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The use of artificial intelligence in the production of educational games: what does research show us through bibliometric analyses?

El uso de la inteligencia artificial en la producción de juegos educativos: ¿qué nos muestran las investigaciones a través de análisis bibliométricos?

L'utilisation de l'intelligence artificielle dans la production de jeux éducatifs : que nous montrent les recherches à travers les analyses bibliométriques ?

O uso da inteligência artificial na produção de jogos educativos: o que as pesquisas nos mostram através das análises bibliométricas?

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Abstract

This study aims to review the state of the art and analyze, through bibliometric techniques, the impact and effectiveness of Artificial Intelligence (AI) technologies in the design and development of digital games for educational purposes. Based on the analysis of 1,663 scientific articles published on the Web of Science platform over the past ten years, four main thematic categories were identified: Education and Games, Technology and Games, Modeling and Strategy, and Artificial Intelligence in Games. Using the VOSviewer® software, the most frequent and strongly connected keywords were mapped, providing an overview of trends, approaches, and recurring elements in literature. The results reveal that AI has significant potential to personalize learning experiences, optimize game

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strategies, and enrich the interactivity of educational environments. The analyses offer practical insights for the development of more effective, engaging, and pedagogically aligned digital games.

Keywords: Technologies, Artificial intelligence, Educational games, Bibliometric analysis.

Resumen

Este estudio tiene como objetivo revisar el estado del arte y analizar, mediante técnicas bibliométricas, el impacto y la eficacia de las tecnologías de Inteligencia Artificial (IA) en el diseño y desarrollo de juegos digitales con fines educativos. A partir del análisis de 1.663 artículos científicos publicados en la plataforma Web of Science en los últimos diez años, se identificaron cuatro categorías temáticas principales: Educación y Juegos, Tecnología y Juegos, Modelado y Estrategia, e Inteligencia Artificial en los Juegos. Utilizando el software VOSviewer®, se mapearon las palabras clave más frecuentes y con mayor fuerza de conexión, proporcionando una visión general de las tendencias, enfoques y elementos recurrentes en la literatura. Los resultados revelan que la IA tiene un gran potencial para personalizar las experiencias de aprendizaje, optimizar las estrategias de juego y enriquecer la interactividad de los entornos educativos. Los análisis ofrecen aportes prácticos para el desarrollo de juegos digitales más eficaces, atractivos y alineados con las necessidades pedagógicas contemporáneas.

Palabras-clave: Tecnologías, Inteligencia artificial, Juegos educativos, Análisis bibliométrico.

Résumé

Cette étude a pour objectif de passer en revue l'état de l'art et d'analyser, à l'aide de techniques d'analyse bibliométrique, l'impact et l'efficacité des technologies d'intelligence artificielle (IA) dans la conception et le développement de jeux numériques à des fins éducatives. À partir de l'analyse de 1 663 articles scientifiques publiés sur la plateforme Web of

Science au cours des dix dernières années, quatre grandes catégories thématiques ont été identifiées : Éducation et jeux, Technologie et jeux, Modélisation et stratégie, et Intelligence artificielle dans les jeux. À l'aide du logiciel VOSviewer®, les mots-clés les plus fréquents et les plus forts en termes de connexion ont été cartographiés, ce qui a permis de dresser un panorama des tendances, des approches et des éléments récurrents dans la littérature. Les résultats révèlent que l'IA possède un grand potentiel pour personnaliser les expériences d'apprentissage, optimiser les stratégies de jeu et enrichir l'interactivité des environnements éducatifs. Les analyses réalisées fournissent des informations pratiques pour le développement de jeux numériques plus efficaces, plus attrayants et mieux adaptés aux besoins pédagogiques contemporains.
Mots-clés : Technologies, Intelligence artificielle, Jeux éducatifs, Analyse bibliométrique.

Resumo

Este estudo tem como propósito revisar o estado da arte e analisar, por meio de técnicas de análise bibliométrica, o impacto e a eficácia das tecnologias de Inteligência Artificial (IA) na concepção e desenvolvimento de jogos digitais com fins educacionais. A partir da análise de 1663 artigos científicos publicados na plataforma Web of Science nos últimos dez anos, foram identificadas quatro categorias temáticas principais: Educação e Jogos, Tecnologia e Jogos, Modelagem e Estratégia, e Inteligência Artificial nos Jogos. Utilizando o software VOSviewer®, foram mapeadas as palavras-chave de maior frequência e força de conexão, permitindo a construção de um panorama sobre as tendências, abordagens e elementos recorrentes na literatura. Os resultados revelam que a IA possui grande potencial para personalizar experiências de aprendizagem, otimizar estratégias de jogo e enriquecer a interatividade dos ambientes educacionais. As análises realizadas oferecem subsídios práticos para o desenvolvimento de jogos digitais mais eficazes, engajadores e alinhados às necessidades pedagógicas contemporâneas.

