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# Educational innovation: Exploring the potential of Generative Artificial Intelligence in cognitive schema building

## *Innovación educativa: Explorando el potencial de la Inteligencia Artificial Generativa en la construcción de esquemas cognitivos*

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### Abstract

This study explores the use of generative artificial intelligence to enhance teaching and learning experience, focusing on strengthening and consolidating cognitive schemas. Research reveals that schemas can profoundly influence the improvement of the learning experience and promote the assimilation of new types of information and retention in students' memory. To improve the teaching and learning experience, the advantages, obstacles, and potential future trajectories of utilizing these technologies were examined by conducting a thorough literature review and analyzing relevant studies. Findings indicate that generative artificial intelligence has the potential to personalize learning, diversify educational content, and improve teaching efficiency and scalability. However, it also poses challenges related to content quality, data privacy, and equity in access to personalized learning. Future research should focus on the effectiveness of educational tools based on generative AI that promote equity and inclusion, ethical approaches, and interdisciplinary collaboration. Overall, this study provides a solid foundation for understanding and harnessing the potential of generative artificial intelligence in enhancing cognitive schemas, thereby promoting more effective, inclusive, and personalized education.

Keywords: Generative Artificial Intelligence, Cognitive Schemas, Technology-Assisted Learning, Personalized Learning, Education.

### *Resumen*

*Este estudio explora el uso de la inteligencia artificial generativa para mejorar la experiencia de enseñanza y aprendizaje, centrándose en el fortalecimiento y consolidación de los esquemas cognitivos. Las investigaciones revelan que los esquemas cognitivos mejoran la experiencia de aprendizaje y favorecen la asimilación de nuevos tipos de información y su retención en memoria de los estudiantes. Mediante una exhaustiva revisión de literatura y análisis de estudios relevantes, se examinaron las ventajas, obstáculos y posibles trayectorias futuras de la utilización de estas tecnologías para mejorar la enseñanza. Los hallazgos muestran que la IA generativa puede personalizar el aprendizaje, diversificar el contenido educativo, mejorar la eficiencia y escalabilidad de la enseñanza, pero también plantea desafíos relacionados con la calidad del contenido, la privacidad de los datos y la equidad en el acceso al aprendizaje personalizado. Futuras investigaciones deberían centrarse en la efectividad del aprendizaje personalizado, el desarrollo de herramientas de IA generativa para la educación, la promoción de la equidad y la inclusión, la exploración de enfoques éticos y la colaboración interdisciplinaria. Este estudio proporciona una base sólida para comprender y aprovechar la IA generativa en la mejora de los esquemas de aprendizaje, promoviendo una educación más efectiva, inclusiva y personalizada.*

***Palabras clave:*** *Inteligencia Artificial Generativa, Esquemas Cognitivos, aprendizaje asistido por tecnología, Aprendizaje personalizado, Educación.*

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# 1. INTRODUCTION

In the educational context, the schema concept emerges as a central element in the knowledge construction process and offers valuable insights to improve the teaching-learning process. Schemas, defined as mental structures that organize and process information, are pivotal in facilitating deeper understanding, solid knowledge retention, and their application in various contexts. Understanding cognitive processes and robust schema formation facilitates knowledge assimilation and stimulates the human brain's ability to creatively address problems, foster critical thinking, and adapt to complex contexts, resulting in more efficient and effective learning (Parrales et al., 2020).

On the other hand, the exponential growth of artificial intelligence technologies has revolutionized students' learning experiences, offering new tools with enhanced capabilities to transform the teaching-learning process (Tyagi et al., 2022). Schools and universities are changing their educational models to adapt to new technologies and offer programs that incorporate artificial intelligence (Sanabria-Navarro et al., 2023). This interest primarily stems from their potential to create personalized educational content, generate immersive learning experiences, and promote academic proficiency (Pendy, 2021). New Generative AI models focus on creating new and realistic content using existing digital content from a specific domain, such as video, images/graphics, text, and audio, which have immense potential to enhance educational processes (Yu & Guo, 2023). This cohesion between learning schemas and artificial intelligence technologies fosters more dynamic, accessible, and effective learning environments (Ahmad et al., 2023).

In the current context, education faces challenges due to rapid technological progress, socioeconomic changes affecting equity, and the increasing number of students with different learning styles and needs (Ubah et al., 2022). This complexity leads to continuous changes in the roles of educators and educational systems to adapt and meet the changing workforce demands of society and prepare students with the necessary competencies in an ever-evolving world (Maj-Waśniowska et al., 2022).

One of the most pressing challenges is improving students' cognitive schemas. Cognitive education focuses on enhancing the quality of education by addressing systematic and logical thinking, metacognitive processes, and the development of learning tools such as abstraction, inference, relation, comparison, and judgment, which are essential for effective learning (Tzuriel, 2021). However, in a dynamic and diverse educational environment, traditional teaching methods may not be sufficient to develop robust and adaptable schemas.

Therefore, there is a need for innovative methods and educational tools that can effectively enhance the building of schemas in an ever-changing learning environment (Darejeh et al., 2022). It is crucial to explore new strategies and technologies that can boost the formation of more efficient, flexible, and personalized learning schemas by adapting to individual students' needs and promoting a deep and lasting understanding of knowledge (Voskoglou, 2020). Generative AI technologies emerge as promising tools with significant potential to transform the teaching-learning process by strengthening the formation and consolidation of learning schemas.

