https://doi.org/10.70882/c52g3e79

SCIENCE FORUM (JOURNAL OF PURE AND APPLIED SCIENCES) 26, (5 Special) (2026), 298 - 308

Science Forum (Journal of Pure and Applied Sciences)

Journal Homepage: https://atbuscienceforum.com.ng/index.php/jpas

Using Artificial Intelligence Applications in Teaching Mathematics (Between Promising Prospects and Necessary Cautions)

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Abstract

The study discusses about artificial intelligence (AI) as a modern educational technology with its conceptual framework, its past, key categories, uses, and ethical issues. It examines the "why" of the integration of AI in education and explores its applications and implications, focusing on mathematics education. The study provides an overview of the use of AI-supported applications to facilitate personalized teaching, formative assessment, problem solving, mathematical visualization and engagement. It also addresses the benefits which could be realized, including enhanced instructional efficiency, differentiated instruction, early identification of misconceptions and increased access to learning resources. However, there are some important issues that must be addressed for effective implementation such as algorithmic bias, data privacy, cyber security, unequal access, inaccuracies in the content generated, and limiting teacher autonomy. The study also explores some of the new developments and the future of AI in maths education, highlighting its evidence-based integration, teacher training, transparent assessment, oversight, and connection to curriculum and pedagogical goals. It ends by making proposals for the protection of responsible, equitable and educationally relevant use of AI in Mathematics classrooms.

Keywords

Artificial intelligence, Applications – Mathematics Teaching.

EISSN: 3156-5190 (Online)
ISSN: 1119-4618 (Print)
JPAS
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Introduction:

The world today is witnessing rapid developments across all spheres of life, compelling nations to keep pace by upgrading their systems. Foremost among these is the educational system; indeed, reforming education has become an imperative for preparing a generation of thinkers capable of navigating these challenges and advancements.

Artificial Intelligence (AI) is a modern branch of computer science dedicated to developing advanced programming methods that enable machines to perform tasks and draw conclusions—albeit within limited parameters—resembling human intelligence. The field begins by defining human intelligence and identifying its dimensions, subsequently seeking to simulate certain aspects of it. It is crucial to clarify that this discipline does not aim to equate or replicate the human mind—created by God in His infinite power and majesty—with a machine crafted by human hands. Rather, this emerging field seeks to understand the complex mental processes involved in human thought and to translate them into corresponding computational operations, thereby enhancing the computer's ability to solve complex problems (Rasha Abu Shamala, 2013, p. 28).

Artificial Intelligence (AI) plays a pivotal role in the future of education, facilitating online textbooks and remote lectures. Educational technology has reached unprecedented levels of advancement; today, AI is essential for automating teaching and learning tasks and helping students and teachers refine their instructional methods. Despite the progress already made, AI's contribution to education, learning, and training continues to grow and is poised to expand further in the future (Mahmoud Al-Astal et al., 2021). AI applications contribute to the rapid, automated development of curricula—keeping pace with the swift evolution of knowledge—thereby replacing traditional, time-consuming printing methods. AI technology can derive information and present it to students tailored to their specific needs and their mental and physical capabilities, while automatically updating lesson content. Furthermore, AI helps improve student listening and concentration, complements the teacher's role by providing supplementary material to foster skill development, and helps address the shortage of qualified teachers.

In the future, school classrooms are expected to shift from traditional educational models to the use of robots and AI applications designed to meet student needs and lesson requirements. Large numbers of students will benefit from these technologies, which offer flexible, continuous engagement, while teachers will also benefit from AI techniques and applications. To achieve the objective of the current research, the following aspects were addressed:

- Artificial Intelligence (concept, historical background, types, fields, and ethics).
- The use of artificial intelligence in education (importance and practical applications).
- The use of artificial intelligence applications in mathematics teaching and learning.
- Advantages of using artificial intelligence applications in mathematics teaching and learning.
- Examples of artificial intelligence applications in mathematics teaching and learning.
- The future of using artificial intelligence applications in mathematics teaching and learning.
- Necessary precautions regarding the use of artificial intelligence applications in mathematics teaching and learning.

Artificial Intelligence (Concept – Historical Background – Types – Fields – Ethics):

The Concept of Artificial Intelligence (AI):

Linguistically, intelligence is defined as the ability to analyze, synthesize, distinguish, choose, and adapt to various situations (Ahmed Omar, 2008). The term "Artificial Intelligence" refers to a set of computer science technologies that enable systems to perform tasks typically requiring human intelligence—such as visual perception, speech recognition, decision-making, and language translation (Holder et al., 2018). Its philosophy centers on machines simulating the human

mind through computer systems capable of learning, data collection and analysis, identifying relationships within data, and making decisions; essentially, the machine is enabled to "think"—learning, deciding, and acting much like a human (Yang et al., 2023).