Palavras-chave: Tecnologias, Inteligência artificial, Jogos educativos, Análise bibliométrica.

The use of artificial intelligence in the production of educational games: what does research show us through bibliometric analyses?

Introduction

The advancement of Artificial Intelligence (AI) is a phenomenon observed worldwide and across various sectors of society. In the field of education, however, it is still progressing at a slow pace. Tavares, Meira, and Amaral (2020) align with this perspective, stating that while technology has brought significant changes to society, this movement is not reflected in the educational field. In a more recent study, Picão et al. (2023, p. 201) mention that the current benefits resulting from the use of AI are related to "personalized learning," where it is possible to create learning environments that adapt to students' needs.

AI can contribute to the development of digital games. Garrido (2009) asserts that the history of humanity has been built through evolutionary stages, and the same process occurs with games, which can use digital means to improve, achieve more efficient strategies, and provide victories—the ultimate goal of games.

Considering the importance of AI in education, the purpose of this study is to review the state of the art and analyze, through bibliometric techniques, the impact and effectiveness of Artificial Intelligence technologies in the design and development of educational digital games.

The goal is to identify the main trends, approaches, and recurring elements in the scientific literature of the past ten years, categorizing them into strategic themes that can support the creation of more effective, personalized, and engaging educational games. The focus is on improving the learning experience of users through the application of Artificial Intelligence (AI) technologies.

The research question was formulated with the aim of understanding how AI can impact and contribute to the design and development of educational digital games. To this end, the study analyzed recent advances and different AI techniques employed in the production of these games,

based on scientific articles published over the last decade. This approach allowed for the mapping of consolidated and emerging practices, offering theoretical and practical insights for the development of innovative educational solutions.

The study is divided into sections, including this introduction, a brief explanation of the concept of games from philosophical, historical, and cultural perspectives; a presentation of the concept of digital games, followed by a brief explanation of artificial intelligence in educational games. Subsequently, the methodology, procedures for data collection and analysis, category analysis, and finally, the study's conclusions and final considerations are presented, highlighting limitations and suggesting new directions for future research on Artificial Intelligence in the development of educational games.

Games

In academic literature, we find various definitions for the word "game." From a philosophical perspective, we refer to Wittgenstein's (1975) contributions, in which he writes about language games and the entire process of understanding in dialogues between people, allowing us to analyze expressions such as the meaning and sense of words. This study enabled the author to draw an analogy with the game of chess: rich in detail and carefully thought-out moves.

This philosophical definition is considered because we understand that games must be thoughtfully designed, assigning meaning to those who will use them, so that the objectives and actions present in the game have not only meaning but also relevance for the intended audience. It also anticipates relationships between individuals—whether through creator-player, programmer-player (in the case of digital games), or even player-player interactions, as in board games, card games, digital games, among others.

For Huizinga (2019), games are seen as a cultural phenomenon present throughout the animal kingdom, expressed through rituals. Thus,

for the author, the act of playing goes beyond rationality, externalizing emotions and reactions that transcend the physical body.

In general terms, Rogers (2013), starting from the definition of games, states that they must contain three important characteristics: the presence of at least one player, the existence of rules, and a condition for victory.

In the educational field, Piaget (2004) also shares thoughts on games, highlighting the strong presence of playfulness and relating it to child development. He considers adaptive and imitative aspects present in games a movement involving actions and thoughts that encompass assimilation and accommodation in a repetitive process. The author also emphasizes that, with the child's socialization, games allow for the creation of rules that reinforce the child's symbolic imagination in relation to the reality in which they live.

Therefore, it is important to consider that games allow for the externalization of various emotions that go beyond the simple act of playing. Planning is essential in their creation, as is recognizing the elements that characterize them as games, always focusing on the benefits that playfulness offers for child development.

Digital games

Discussing games in digital format leads us to consider the contributions of Rogers (2013, p. 27), in his book Level Up: A Guide to Designing Great Games, where the author shares the essential elements that must be included in game development. The book addresses the production of video games, which he initially defines as "games made available on a video screen," thus adapting the term to the definition of digital games from this perspective.

In the educational field, Papert contributes to the integration of the digital universe into mathematics education, advocating the thesis that the use of concrete materials enables the acquisition of abstract knowledge, which is rarely assimilated through theory alone. When using digital tools

in his studies with a child, he wrote: "I was playing like a child and feeling a volcanic explosion of creativity. Why couldn't computers provide children with the same experience?" (Papert, 1993, p. 33).