The main objective of this study is to examine the use of generative AI tools to personalize and enhance the teaching-learning process, as well as to strengthen students' cognitive schemas, facilitating the assimilation and retention of knowledge. We examine the role of generative artificial intelligence in the face of the growing need to explore new tools to create more effective and adaptable learning systems that strengthen cognitive schemas in an educational environment characterized by student diversity, rapid technological evolution, and changes in the labor market demands.

This work contributes to knowledge advancement in the educational field by providing insights and recommendations that can guide future research on the application of generative artificial intelligence in the learning process.

## 1.1. Cognitive Schemas

In the field of cognitive psychology, schemas are defined as organized mental structures or patterns that organize and interpret information, facilitating knowledge construction through the deep understanding, interpretation, and long-term retention of information (Torney-Purta, 1991; Soriano, 2017). These schemas are developed from experience and prior knowledge and play a crucial role in assimilation, interpretation, and information retention (Derry, 1996).

As individuals interact with their environment and access new information, their schemas adjust to accommodate new experiences and situations. This continuous adaptation allows for a deeper and more comprehensive understanding of the world around them, facilitating the learning process and cognitive development (Brewer, 2000).

The relevance of cognitive schemas lies in their ability to organize process, understand, and remember information. By developing schemas in a specific knowledge domain, individuals can process information more efficiently, identify patterns, establish connections, and reach conclusions swiftly (Moreira et al., 2002). Furthermore, schemas also influence how individuals assimilate and retain knowledge, enhancing their ability to use and apply it in different contexts and resolve problems creatively (McVee et al., 2005).

In his study, Hejný (2018) proposed schema-oriented education to improve mathematics teaching. This approach was based on constructing schemata to create a dynamic network of mathematical knowledge and skills for the student.

According to Akram (2019), the human brain can store various types of knowledge in the form of schemas that are retained in long-term memory. These schemas are crucial in improving the learning experience and consolidating new knowledge in students' memory. To improve schema formation in the classroom, teachers should incorporate activities that stimulate the connection between new information and existing knowledge and provide students with the learning environment to apply new knowledge in real-world situations.

Furthermore, Dang et al. (2019) argued that individuals employ mental structures to orient themselves in time and space, as well as to categorize and make sense of their experiences in a relevant manner. The consolidation of these schemas can be enhanced through the repetition of experiences and reinforcement of certain beliefs.

In another study, Sweller (2020), based on the theory of cognitive load, proposed recommendations regarding the design of instructional procedures that facilitate the construction of high-quality knowledge schemas in long-term memory. Most instructional procedures can be implemented more effectively through technology-based learning environments that support constructive activity, metaconceptual awareness, and cognitive flexibility. Sweller suggests that the principal learning mechanisms are schema acquisition and automation, when considering intellectual activities. Thus, he deems it necessary to reduce extraneous cognitive load in instructional design to mitigate its effects on schema formation during the learning process. An overview of the primary effects of cognitive load in technology-assisted instructional design is shown in Table 1.

Table 1

*Relevant effects in technology-assisted instructional design (Sweller, 2020)*

| Instructional Effect | Description |
|---|---|
| Worked | Example Studying worked examples is superior to solving the equivalent problems |
| Split-attention | If multiple sources of information need to be considered simultaneously, physically integrating them is superior to requiring learners to split their attention between them |
| Modality | If a diagram and text need to be considered simultaneously and the text is simple and short, presenting the text in spoken rather than written form is superior |
| Transient | High element interactivity information should be presented in permanent rather than transient form or presented in smaller chunks |
| Redundancy | Eliminating unnecessary information results in superior learning |
| Expertise reversal and element Interactivity | With increases in expertise and decreases in element interactivity, information that is essential for novices becomes redundant for more expert learners, decreasing learning |
| Working memory depletion | Working memory use depletes working memory resources that recover after rest |

Jung et al. (2022) presented a schema-based instructional design model for self-paced learning environments. In their study, they highlighted the importance of the schema-based approach, which involves an initial analysis of students' needs and the learning environment, followed by the creation of a knowledge map to classify and visualize knowledge structure. Subsequently, in the design and development phase, instructional strategies were proposed to promote schema activation, construction, and automation and to update existing schemas.

The schema concept provides an understanding of how students organize and assimilate information, enabling the design of more effective educational activities. Brain functions are closely related to cognitive schemas, facilitating information processing and interpretation.

## 1.2. Generative Artificial Intelligence

Generative artificial intelligence is a subtype of artificial intelligence that can generate innovative content across diverse formats, including images, text, or music (Lv, 2023). This technology enhances productivity and creativity, automates content creation, and aids in problem solving. These models are trained on large amounts of information, allowing them to capture complex relationships and underlying structures in the data and use this information to generate meaningful and valuable outcomes (Feuerriegel et al., 2023).

Since 2013, generative AI has experienced a remarkable impulse thanks to the introduction of innovative neural network designs like Variational AutoEncoder (VAE), Generative Adversarial Network (GAN), and diffusion models. These models highlighted a high capacity to create data in various formats, like text, images, videos, and voice, and to generate synthetic data mimicking datasets. In 2017, Vaswani A. proposed a novel neural network architecture—attention-layer-based transformer and positional encoding—that incorporates a positional token containing information about the word order in the input (Vaswani et al., 2017). In 2018, two transformer-based models made their debut: Google introduced BERT, and OpenAI unveiled the first pre-trained generative transformer model (GPT-1). Other notable LLMs introduced afterward include GPT-4 (by OpenAI), PaLM (by Google), GPT-Neo (by EleutherAI), and LaMDA (by Google), among others, garnering significant and widespread attention. Large Language Models (LLMs) have emerged as game-changing innovations, largely because of their ability ability to grasp intricate connections between words and phrases in the input text.

