision-making performance, participants underwent a pre-test and a post-test after interacting with the simulation. Before using the simulation, the average decision-making test score was M = 62,5 (SD = 9,4), indicating moderate performance with scores generally dispersed within about 9 points of the mean. After the simulation intervention, the average post-test score significantly increased to M = 87,9 (SD = 6,8). This improvement not only demonstrates a substantial increase in decision-making accuracy but also suggests that participants' scores became more consistent, with less variability around the higher mean.

To determine whether the observed improvement was statistically significant and unlikely due to chance, a paired-sample t-test was conducted. The results, t-test, $t(44) = 13{,}21, p < 0{,}001$ provide strong evidence that the simulation was effective. The t-value of 13,21, with 44 degrees of freedom, reflects a substantial difference between pre-test and post-test scores relative to the variability within the data. The p-value, indicating less than a 0,1 % probability that the improvement occurred by chance, confirms a statistically significant increase in decision-making accuracy.

This finding confirms that the immersive and interactive simulation environment significantly improved participants' strategic thinking and decision-making skills. Moreover, 86,7 % of participants showed individual score improvements, while no participant showed a decrease in score.

Participants indicated that the interface was intuitive, and the animation aided in clarifying abstract economic mechanisms. They also emphasized that the real-time feedback from smart contracts enhanced their understanding of the consequences of their virtual transactions. Taken together, these findings strongly suggest that the immersive and interactive simulation environment effectively enhanced participants' strategic

https://doi.org/10.56294/saludcyt20251895 ISSN: 2796-9711

thinking and decision-making abilities.

Table 2. Pre- and Post-Test Accuracy Comparison

Measurement	Mean (M)	Standard Deviation (SD)
Pre-Test Accuracy	62,5	9,4
Post-Test Accuracy	87,9	6,8

System Usability Evaluation

The System Usability Scale (SUS) assessment results showed that participants gave the system an average score of 83,1, which falls within the "excellent" range, indicating a high level of user-friendliness. A closer analysis of the feedback revealed that 91,1 % of users rated the system as either "good" or "excellent." Only a small proportion, 4,4 %, provided a "neutral" rating, indicating neither a positive nor negative impression. Notably, no participants rated the simulation as "poor" or "unusable," which is a strong indicator of the system's overall usability.

Observational Insights

During the simulation sessions, researchers observed that participants demonstrated higher levels of engagement, collaboration, and time-on-task compared to traditional lecture-based sessions. Qualitative observations indicated that animated visualizations and real-time blockchain transaction feedback helped learners grasp economic principles such as scarcity, opportunity cost, and trade-offs more concretely.

DISCUSSION

The findings of this study highlight the effectiveness of integrating blockchain technology, metaverse environments, and animated simulations to enhance decision-making and user engagement in economic education. Participants demonstrated a statistically significant improvement in post-test scores, indicating that immersive and transparent platforms can improve conceptual understanding of complex economic scenarios. These results align with previous research suggesting that simulations help learners better comprehend abstract concepts by transforming them into tangible, interactive experiences.[17,18]

A key strength of this research lies in its practical application of blockchain technology within an educational simulation, moving beyond theoretical exploration. Blockchain's capacity to facilitate secure, traceable, and immutable transactions played a pivotal role in building learners' trust in the simulation outcomes. The integration of smart contract mechanisms at each decision point provided immediate and transparent feedback, allowing participants to observe the real-time consequences of their choices. This responsiveness not only supports deeper learning but also mirrors real-world economic dynamics, where decisions often lead to cascading effects.[19]

Usability data further supports the simulation's design effectiveness. The average System Usability Scale (SUS) score of 83,1 falls well within the "excellent" range, reinforcing the importance of user-friendly design in the adoption of educational technologies.[20] Participants noted that the animated interfaces were intuitive and helped contextualize dynamic processes such as inflation, resource distribution, and penalties for speculation. This supports the findings of Kim and Reeves,[21] who concluded that gamified and animated learning materials enhance both learner motivation and retention.