The movement to bring digital games into the educational perspective is inspired by Prensky's (2021) assertion that a growing number of educators have turned to games to develop content and create alternative paths to solve instructional challenges that have not yielded success. He even suggests that today's students and teachers inhabit entirely different worlds, with educators belonging to a pre-digital generation and students immersed in a fully digitized universe. This highlights a significant challenge in establishing communication between the two.

Artificial intelligence in educational games

First, it is important to consider the broader use of AI. For this, we refer to Aguiar's (2023) contributions, who states that AI has long been used in the healthcare field to diagnose diseases and assist in examinations. In education, it emerges with the increasing access to Digital Information and Communication Technologies (DICTs), enabling interactions in educational environments—a transformative force surrounded by implementation challenges.

Vicari (2021) notes that when AI began in 1956, it was viewed in isolation, and gradually, various fields of knowledge became interconnected. The author also mentions "Computational Creativity," which will increasingly be linked to education (Vicari, 2021, p. 1). In this sense, we associate this creativity with the development of games with educational objectives.

Cardoso (2024) affirms that one of the earliest contributions of AI in the field of games occurred when Arthur Samuel wrote a program capable of playing checkers. This program learned to play so well that it eventually defeated its own creator, proving that it was possible to build a program that could go beyond what it was taught.

Methodology

The methodology adopted in this study is based on bibliometric analysis, a widely used quantitative approach to examine and understand scientific production in a specific field. To conduct this analysis, we employed the VOSviewer® tool, which is specifically designed to visualize and explore co-occurrence networks of terms, authors, institutions, and countries in bibliographic databases.

Bibliometric analysis is essential for identifying patterns, trends, and relationships among bibliographic elements, providing valuable insights into the structure and dynamics of a research area. Through this analysis, we can examine scientific productivity, identify areas of interest, collaborations among researchers and institutions, and assess the relevance and impact of specific scientific works.

By using VOSviewer®, we are able to create knowledge maps that highlight thematic groups and co-occurrence patterns of terms in scientific articles. These maps help us visualize the structure of the research field and identify emerging areas of interest. Additionally, bibliometric analysis allows us to track changes over time and evaluate scientific progress, providing a solid foundation for strategic decision-making in research policies and funding.

The search was conducted using the following descriptors on the Web of Science: artificial intelligence, games, education. Initially, the platform returned 2,027 articles, covering the entire period from 2014 (the date of the first publication) to 2024 (the current date).

The decision to use the keywords "artificial intelligence," "games," and "education" is directly related to the objective of analyzing the impact and effectiveness of technologies in educational games. These keywords were selected for their relevance to the central theme of the study. "Artificial intelligence" is essential for understanding how technology can be employed in this context, while the term "games" highlights the medium for delivering educational content, and the word "education" emphasizes the educational purpose of the games. The combination of these keywords reflects an

interdisciplinary approach, bringing together knowledge from fields such as artificial intelligence, computer science, educational psychology, and game design, providing a holistic understanding of the use of AI in the creation of educational games and its implications for pedagogical practice.

However, the search was refined using the terms "artificial intelligence" and "educational games," focusing on articles published in the last ten years.

In this new phase, 1,663 articles were found. The decision to restrict the search to this period is based on the importance of focusing on recent studies that cite the use of artificial intelligence in educational games. This approach allows for the exploration of the most current trends and progress in this field, helping to guide the development of educational games.

After presenting the category analyses, a table was compiled with the most frequent keywords, and potential actions were identified for consideration in the development of educational games. For this study, the decision was made to focus on the five most frequent keywords, allowing for a detailed examination of these terms to identify elements that may assist educational game developers. For future research, the intention is to analyze the keywords in descending order of frequency to examine their contexts in the literature and how they may further contribute to research within this thematic domain.

Data construction and analysis procedures

The data were processed in VOSviewer®, initially considering a minimum criterion of five co-occurrences, which resulted in 332 keywords out of a total of 6,168. To ensure consistency, synonyms and spelling variations were standardized, retaining only the most frequent form. For example, "AI" (19 occurrences) and "artificial intelligence" (224 occurrences) were treated as synonyms, with the more frequent term preserved. After this adjustment, 6,140 keywords remained, with 328 of them having at least five co-occurrences.

Given the high number of terms, the set was reduced to 80 keywords. This reduction aimed to enable a cleaner analysis, with less visual overlap on the map and greater emphasis on the most relevant terms, avoiding dispersion and informational noise. With this selection, it became possible to identify clearer co-occurrence patterns, facilitating the visualization of groupings and allowing for more consistent interpretations. The final categorization was conducted by VOSviewer®, with the groupings interpreted based on co-occurrence frequency, link strength, and the composition of terms in each category.

Analyses academic production analysis

Initially, the data related to research output were organized in descending order, allowing for an evaluation of productivity and relevance. Leading in the number of published articles, China contributed significantly with 604 publications. These articles received a total of 6,089 citations, reflecting a high level of recognition and influence within the academic community. With a total link strength of 316, China demonstrates a strong presence in the global research network in this field.