As research in generative AI advances, Large Multimodal Models (LMMs) have gained significant attention. These models stand out from their predecessors by accepting multiple data types, such as text, images, video, code, and audio (Gozalo-Brizuela & Garrido-Merchán, 2023). This helps them provide more accurate insights and interpretations of the complex and varied data we encounter in the digital realm. Multimodal systems can receive information from multiple sources, giving them a deeper understanding of context and making them more reliable and high-quality (Suzuki & Matsuo, 2022). In 2021, OpenAI introduced DALL-E, an LMM capable of generating images from text. In 2022, several other models with multimodal capabilities were unveiled, such as PaLM-E (by Google), GPT-4 Vision (by OpenAI), Stable Diffusion (by Runway ML), Midjourney V6 (by Midjourney), Gemini (by Google), Gopher (by DeepMind), Claude (Anthropic), Codex (by OpenAI), and Vall-E (by Microsoft). The most recent language model released by OpenAI in May 2024, GPT-4o, represents a significant evolutionary advancement in the development of generative artificial intelligence models. This model constitutes an improved version of GPT-4, offering native multimodal capabilities and reduced latency compared to its predecessor. One of the most prominent aspects of GPT-4o is its enhanced reasoning capacity, which enables deeper understanding and the generation of more coherent responses. Furthermore, the proposed model offers improvements in terms of quality control and security, which increases the reliability of content generation. Additionally, the GPT-4o's ability to perform real-time analysis of images and videos captured by the camera expands the range of applications and enables more natural and automated interactions (OpenAI, 2024).

The creativity produced by this technology has had a significant impact across various industries. Large Language Models (LLMs) have demonstrated proficiency in executing tasks related to natural language with precision and coherence, including generating high-quality creative text, advanced automatic translation, contextually relevant and coherent dialog responses, sentiment analysis, text classification, and summaries (Epstein et al., 2023). In addition, generative AI-based image generators, commonly referred to as multimodal models (LMMs), have demonstrated exceptional capabilities in producing images and videos from textual descriptions. These models are used to create innovative designs, create stunning visual effects, and render realistic scenes. Additionally, they are used to compose original music and generate images with remarkable precision (Fareed et al., 2024).

In the educational field, generative AI possesses significant potential for creating and delivering educational content. In addition, these technologies can generate a wide variety of resources, including images, videos, and interactive applications, which can be adapted to students' learning needs and their particular learning styles. The disruption caused by Generative AI in all spheres of human life makes it imperative to instruct educators and students on how to handle and formatively use these tools (Mills et al., 2023). This academic training could include generating exercises and problems adapted to each student's skill level and comprehension or crafting explanations and examples to address specific areas of confusion or difficulty (Menekse, 2023). Generative AI tools can also facilitate the creation of interactive learning environments and immersive learning experiences with personalized feedback that encourages active participation and student engagement. Such technologies can generate realistic simulations, games, and practice activities that allow students to explore concepts practically and experience the learning process interactively, adaptively, and informatively (Chheang et al., 2024).

However, the misuse of Generative AI can compromise the quality of content and raise ethical and legal concerns regarding the outcomes obtained. Accuracy and relevance evaluation of AI content generated is crucial to overcome these challenges and address potential biases. In addition, guidelines and policies should be established to regulate the use of AI-generated content, focusing on the quality and originality of ideas. Collaboration among educators, researchers, and professionals is essential for developing best practices and guidelines for AI model usage that promote the ethical and responsible use of Generative AI in the educational field (Chen et al., 2023).

## 2. METHOD

In this study, a systematic review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement to provide transparent and high-quality results presented in a clear and reproducible manner. The selected studies, which focused on improving cognitive processes, provided exhaustive and up-to-date details on the application of Generative AI and empirical results supported by substantiated conclusions. The most relevant findings obtained from the data analysis were synthesized and summarized.

In the literature search, rigorous selection criteria were implemented to ensure the comprehensiveness and quality of the research on the application of Generative AI in the learning process. The search for relevant studies in the Scopus database was conducted using Boolean combinations of the following keywords: SCHEMA, SCHEME-ORIENTED, GENERATIVE ARTIFICIAL INTELLIGENCE, GENERATIVE AI, GENERATIVE MODEL, LEARNING, COGNITIVE, located in the title, abstract, and keywords of the articles, covering original journal articles and reviews. In total, 255 articles were identified using the search strategy.

Temporal filters were established to limit the search to studies published within the last five years, thus ensuring the relevance and timeliness of the collected information. Furthermore, inclusion criteria were applied to select relevant studies for the analysis.

- Document types: scientific articles and reviews.
- Time frame: the last five years to ensure relevance and currency.
- Publication Stage: Article in press and final.
- Languages: English and Spanish.
- Data sources: Scopus database.

Based on the retrieved metadata, articles were excluded according to the following criteria: articles without authors, articles lacking DOIs, duplicate documents, and retracted articles. Subsequently, the abstracts and full texts were reviewed to confirm their relevance to the research topic. Because of this rigorous selection process, 41 valid records were obtained and subsequently used for analysis.