This study also builds upon the work of Yoo et al.[22] who emphasized the value of immersive learning ecosystems in developing analytical thinking. By combining visual animation with transactional transparency, the simulation enabled users to experience the cause-effect relationships often obscured in traditional, static economic models. This not only enhanced usability but also aligned with heutagogical approaches, which emphasize learner autonomy and real-time feedback.[23]

In terms of learning outcomes, the use of a pre-post design allowed for accurate measurement of cognitive gains. A paired-sample t-test revealed that 86,7 % of participants improved their decision-making scores, supporting the hypothesis that immersive simulations enhance learning effectiveness. Similar results have been observed in VR-based finance simulations, where learners demonstrated improved budgeting and forecasting skills.[24,25,26]

A novel contribution of this study Is the Introduction of a policy layer within the simulation, allowing users to experiment with hypothetical economic policies in a risk-free environment. As shown in table 2, simulations such as the Anti-Speculation Tax and Resource Rationing enabled participants to analyze policy impact delays and effectiveness—critical thinking skills that are often overlooked in traditional instruction. This aligns with OECD [27] recommendations for future-ready curricula that emphasize economic literacy and policy evaluation.

From a pedagogical perspective, the integration of blockchain into educational simulations remains relatively novel yet promising. While Grech and Camilleri [28] highlighted the potential of decentralized records and adaptive learning paths, few educational models have operationalized blockchain at the simulation level. This study addresses that gap by presenting a real-world implementation, supported by both performance data and user satisfaction metrics.[29,30,31]

The simulation was tested in a controlled academic setting with a sample size of n = 45. While all participants possessed a basic understanding of digital technologies, the relatively small sample size may limit the generalizability of the findings. Additionally, the participants' digital fluency may have introduced a selection bias, potentially overestimating the ease of adoption for users with less technological familiarity.[32]

Although the simulation framework includes a metaverse component, the study does not provide a detailed explanation of its specific pedagogical function. Instead, it presents a general virtual experience without comparing its educational value to other technologies. This gap presents opportunities for future research to examine the distinct benefits of metaverse-based learning environments in more depth.[33]

Future studies should aim to test the model across a wider range of educational contexts and integrate adaptive AI to personalize economic scenarios based on learner profiles.[34] Additionally, further research is needed to assess long-term knowledge retention and the transferability of skills acquired through such simulations to real-world decision-making contexts.

CONCLUSION

This study aimed to examine whether a blockchain-integrated, animated metaverse simulation can effectively improve users' economic decision-making and perceived system usability. In response to this objective, the findings demonstrate that embedding smart contracts and blockchain architecture within immersive learning environments not only facilitates system transparency and traceability but also enables learners to interact meaningfully with economic variables and decision-making processes in a controlled, gamified context.

The simulation design successfully operationalized core economic principles—such as resource allocation, trade-offs, and market behavior—through animated, interactive elements that enhanced user engagement and cognitive processing. Notably, the integration of blockchain mechanisms improved the trustworthiness and auditability of simulation outputs, aligning with user expectations for transparent feedback and verifiable outcomes in digital learning systems.

Regarding usability, the study revealed that participants perceived the system as intuitive and relevant to their learning goals. The interface design and animation contributed to reduced cognitive friction, while the blockchain layer added instructional depth without compromising accessibility. These outcomes support the use of such hybrid technologies as viable tools for modern economic education, particularly in scenarios requiring real-time simulation of complex systems.

However, the study also recognizes limitations. The short-term scope of implementation and the controlled learning environment may not fully capture long-term learning gains or generalizability across diverse educational contexts. Therefore, future research should investigate longitudinal learning effects, comparative efficacy across disciplines, and scalability of the model in broader institutional settings. Additionally, further inquiry is warranted into ethical, technical, and pedagogical frameworks necessary for sustaining blockchain-based simulations in formal education.

Ultimately, this research contributes to the growing discourse on digital transformation in education by empirically validating an innovative approach that merges blockchain, animation, and immersive simulation to enhance both conceptual understanding and practical competence in economic decision-making.

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FINANCING

This paper is funded by Universitas Negeri Padang.

CONFLICT OF INTEREST

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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ANNEX

Smart Contract Snippet

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

contract GameToken {
   string public name = "EduMetaToken";
   string public symbol = "EDMT";
   uint8 public decimals = 18;
   uint public totalSupply = 1000000 * 10 ** uint(decimals);
   mapping(address => uint) public balanceOf;

   event Transfer(address indexed from, address indexed to, uint value);

   constructor() {
      balanceOf[msg.sender] = totalSupply;
   }

   function transfer(address to, uint value) public returns (bool success) {
      require(balanceOf[msg.sender] >= value, "Insufficient balance.");
      balanceOf[msg.sender] -= value;
      balanceOf[to] += value;
      emit Transfer(msg.sender, to, value);
      return true;
   }
}
```

https://doi.org/10.56294/saludcyt20251895 ISSN: 2796-9711