In second place, with 368 published articles, the United States also ranks among the top producers in the area of educational digital games. Its articles received 5,092 citations, indicating high influence and impact in research. With a total link strength of 222, the United States shows a well-established research network in this domain.

Next, Japan occupies third place among the leading producers, with 217 published articles and 1,592 citations. Although it has a smaller number of articles compared to the leaders, Japan remains active in research involving educational digital games, with a total link strength of 99.

In fourth place is Spain, with 131 published articles, also standing out as one of the main contributors in the field of educational digital games. Its articles received 2,019 citations, indicating a presence within the academic community. With a total link strength of 68, Spain demonstrates participation in research in this area.

Fifth place goes to Singapore, with 115 published articles. Singapore is also among the top producers of research on educational digital games. Its articles received 2,955 citations, with a total link strength of 169.

Compared to the five leading countries, Brazil presents a more modest contribution to research on educational digital games, with 42 published articles and 725 citations. Although its number of articles and citations is lower, Brazil still shows involvement in research in this field. Its total link strength of 35 indicates a presence in the global research network, but there is room for greater growth and impact in the area of educational digital games.

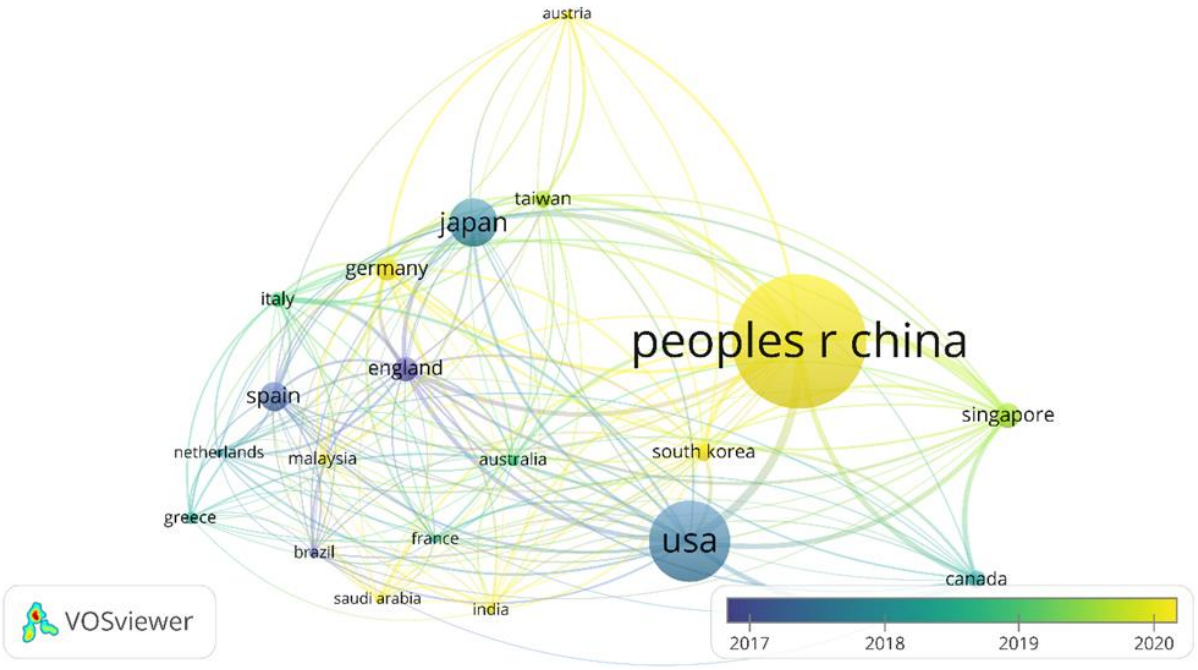
Table 1

Production Organized by Country

Sequence	Country	Articles	Citations	Link Strength
1	China	604	6089	316
2	United States	368	5092	222
3	Japan	217	1592	99
4	Spain	131	2019	68
5	Singapore	115	2955	169
6	United Kingdom	112	2766	153
7	Germany	105	2325	108
8	South Korea	83	1987	89
9	Canada	80	1393	105
10	Taiwan	79	1259	75
11	Italy	72	1616	85
12	Greece	55	769	33
13	Australia	53	1444	61
14	Malaysia	46	802	39
15	Brazil	42	725	35

Figure 1

Production Organized by Country Generated in VOSviewer®



This initial analysis highlights Brazil's position in relation to global research output and invites reflection on the importance of scholarly contributions. The data show that although China leads in the number of publications, the citation ratio—10.89 citations per article—is lower than Brazil's, which stands at 17.26. This suggests that Brazilian studies are being considered by researchers in the field at a proportionally higher rate. This broader analysis reveals that research progresses at different paces across countries and encourages further investment in studies that foster deeper discussions on the investigated topic.