A term co-occurrence network was generated using the corpus of documents with VOSviewer software to examine the relationships between terms and identify the organization of subthemes within the research topic. VOSviewer was configured with the normalization method "Association Strength," attraction set to 2, and resolution set to 1.1 to visualize the co-occurrence network.

Drawing from the insights obtained through co-occurrence analysis, we examined the documents to identify use cases for generative AI. The most significant use cases of Generative AI for educational applications were derived from the selected information.

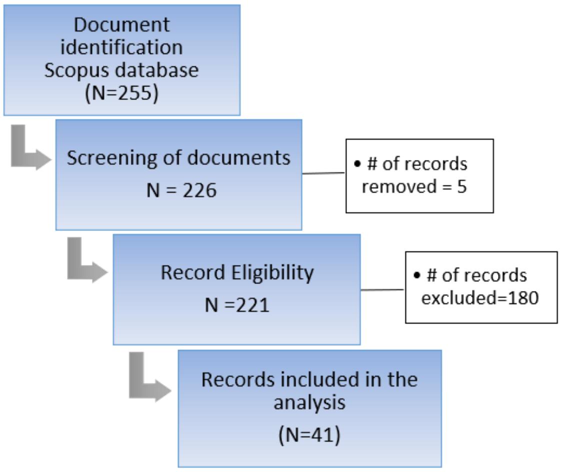
We identified use cases of Generative AI that can enhance the development of cognitive schemas. These cases focused primarily on improving conceptual understanding, tailoring content and activity difficulty to individual learning needs and styles, stimulating creativity and innovation, and fostering collaborative learning. These use cases can be integrated into the design of particular instructional strategies to promote schema activation, construction, and automation and update existing schemas.

Furthermore, we proposed several Generative AI tools suitable for implementing these use cases. These tools were identified through online research, considering criteria that align with the defined services in the use case classification.

One potential limitation in this systematic review is the rapid evolution of generative AI, which presents a significant challenge due to the frequent changes in tools and applications. This accelerated development can lead to the swift obsolescence of the IA studies reviewed, thereby limiting the longevity of several of our results.

**Figure 1**

*PRISMA flow chart of research strategy*




## 3. RESULTS

Developing the search strategy (Figure 1) resulted in 255 collected documents within the categories of original articles and reviews. After a thorough cleaning of the metadata, ineligible articles were excluded through an individual assessment of titles, keywords, abstracts, and text. This process yielded a refined dataset comprising 41 records, which were subsequently subjected to analysis.

The comprehensive literature review and relevant studies provided an integrated and detailed insight into the application of Generative AI in learning processes, aimed at strengthening cognitive schemas. The most relevant articles identified in the systematic literature review are detailed in Table 2, located in the Annexes section.

### 3.1. Analysis of Thematic Structure

The co-word analysis enabled us to explore the conceptual and thematic framework of the investigated scientific domain. Figure 2 presents the co-word network, highlighting the words with the highest frequency of occurrence in the analyzed documents and their interrelations.

Four clusters are identified, represented by the colors yellow, red, blue, and green.

In Cluster 1 (yellow), the most prominent terms are artificial intelligence, LLM, ChatGPT, generative AI, chatbot, prompt engineering, GPT model, game-based learning, and critical thinking. This clustering indicates that the primary focus is the integration and impact of advanced AI technologies in educational settings, with an emphasis on the use of Large Language Models (LLMs) and generative AI tools like ChatGPT for interactive learning experiences, as well as employing game-based learning strategies to enhance critical thinking skills.

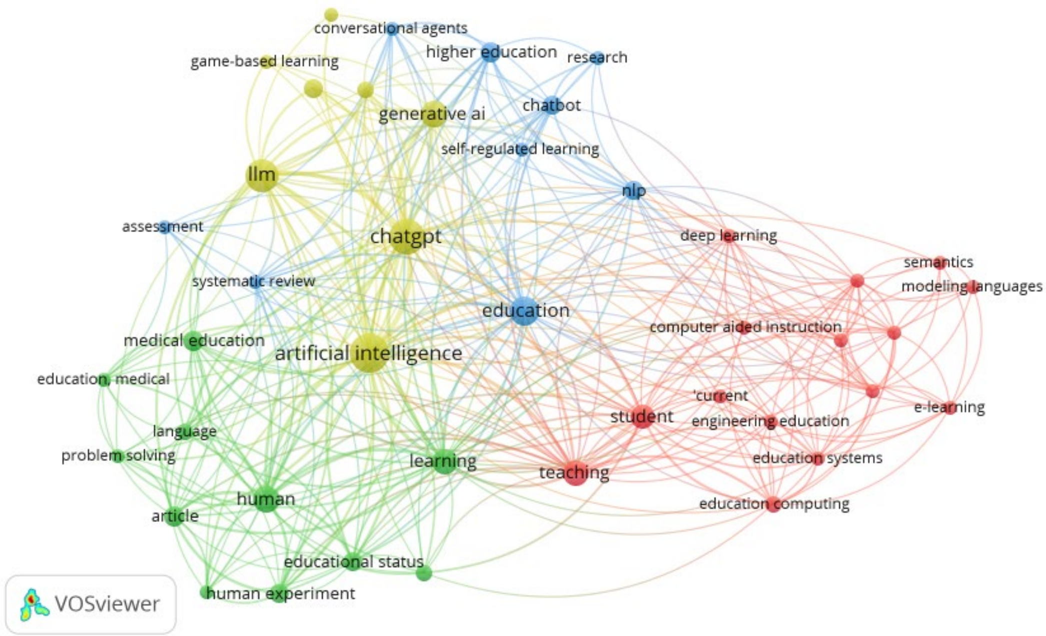
In Cluster 2 (red), the most relevant terms include teaching, student, engineering education, education computing, education systems, e-learning, deep learning, computer-aided instruction, language processing, modeling language, and semantics. These elements reflect the role of digital and computational methods in modern education through using deep learning and language processing in e-learning and computer-aided instruction, especially within engineering education.