Categories: elements in game design category 1:

Education and games

This category focuses on the core educational elements in digital games, covering concepts such as "education" and "educational games" as well as more specific aspects like "gamification," "virtual reality," and "augmented reality." The frequent terms suggest an interest in how games can be used as learning tools, as well as in design, motivation, and student

engagement. The presence of "intelligent tutoring systems" indicates a growing use of smart systems to provide personalized educational guidance.

The terms in this cluster reveal several trends:

i. Diversity of Educational Topics: Frequent terms such as "education," "game-based learning," "serious games," and "educational games" reflect a central concern with education as a fundamental component in digital game design. This suggests a broad and inclusive approach to using games in education, ranging from specific curricular topics to the development of transversal skills and competencies.

ii. Emphasis on Design and User Experience: Terms like "design," "motivation," "engagement," and "experience" highlight the importance of game design in creating engaging and motivating educational experiences. This points to a recognition of the need to consider elements such as challenge, feedback, and narrative to maximize the educational impact of digital games.

iii. Exploration of Emerging Technologies: The presence of terms such as "virtual reality," "augmented reality," and "simulation" suggests a growing interest in immersive and simulated technologies to enrich learning experiences offered by educational games. This indicates a trend toward exploring new forms of interaction and knowledge representation.

iv. Emphasis on Evaluation and Analysis: Terms like "learning analytics," "assessment," and "performance" reflect an awareness of the importance of evaluating the impact and effectiveness of educational games. This shows a concern with measuring learning outcomes and using data to inform decision-making in the design and implementation of digital educational games.

v. Potential for Personalization and Adaptation: The inclusion of "intelligent tutoring systems" suggests an interest in integrating smart systems to provide personalized support and guidance to players during the learning experience. This points to a recognition of the importance of personalization and adaptation to meet individual student needs.

Table 2

Education and Games

Keywords	Frequency	Total Link Strength
education	155	428
serious games	126	274
game-based learnin	83	135
design	67	243
virtual reality	67	170
performance	65	223
gamification	61	139
computer games	59	105
educational games	59	99
motivation	49	138
students	49	174
augmented reality	40	121
children	39	89
technology	36	104
e-learning	34	81
impact	34	115
engagement	33	119
video games	33	64
simulation	32	98
learning analytics	29	74
learning	27	57
science	24	93
knowledge	23	77
intelligent tutoring s	21	48
environment	20	86
mathematics	18	55
skills	18	69
assessment	17	42
computational think	17	49
game design	17	41
experience	16	50
tools	14	55
Feedback	11	40
Robotics	10	42
Online	9	34

This category reveals a wide range of themes and concerns related to the integration of education and digital games, highlighting the importance of design, technology, and evaluation in creating effective and engaging educational experiences. This analysis can inform the future development of educational games by identifying key areas of focus and research to maximize their educational potential.

Category 2: technology and games

This category explores the intersection between technology and games, with emphasis on topics such as "reinforcement learning," "deep learning," and "blockchain." There is a clear trend toward addressing more technical and advanced aspects, indicating an interest in how emerging technologies can be applied in the context of digital games. Additionally, terms like "security" and "internet of things" suggest a consideration of the challenges and opportunities related to technological infrastructure.

i. Emphasis on Advanced Technologies: The most prominent terms, such as "reinforcement learning," "deep learning," and "blockchain," reflect a clear focus on advanced technologies with the potential to transform how games are designed and played. This suggests an interest in exploring how machine learning algorithms can be applied to enhance gameplay and how blockchain technology can be used to create safer and more transparent gaming environments.

ii. Technical and Infrastructure Aspects: Terms such as "security," "internet of things," and "edge computing" indicate a concern with the challenges and opportunities related to the technological infrastructure of digital games. This suggests a recognition of the importance of cybersecurity, connectivity, and distributed data processing to ensure high-quality and reliable gaming experiences.

iii. Approaches to Analysis and Optimization: The presence of terms like "optimization," "task analysis," and "resource allocation" suggests an interest in analytical and optimization approaches to improve gameplay and system efficiency. This indicates a concern with enhancing performance and user experience through careful task analysis and effective resource management.

iv. Exploration of the Metaverse and Collaboration: The term "metaverse" suggests a growing interest in creating persistent and interconnected virtual spaces, while terms like "collaboration" and "communication" reflect the importance of social interaction and teamwork

in digital games. This points to an exploration of new gaming models that transcend traditional single-player and multiplayer boundaries.

Table 3

Technology and Games

Keywords	Frequency	Total Link Strength
Games	324	765
reinforcement learning	75	175
game theory	68	166
System	59	161
deep learning	56	158
Optimization	47	123
Networks	44	113
Internet	32	82
internet of things	27	76
task analysis	27	107
Blockchain	25	73
Security	20	73
Training	19	66
Framework	18	71
Challenges	17	55
communication	17	52
Metaverse	14	51
resource allocatio	14	41
edge computing	13	42
computational modeling	12	54
Pricing	12	38
Collaboration	10	42
data models	10	40
wireless communication	10	33
resource management	8	46
Servers	7	40

The category 2 highlights the importance of emerging technologies and technological infrastructure in the evolution of digital games, as well as the potential of these technologies to enhance gameplay, security, and interactivity. This analysis can inform the future development of digital games by identifying key areas of focus and research to drive innovation in this field.

Category 3: Modeling and strategy in games

This category focuses on the strategies and dynamics present in games, with terms such as "model," "algorithm," and "strategy." There is a strong emphasis on modeling behaviors and decision-making processes, suggesting an interest in understanding and optimizing the player experience. Terms like "cooperation" and "competition" indicate an interest in the social and interactive dynamics of games.

Several key points can be observed:

i. Modeling and Algorithms: The most frequent terms, such as "model" and "algorithm," indicate a central interest in modeling systems and processes within digital games. This suggests an analytical and quantitative approach to understanding and manipulating game dynamics, with the goal of improving gameplay and user experience.

ii. Strategy and Decision-Making: The presence of terms like "strategy" and "decision making" highlights the importance of strategy and decision-making as fundamental elements in the player's interaction with the game. This suggests an interest in understanding how players formulate and execute strategies to achieve their goals within the game context.

iii. Social and Competitive Dynamics: Terms such as "cooperation," "competition," and "behavior" indicate an interest in the social and interactive dynamics that arise when players interact with one another within the game. This suggests a consideration of the importance of collaboration and competition to enrich the player experience and promote long-term engagement.

iv. Management and Information: The presence of terms like "management" and "information" suggests a concern with resource and information management within games. This indicates a recognition of the importance of providing players with the tools and information needed to make informed and effective decisions during gameplay.

v. Evolutionary Games and Complex Dynamics: The inclusion of terms such as "evolutionary games" and "dynamics" suggests an interest in exploring complex and emergent dynamics that can arise when multiple

agents interact within the game. This points to a more holistic and dynamic approach to modeling and understanding the player experience.

Table 4

Modeling and Strategy in Games

Keywords	Frequency	Total Link Strength
Model	83	192
Algorithm	43	57
Strategy	39	121
Cooperation	37	56
evolutionary gam	33	64
Dynamics	31	61
Management	29	71
Information	24	44
decision making	23	42
Behavior	20	57
Competition	18	45

The category 3 highlights the importance of behavior modeling and strategic planning in digital games, as well as the consideration of social and competitive dynamics that emerge during player interaction. This analysis can inform the future development of digital games by identifying key areas of focus and research to enhance player experience and promote long-term engagement.

Category 4: artificial intelligence in games

This category lies at the heart of the subject, with a direct focus on "artificial intelligence" and "machine learning." Here, we find an exploration of the foundations of AI applied to games, with terms such as "neural networks" and "classification." The presence of "go" suggests a specific interest in how AI can compete or collaborate with human players in complex games. This category appears to be essential for understanding how AI can be integrated into educational games.

Several key points can be observed:

i. Application of AI in Games: The most prominent terms, such as "artificial intelligence" and "machine learning," indicate a central interest in applying AI to enhance gameplay, the intelligence of NPCs (non-player

characters), and the overall player experience. This suggests an advanced approach to digital game development, using AI techniques to make games more challenging, dynamic, and engaging.

ii. Specific AI Approaches: The presence of terms such as "neural networks" and "classification" indicates a more detailed exploration of specific AI techniques and algorithms that can be applied in games. This suggests an interest in how neural networks and classification algorithms can be used to make intelligent decisions, recognize patterns, and create more personalized and immersive gaming experiences.

iii. Complex Games and AI Challenges: The inclusion of the term "go" suggests a specific interest in complex games that pose challenges for AI algorithms. The game of Go is known for its complexity and is a common testing ground for advanced AI algorithms. This indicates a recognition of AI's potential to compete or collaborate with human players in digital games.

iv. Exploration of Large Data Sets: The presence of terms such as "big data" reflects an awareness of the importance of large datasets for training and refining AI models in digital games. This indicates a data-driven approach to game development, using data analysis to inform decision-making in game design and implementation.

v. Potential for Integration into Educational Games: The presence of AI in digital games suggests that there is room for its integration into educational games. AI can be used to personalize the learning experience, provide adaptive feedback, and create dynamic learning environments that adjust to individual student needs.