Cluster 3 (blue) encompasses various terms, such as education, higher education, conversational agent, self-regulated learning, chatbot, NLP, and assessment. This cluster focuses on human-centric educational tools, emphasizing using conversational agents and chatbots powered by natural language processing (NLP) to facilitate self-regulated learning and assessment in higher education.

Cluster 4 (green) encompasses terms such as medical education, human, learning, problem-solving, human, human experiment, education status, simulation, and curriculum. The focus of this group is on medical and experiential education, highlighting the importance of human-computing relationships in learning. This includes using simulations and problem-solving.

**Figure 2**

*Co-occurrence network of words*




Based on the insights obtained from the co-occurrence analysis, we analyzed the documents to derive use cases for generative AI. Generative AI models are being implemented across a wide range of tools and applications in various industries. Generative AI models can create content in various categories, such as natural language processing, image processing, music, and video creation, that can be used to enhance educational processes by implementing tools for personalized experiences, realistic content generation, intelligent conversational dialogue, data analysis, and virtual instruction.

## 3.2. Guidance for Schema-Based Instructional Design

Given that teaching is intrinsically linked to the cognitive processes of creating and maintaining schemas in learning, establishing a schema-based instructional design process that considers the importance of schemas and cognitive load in learning new forms of knowledge and data within classroom teaching and learning contexts is crucial.

The stages of the process are described in detail below.

### 1. Context analysis

Context analysis serves as a foundational step in instructional design, ensuring that educational strategies are tailored to the specific needs, capabilities, and circumstances of learners and the learning environment, thereby enhancing the overall effectiveness of the educational process.

Needs Analysis: Assess the existing conditions and available resources necessary for optimal learning outcomes, and identify the gaps between the instructional goals and the current state.

Learner Analysis: Assess and identify students' prior knowledge and learning strategies to align them with learners' preferred learning styles. Additionally, determine learners' motivation, confidence, and proficiency in using technology, their capacity for self-directed learning, and their confidence in engaging in online communications.

Learning Environment (Context) Analysis: Determine the physical or virtual setting and logistics of learning. Establish whether the instruction will be online, face-to-face, or hybrid, and determine the group size for the instructional sessions.

Identify Potential Solutions and Feasibility Analysis: Develop strategies to address identified problems and achieve learning outcomes. Evaluate the financial and technical resources and constraints and determine the operational feasibility of implementing the instructional design.

### 2. Schema Analysis

Schema analysis serves as the pivot of the design process, encompassing the development of a schema model that facilitates the categorization and visualization of organizational knowledge.

Cognitive Task Analysis: Involve identifying the mental models and cognitive processes used by experts in the field. Behavioral task analysis captures observable behaviors, whereas procedural task analysis delves into the documentation of covert actions and the underlying conceptual frameworks.

Cognitive Task Analysis: Involve identifying the mental models and cognitive processes used by experts in the field. Behavioral task analysis captures observable behaviors, whereas procedural task analysis delves into the documentation of covert actions and the underlying conceptual frameworks.

Knowledge mapping: create a schema knowledge map that offers an efficient and effective method for categorizing and visualizing the organizational knowledge inherent in schemas.

### 3. Design and Development

Using compiled learning experiences and materials, instructional techniques and strategies should be framed to foster schema activation, construction, automation, modification, and elaboration. Table 3 provides an overview of the processes associated with the design and development phase and the applicable instructional strategies.

## 4. Evaluation

To measure students' mental efforts, cognitive load can be used as a proxy to assess the depth and quality of learners' understanding and determine their engagement with a given learning task. Assessments can be conducted using the following methods: self-explanation of acquired knowledge, a checklist approach, and concept mapping.

Table 3

*Description of Schema-Based Instructional Design and Development Process*

| Stage | Description | Instructional Strategies |
|---|---|---|
| Schema activation | Schema Activation involves leveraging a learner's prior knowledge and experiences to expedite the learning process. | pre-reading activities, pre-organizers, advance organizers, previews, and thematic organizers. |
| Schema construction and Schema automation | Critical considerations:<br>• Utilizing goal-free problems to minimize extraneous cognitive load associated with means-end analysis.<br>• Employing worked examples to streamline means-end searches and enhance working memory capacity by reducing extraneous cognitive load.<br>• Offering completion problems that provide partial solutions, enabling learners to deduce remaining solutions.<br>• Minimizing split attention whenever feasible in instructional settings.<br>• Integrating visuals such as diagrams and presenting verbal information audibly to enhance learning.<br>• Eliminating redundant information and reducing working memory load.<br>• Implementing the variability effect to expose learners to different contexts of a concept. | Schema construction strategies:<br>Cases, interactive video-recordings, hierarchical concept maps and vee diagrams<br>Schema automation strategies:<br>Goal-free problems, worked examples, completion problems, split-attention effect, modality effect, redundancy effect and variability effect. |
| Schema modification | The schema modification process, known as accommodation, focuses on re-evaluating a learner's existing schema to enhance the efficient utilization of mental efforts. | Unlearning/relearning and Reflection |
| Schema elaboration | Schema elaboration involves the process of maturing, saturating, or refining acquired schemas through instruction in a different domain, which fosters connections among related schemas. | Pattern recognition and Parallel schema interaction |

## 3.3. Specific use case of Generative AI in the learning process

The use of generative AI in education is a topic of growing interest because of its ability to develop functions as part of a human-AI cooperative and social learning system. The implementation of generative AI in education has the potential to redefine instructional methods and enhance student learning outcomes. This technology enables the personalization of educational experiences, interactive content creation, and the provision of adaptive assessments, stimulating greater student engagement and improved knowledge retention.

Recent studies have investigated the use of chatbots and advanced language models in the educational domain, focusing on student performance monitoring and evaluation, and interactive and engaging educational resource creation. In addition, generative AI has demonstrated proficiency in enhancing educational strategies, such as personalized learning experiences and interactive content creation. Using generative AI in open collaboration environments allows for emerging approaches that can help educators navigate and thrive in a rapidly evolving AI era.

Below are the educational use cases of generative AI that enhance learning schemas, primarily aimed at improving conceptual understanding, adapting content and activity difficulty according to individual learning needs and styles, stimulating creativity and innovation, and fostering collaborative learning. Table 4 presents the generative AI-Based Instructional Strategies classified according to the stages of the schemes.

### *3.3.1. Learning personalization*

Generative AI can create personalized educational content tailored to individual student needs. This approach involves adjusting learning materials, creating customized learning paths, and developing exercises and problems that align with each student's skill level and comprehension.

IA tools: Rewordify and DreamBox Learning.

### *3.3.2. Engaging educational content creation*

In education, Generative AI can produce relevant and up-to-date educational content that promotes student engagement, including text, videos, images, and interactive applications. These resources can be automatically generated from large datasets.

IA tools: ChatGPT, Bard, Copilot, Dall-E 2, Midjourney, Stable Diffusion, Pictory AI, Synthesia, and Gamma.

### *3.3.3. Active-learning facilitation*

Generative AI tools can drive active-learning by generating interactive and participatory learning experiences. These technology-enriched environments encompass simulations, games, and practical activities that allow students to explore concepts actively.

IA tools: Course Hero, Vortex Studio, Labster, Nearpod, PhET, and Kahoot.

#### 3.3.4. *Support for teaching and tutoring*

Generative AI tools can generate complementary educational resources, provide feedback and automated assessment of student progress, assist in setting up adaptive learning environments, and analyze student performance data to identify areas needing support (Amani et al., 2023). This enables educators to focus on personalized activities for students and dedicate more time to analyzing individual academic progress. Generative AI tools can help educators become more efficient and productive.

IA tools: M-Powering Teachers, Rewordify, Gradescope, and Turnitin.

Despite the promising progress of generative AI, integrating this emergent technology into education involves addressing concerns related to data privacy, copyright, and algorithmic bias. A major challenge is its impact on the academic integrity of scholarly work, because of its ability to generate responses similar to those of humans in all domains. Furthermore, it requires responses to concerns regarding the opacity and accuracy of the generated data. Many of these issues will be mitigated by the advanced capabilities of new multimodal models, such as the recently launched GPT-4o.

Table 4

*Generative AI based Instructional Strategies*

| Use cases of Generative AI | Schema Activation | Schema Construction | Schema Automation | Schema Modification | Schema Elaboration |
|---|---|---|---|---|---|
| Learning Personalization | Pre-reading activities generated by AI, tailored to each student's prior knowledge. | Personalized Goal-free problems to individual student levels to minimize cognitive load. | AI-generated completion problems tailored to each learner's progress. | AI-driven reflection prompts that encourage the re-evaluation and modification of existing schemas. | Personalized thematic organizers created by AI to enhance and refine existing schemas. |
| | Custom pre-organizers and advanced organizers created by AI to prime learners for new content. | Worked examples customized by AI to align with each student's skill level. | Interactive exercises and problems generated by AI to automate schema construction through practice. | | |
| Engaging Educational Content Creation | AI-generated previews and thematic organizers to introduce new topics and activate prior knowledge. | Interactive video recordings and hierarchical concept maps created by AI to build foundational schemas. | AI-generated simulations and practical activities that promote schema automation through repetition and application. | | AI-developed cases and interactive applications that encourage deeper exploration and connection of concepts across different domains. |
| Active-Learning Facilitation | AI-generated simulations and games designed to activate relevant prior knowledge | Practical activities and interactive learning experiences generated by AI to | AI-driven participatory exercises that promote repeated application and automation of | | Parallel schema interaction activities created by AI to facilitate pattern recognition and |

| Use cases of Generative AI | Schema Activation | Schema Construction | Schema Automation | Schema Modification | Schema Elaboration |
|---|---|---|---|---|---|
| | before diving into new content. | construct new schemas. | newly constructed schemas | | schema refinement through diverse, yet related, contexts. |
| Support for Teaching and Tutoring | AI-generated advanced organizers and previews that prepare students for new content. | AI-created hierarchical concept maps and Vee diagrams to facilitate the construction of new knowledge structures. | Adaptive learning exercises and AI feedback to support the ongoing practice and automation of schemas.<br><br>AI-generated automated assessments that help students identify and solidify automated knowledge | Reflection prompts and unlearning/relearning activities generated by AI to assist in modifying existing schemas based on feedback. | AI-facilitated pattern recognition tasks and parallel schema interaction activities that deepen and elaborate existing knowledge structures. |