Table 5

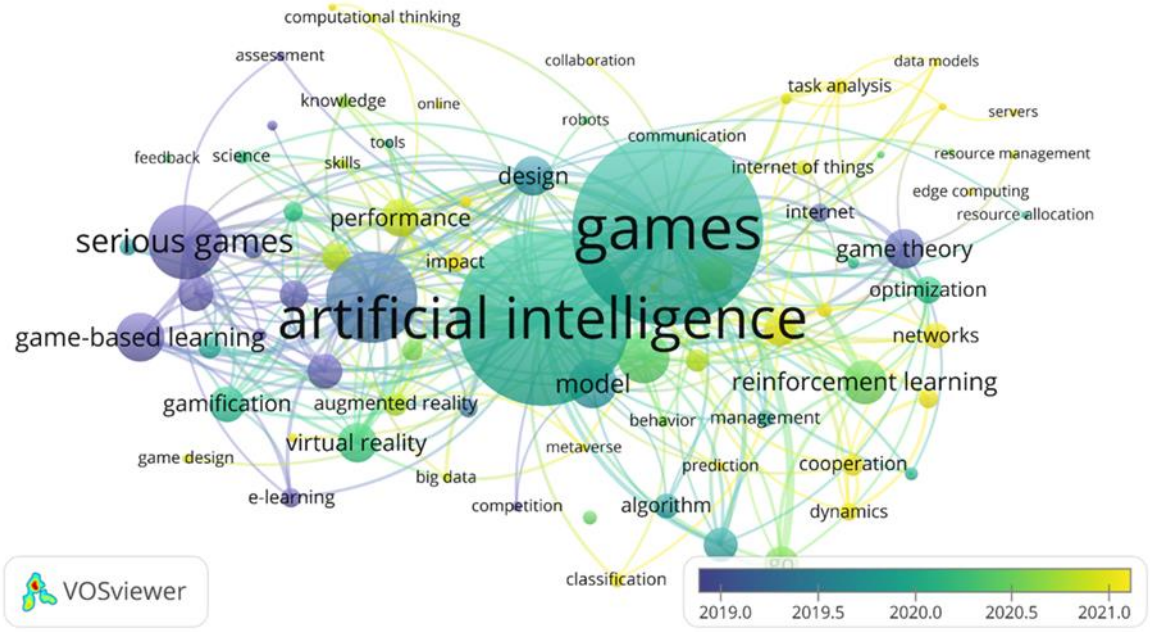
Artificial Intelligence in Games

Palavras-chave	Frequência	Força total de conexão
artificial intelligen	295	642
machine learning	88	213
Go	59	133
neural networks	58	131
Classification	24	47
Prediction	18	43
big data	16	51
Robots	15	40

This analysis indicates that the integration of AI into digital games can expand pedagogical possibilities, especially by enabling learning experiences that are more tailored to the profile of students who have access to the game.

Figure 2

Elements in Game Design Generated in VOSviewer®



Results and Discussion

The analyses presented throughout the study allowed us to identify several findings based on relationships established as essential in the design of

games using Artificial Intelligence. Table 6 displays the five most frequent keywords within each category.

Table 6

Categories and Keywords with Highest Frequencies

Categories	**Most Frequent Keywords**				
Education and Games	education	serious games	game-based learning	design	virtual reality
Technology and Games	games	reinforcement learning	game theory	system	deep learning
Modeling and Strategy in Games	model	Algorithm	strategy	cooperation	evolutionary games
Artificial Intelligence in Games	artificial intelligence	machine learning	go	neural networks	classification

The keywords are considered relevant for the planning of digital games with educational objectives. Based on this set, Table 7 was developed to suggest possible actions to be implemented, using the keywords gathered in Table 6 as reference.

Table 7

Categories and Most Frequent Keywords

Most Frequent Elements Presented	Possible Actions to Be Developed
Education	When designing a game project, education can be incorporated by considering the skills intended to be developed in users. One possibility is to create games with the purpose of accelerating curricular competencies beyond traditional analog activities.
Serious games	Considering the purpose of viewing games beyond entertainment—assigning them the potential to foster academic advancement—it is important to understand them as objects of study. Their development requires a serious approach, as they are connected to various fields of knowledge that go beyond technology alone.
Game-Based Learning	In this sense, the game aims to promote learning and to reshape concepts that are often deeply rooted. From this perspective, it becomes possible to incorporate various features that foster the advancement of learning.
Design	Educational games are developed through structured projects, with a clear purpose to be achieved. A digital game that includes elements for concept acquisition must be designed with consideration for abstraction in the absence of the game itself, so that the experiences within the project can later be related to analogous real-world situations.
Virtual Reality	It enables a better user experience, considering that virtual reality fosters a more engaging dynamic, contributing to academic interest (Biaty et al., 2022). In this sense, games can replicate scenarios drawn from children's everyday lives, representing a field with great potential to be explored during project implementation.