## 4. DISCUSSION AND CONCLUSIONS

In the structure of the educational process, cognitive schemas are fundamental pillars for enhancing the formative experience and fostering the assimilation of new knowledge. These schemas act as catalysts by allowing students to intertwine newly acquired information with their prior knowledge, resulting in deeper understanding and improved learning retention. Generative artificial intelligence tools have emerged as cutting-edge resources for enriching educational dynamics. These tools enhance attention, promote adaptability in the teaching process, increase creativity, and encourage collaborative work, stimulating the brain and facilitating the assimilation and retention of knowledge. Moreover, these AI tools can facilitate the development of higher-order cognitive skills, such as critical analysis, reflective evaluation, and innovative capacity.

In the educational context, Generative AI tools are becoming increasingly important resources for improving schemas. These tools promote intelligent tutoring, facilitate the generation of personalized educational content, and boost the creation of simulations, immersive learning environments, and the automation of feedback and evaluation processes.

In a study conducted by Jaboob et al. (2024), students experienced notable satisfaction when using AI applications, which positively influenced their behavior and cognitive performance. This finding aligns with the conclusions of Howard-Jones (2010), who emphasizes the importance of emotions in knowledge acquisition, given their impact on students' motivation, attention, memory, and decision-making. Generative AI integration in education promotes active participation, personalized adaptation, effectiveness, and idea generation. Furthermore, the use of technology in classrooms, especially visual learning and recent innovations, is increasingly gaining ground among the student community.

These examples illustrate the great potential of generative AI in educational applications and demonstrate that it can be innovatively employed to enrich learning schemas. However, it is crucial to persist in the research and development of these technologies to optimize their capacity and overcome the ethical challenges and dilemmas inherent in their implementation in the educational sphere.

Some key advantages of integrating generative AI in educational environments include the following:

- Significant improvement in student motivation and engagement.
- Acceleration of the learning process and facilitation of information retention.
- Promotion of active participation and the acquisition of meaningful knowledge.
- Increase in accessibility to educational content adapted to various learning modalities.
- Provision of personalized and timely feedback to students regarding their performance.
- Fostering student autonomy and responsibility in the learning process.

Generative AI implementation in education brings many advantages, but it also presents challenges and issues that need attention for the best results. These challenges involve the possibility of creating content that's not up to standard or not relevant, worries about protecting intellectual property, safeguarding student data privacy and security, and the potential for reinforcing biases present in current educational materials, among other important considerations.

It is important to emphasize that generative AI tools do not take over the teacher's role in education. Teachers still play a vital role in choosing the right tools, evaluating the content they generate, and integrating it effectively into the teaching-learning process.

For generative AI to be effectively integrated into educational settings, teachers should gain more skills and knowledge about how to use this technology professionally. Moreover, it is crucial to create a strong framework that guarantees the responsible development of AI models focused on transparency and explainability and supported by ethical guidelines to ensure the responsible use of these tools in education.

This study explored how generative AI contributes to building cognitive schemas in education, uncovering evidence that these tools can tailor educational content to individual student needs, enhancing both the effectiveness and relevance of learning. Additionally, we observed that generative AI can produce diverse educational resources, enriching the learning journey and addressing various cognitive styles. By leveraging generative AI, educators can develop more impactful and student-centered teaching methods, fostering deeper and more personalized learning experiences.

Generative AI holds promise for education but presents challenges. These include the risk of low-quality or irrelevant content, privacy and intellectual property concerns, and the potential reinforcement of biases. The teacher's participation is essential in selecting and evaluating tools and integrating them effectively. Educators need training to use generative AI responsibly, aligned with a framework with clear ethical guidelines for proper implementation.

Future research should focus on assessing the effectiveness of generative AI tools compared with traditional teaching methods, which will provide valuable insights into how AI-generated educational content impacts both academic achievements and student engagement. Considering the advancements in the development of novel generative AI tools, it's advisable to implement a continuous evaluation process for these tools. This would streamline the creation and dissemination of educational content tailored to individual student needs. Furthermore, exploring how generative AI can enhance equity and inclusion, especially for marginalized students or those with special needs, is imperative.

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# 6. APPENDIX

Table 2

*List of relevant studies on the application of generative AI in education.*

| Title | Focus | Authors |
|---|---|---|
| Generative Artificial Intelligence as a Tool for Teaching Communication in Nutrition and Dietetics Education-A Novel Education Innovation | Describes the creation of an AI-driven platform to simulate virtual patients to improve communication skills in nutrition and dietetics students, offering cost-effective training and receiving positive initial feedback. | Barker, L. A.; Moore, J, D.; Cook, Helmy A. |
| Artificial intelligence and medical education: application in classroom instruction and student assessment using a pharmacology & therapeutics case study | Explores the application of three generative AI tools to create educational content with specific learning outcomes, test items, and standard-setting parameters for medical students. | Sridharan, K.; Sequeira, R. P. |
| Physical education teaching mode assisted by artificial intelligence assistant under the guidance of high-order complex network | Analyzes the integration of artificial intelligence (AI) teaching assistants in tennis instruction using compressed sensing=FCM (CS-FCM) to learn fuzzy cognitive maps. FCMs can be integrated with generative AI to enhance their capabilities and applications through enhanced modeling and simulation, which generate intuitive and interactive visual representations. | Song, X. |
| Leveraging the Potential of Large Language Models in Education Through Playful and Game-Based Learning | Examines LLMs' educational potential and proposes playful and game-based learning strategies to mitigate risks, ensuring expertise development while enhancing human-AI interaction in education. | Huber, S. E.; Kiili, K.; Nebel, S.; Ryan, R. M.; Sailer, M |
| Can artificial intelligence support creativity in early design processes? | Explores Generative AI to enhance design creativity and quality while reducing cognitive load, demonstrating its transformative potential in design education through improved design outcomes and efficient cognitive load management. | Chandrasekera, T.; Hosseini, Z.; Perera, U. |
| Digital transformation in engineering education: Exploring the potential of AI-assisted learning | Studies ChatGPT's potential in enhancing engineering education, emphasizing the need for student training and guidance, and proposes an AI-assisted learning flow for effective integration into educational practices. | Pham, T.; Nguyen, B.; Ha, S.; Ngoc, T.N. |
| Old dog, new tricks? Exploring the potential functionalities of ChatGPT in supporting educational methods in social psychiatry | Inspect ChatGPT's roles in social psychiatry education, highlighting its potential as a teaching tool, including information provider, debate facilitator, self-directed learning tool, and content creator for course materials | Smith, A.; Hachen, S.; Schleifer, R.; Bhugra, D.; Buadze, A. |
| Natural language processing for automatic evaluation of free-text answers — a feasibility study based on the European Diploma in Radiology examination | Assesses NLP's capability to automate free-text answer evaluation in medical exams to support the review process as a decision support system for reviewers and to support examination design. | Stoehr, F.; Kämpgen, B.; Müller, L.; Zufiría, L. O. |

| Title | Focus | Authors |
|---|---|---|
| Unlocking the opportunities through ChatGPT Tool towards ameliorating the education system | Examines ChatGPT's role in education, emphasizing its applications, such as automated grading, personalized learning experiences, and content customization. The results highlight its capability to automate grading, translate text, and customize educational content based on student needs. | Javaid, M.; Haleem, A.; Singh, R. P.; Khan, S.; Khan, I. |
| Race with the machines: Assessing the capability of generative AI in solving authentic assessments | Presents a framework to evaluate generative AI tools in assessments, revealing strengths at lower Bloom's taxonomy levels and weaknesses at higher levels, thus urging a reevaluation of educational goals and assessments. The findings suggest a need to reimagine educational goals and assessments to emphasize higher cognitive skills and enhance educators' capabilities to prepare students for a rapidly changing professional environment. | Thanh, B. N.; Vo, D. T.; Nhat, M. N.; Pham, T. T. T.; Trung, H. T.; Xuan, S. H. |
| Integrating generative AI in knowledge building | Explores high school students' use of ChatGPT for knowledge building and the development of AI literacy through empirical accounts following a teacher's pedagogical design. This study offers practical implications for integrating GenAI in K-12 education and urges educators to create spaces and scaffolds for students to engage with GenAI mindfully in the classroom. | Chen, B.; Zhu, X.; Díaz del Castillo H., F. |
| ChatGPT in physics education: A pilot study on easy-to-implement activities | Demonstrates the potential of implementing ChatGPT to enhance learning and support teachers' skills in secondary-school physics classrooms, highlighting its potential to enhance learning and critical thinking despite inherent limitations and biases. | Bitzenbauer, P. |
| How ChatGPT can inspire and improve serious board game design | Examines ChatGPT's role in educational board game design and underscores the need for human oversight to mitigate biases and inaccuracies in game development. The research highlights ChatGPT's utility in suggesting game themes and mechanisms, providing customization templates, and offering feedback on prototypes to enhance game components and mechanisms. | Junior, W. G.; Marasco, E.; Kim, B.; Behjat, L.; Eggermont, M. |
| Teaching and assessment of the future today: higher education and AI | Examines the capabilities of LLMs in performing tasks traditionally requiring human cognition, including data analysis, problem-solving, and content generation. It also discusses the rapid progression of AI models, noting their expanding functionalities, such as real-time information access and image analysis. | Lacey, M. M.; Smith, D. P. |
| Multimodality and English for Special Purposes: Signification and Transduction in Architecture and Civil Engineering Models | Investigates the necessity of multimodal literacy in architecture and civil engineering education, emphasizing the importance of transforming text-centric learning into multimodal communication skills required in professional practice. The study tasked students in English for Architecture and Civil Engineering courses to create digital, multimodal artifacts explaining concepts to a lay audience. | Hellwig, A. F. J.; Jones, P. T. ; Matruglio, E.; Georgiou, H. |
| Educational Design Principles of Using AI Chatbot That Supports Self-Regulated Learning in Education: Goal Setting, Feedback, and Personalization | Proposes integrating AI chatbots in education through prompting, reverse prompting, and learning analytics, emphasizing goal setting, self-assessment, and personalization to improve students' self-regulated learning and ethical use of ethical concerns using SRL and JOL frameworks. | Chang, D. H.; Lin, M. P.; Hajian, S.; Wang, Q. Q. |
| Challenge, integration, and change: ChatGPT and future anatomical education | Discusses the application of ChatGPT in anatomy teaching in medical education. ChatGPT enhances student engagement and independent learning in anatomy, offering individualized and immediate medical knowledge through interactive simulations. | Leng, L. |