Games	The term "game" is prominently emphasized, as it represents the context of gameplay enhancement and the potential that games can achieve. When developing projects that incorporate technology for game creation, it is essential to consider learners' interest in games so that the outcomes can be meaningfully evaluated.
Reinforcement Learning	Games have the potential to provide reinforcement that supports learning. The skills that need to be developed can be addressed through tools embedded in games, such as the setting, as well as through relationships that can be established between the child's context and the characters involved in the game.
Game Theory	Game Theory considers that individuals' actions depend on the actions of others (Figueiredo, 1994). When designing a game from a collaborative perspective, this element contributes to the development of social skills throughout life.
System	The system is considered an essential element for the usability of the games produced. Understanding the Operating System used in game development allows for the creation of projects that function with greater precision. On Windows, Operating Systems are constantly being updated to provide users with an improved experience (Canaltech, 2022).
Deep Learning	The term is closely related to machine learning, particularly in the context of digital game programming, considering that game development involves the integration of complex data (Hu et al., 2023). Understanding the term helps ensure careful attention to programming and imported elements—such as file size and compatibility—so that the final result is more effective.
Model	Models are useful as they support analysis for the creation of new games (Lucchese & Ribeiro, 2009). Ready-made game tutorials assist in the execution of new projects and allow for progress through the

	combination of code elements supported by the software used.
Algorithm	The algorithm serves as the foundation for programming that relies on logic in game development. Studying algorithms related to games encourages student engagement with mathematical reasoning. The actions within a game are connected to various combinations of algorithms (Rapkiewicz et al., 2007).
Strategy	Strategy is defined as an element present in the game, based on a set of actions through which gameplay unfolds—from scenario analysis to character interaction—in pursuit of balance to win the game (Pénard, 2008). When designing the game, it is essential to establish which strategies the user should employ to achieve the project's intended goal.
Cooperation	It is a feature that can be present in games. When cooperative, it allows players to commit to achieving shared goals, but it can also be reduced to non-cooperative models, as these are linked to individual characters (Lucchese & Ribeiro, 2009). Therefore, when designing games from a collaborative perspective, it is recommended to include situations of mutual assistance that can be explored beyond the game itself.
Evolutionary Games	It refers to games that apply evolutionary concepts to problem-solving. These games aim to acquire resources for a specific community, in which two players interact symmetrically and independently, obtaining specific outcomes based on their actions (Borges et al., 2019).
Artificial Intelligence	There are several ways to implement Artificial Intelligence in games, one of which is to create a more realistic environment by designing characters, improving resource optimization, and expanding the possibilities of the resources used in the game (Barbosa, 2024). When developing a game project, specific elements can be selected to compose the setting, characters, and other components that enhance the user's sense of realism through the use of Artificial Intelligence.

Machine Learning	It refers to a set of methods and algorithms that extract knowledge from stored data and can continuously improve their capabilities by learning from experience (Bertolini et al., 2021). This type of learning is present in games, which evolve as new versions are released to offer users a better experience.
Go	This refers to a game developed by DeepMind that reached a superhuman level, capable of self-programming without human intervention and handling multiple tasks (Gibney, 2017). It is a term frequently cited in the development of games involving Artificial Intelligence.
Neural Networks	They assist in the various stages of gameplay. Charles and McGlinchey (2007) state that neural networks are responsible for input and output movements, which are part of game execution, comparing them to supervised learning. Specific commands result in specific outcomes. When programming a game, it is essential to understand the target age group and define the challenges that will make the experience engaging and stimulating for the user.
Classification	There are various classifications for games. Caillois (2001) suggests that the same material can be categorized under different labels that define games. When designing them, it is essential to clearly present their direction or intended purpose.

Following the analyses, it was found that the elements described in Table 2 contribute to broadening the understanding of how Artificial Intelligence can be used in the development of digital games with diverse purposes. The application of AI in the creation of scenarios, characters, and movements is closely related to the user experience, ensuring that the game fulfills its intended objectives.

By revisiting Wittgenstein's (1975) philosophical contributions on games, it is emphasized that game design should consider the meaning and

significance of the elements employed, in order to assess their impact on users.

In this direction, the cultural phenomenon of play, as described by Huizinga (2019), is also updated in digital formats, incorporating the elements proposed by Rogers (2013) regarding participants, ensuring conditions for engagement and achievement without disregarding the processes of assimilation and accommodation outlined by Piaget (2004), which are intrinsic to the act of playing.

Thus, the analyses conducted using VOSviewer® do not directly indicate improvements in the production of educational digital games, but they do provide conceptual insights and categories that can support reflection, guide design choices, and foster discussions on how AI can be integrated into educational contexts.

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