Artificial intelligence entails the simulation of human intelligence by programmed machines—specifically computer systems—to think like humans and mimic their actions. The term can also apply to any machine exhibiting traits associated with the human mind, such as learning and problem-solving. Specific applications of AI include expert systems, natural language processing, speech recognition, and object vision (Chounta et al., 2021).

It is also defined as a branch of computer science concerned with the study and creation of computer systems that exhibit forms of intelligence—meaning systems that learn new concepts and tasks, systems capable of thinking and drawing useful inferences about the world we live in, and systems that comprehend natural languages. ...and systems that perceive and understand visual scenes, and are capable of performing tasks requiring human intelligence.

Artificial Intelligence (Historical Background):

The historical roots of artificial intelligence (AI) trace back to the early days of human interaction with machines. The term "artificial intelligence" first appeared in 1956 at the Dartmouth Conference. A brief overview of the history of AI follows, based on the work of Abdullah Mousa and Ahmed Bilal (2019).

Between 1940 and 1950, the concept of AI centered on simulating the human mind. Early attempts involved creating automated models capable of exhibiting simple behaviors—such as learning via neural networks. In 1958, John [McCarthy] invented LISP, a programming language designed for AI.

The 1980s saw the emergence of expert systems and machine learning. Programming efforts shifted toward knowledge acquisition and extraction—embedding knowledge into machines and endowing them with capabilities such as vision or movement.

In the 1990s, AI researchers revisited neural networks. This resurgence was driven by massive advancements in computing power (speed and storage capacity) and progress in psychology (specifically regarding intelligence), as well as developments in neural network science. Consequently, all fields of AI advanced, including machine learning, case-based reasoning, natural language understanding, virtual reality, and gaming.

Types of Artificial Intelligence:

There are three classifications of artificial intelligence (Hanan Al-Awfi & Taghreed Al-Ruhaili, 2021; Noha Al-Ruwaished, 2023; Samar Al-Shalhoub et al., 2024; Dhabiya Al-Qahtani, 2024; Noura Al-Saudi, 2024; Copeland, 2023):

• **Weak or Narrow Artificial Intelligence (ANI)**

This refers to AI embedded in machines capable of accurately performing a set of pre-defined functions; the machine possesses no reasoning capability. Examples include Google Search, as well as speech and image recognition software. It is the simplest form of artificial intelligence.

• **Strong Artificial Intelligence (AGI) – Artificial General Intelligence**

This is a more advanced type of intelligence designed to solve highly complex problems. The machine possesses the ability to reason and make decisions by analyzing input data and utilizing it for planning, problem-solving, inference, and prediction. This type is significant in AI development for creating machines with human-like intelligence capable of replacing human labor in certain professions. Artificial Neural Networks (ANN) represent one approach within this category, focusing on creating a neural network system for the machine that mimics the neural networks found in the human body. Examples include smart self-driving cars, personal assistants, and instant chatbots.

• **Super Artificial Intelligence (Super AI)**

This refers to intelligence in which machines surpass human capabilities in areas such as reasoning, problem-solving, and more, enabling them to perform tasks better than a knowledgeable human specialist. These systems possess the ability to learn, plan, communicate autonomously, and make judgments. This necessitates adherence to principles and regulations governing the human-machine relationship, in accordance with AI ethics. It is worth noting that this type of AI is still in the experimental stage; it is often viewed as a hypothetical scenario—akin to depictions in science fiction films and literature—where machines might gain control over the world. Scientists such as Stephen Hawking and Elon Musk have predicted that this form of super-intelligence will revolutionize not only the industrial sector but also fields such as medicine, education, engineering, and space exploration.

The various types of artificial intelligence can be illustrated in the following figure:



Figure 1. Types of Artificial Intelligence

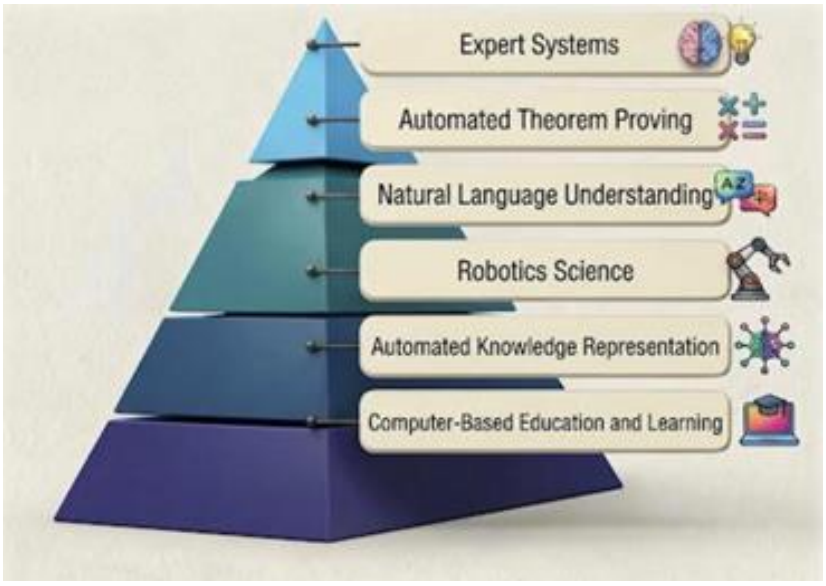


Figure 2. Fields of Artificial Intelligence

Fields of Artificial Intelligence:

There are several fields of artificial intelligence, including: expert systems, automatic theory proving, natural language understanding, robotics, automated knowledge representation, and computer-assisted learning and education (Su & Zhong, 2022). The fields of artificial intelligence can be illustrated in figure 2.

Ethics of Artificial Intelligence Use:

There are several principles and ethical guidelines governing the use and deployment of artificial intelligence; these include, but are not limited to (Abdullah Mousa & Ahmed Bilal, 2019; Mohamed Badawi, 2022; Ping, 2019):

1- Integrity and Fairness: Designing, collecting, developing, deploying, or using AI systems requires taking necessary measures to eliminate bias, discrimination, or stigmatization affecting individuals, groups, or specific categories of people.

2- Privacy and Security: Data confidentiality ensures that access to information is restricted to authorized personnel and that specific controls are in place to manage access permissions for information and data.

3- Humanity: AI systems must be built using an ethically sound methodology grounded in human rights and fundamental values.

4- Social and Environmental Benefits: The principle of social and environmental benefits promotes positive impacts aligned with social and environmental priorities—benefiting individuals and society as a whole—while focusing on sustainable goals and objectives.

5- Reliability and Safety: This principle ensures that the AI system adheres to specified standards and operates fully in accordance with the mechanisms intended and anticipated by its designers.

6- Transparency and Explainability: This means that the data, processes, and purpose of an AI system must be transparent and explainable—both directly and indirectly—depending on the system's context, purpose, and potential outcomes

7- Accountability and Responsibility: Human oversight and appropriate management must be implemented throughout the entire lifecycle of the AI system to ensure that adequate mechanisms are in place to prevent the misuse of this technology; AI systems should not deceive people or undermine their freedom of choice.

The Use of Artificial Intelligence in Education (Importance and Practical Applications)

The Importance of Using Artificial Intelligence Applications:

Undoubtedly, the expansion of artificial intelligence (AI) applications has heightened the significance of this technology. It has become a focal point for researchers and specialists, as it offers high-performance, human-like capabilities—not to replace humans, but to enhance human potential, enable a deeper understanding of individual challenges, and facilitate the delivery of more efficient, high-quality services and solutions (Abdullah Mousa & Ahmed Bilal, 2019).

There are numerous advantages to using AI applications across various aspects of life; these include, but are not limited to (Kewalramani et al., 2021; Ali, 2022):

• The provision of many applications that have become vital to daily life; the smartphone—with its array of smart systems and apps—is a prime example of the human need for such technology.

• The ability of these machines to operate continuously without fatigue or boredom, maintaining consistent productivity regardless of environmental conditions.

• The capacity to utilize AI applications for routine, repetitive tasks as well as for activities that pose risks to human safety.

• The use of AI applications yields precise results in task performance and significantly reduces error rates.

• The ability of AI applications to make decisions unaffected by emotional factors, thereby minimizing bias that might otherwise hinder operations and ensuring equal opportunities for all without discrimination. • Improving the performance of organizations that rely on AI applications by automating processes and tasks that previously

required human labor, and by comprehending environments on a scale beyond human capability.
• Increasing reliance on predictive capabilities to automate highly complex tasks and duties.

Artificial Intelligence Applications in Education:
There are several applications of artificial intelligence in the field of education, generally categorized as follows (Mohamed Badawi, 2022; Meng et al., 2022; Su & Yang, 2022):
• Intelligent Tutoring Systems (ITS): These are computer-based educational systems that utilize independent data and knowledge bases regarding educational content and learning strategies (which dictate teaching methods). They attempt to infer a learner's ability to comprehend topics and identify their strengths and weaknesses, thereby enabling the system to dynamically adapt the learning process. An ITS comprises domain-specific knowledge, learner-specific knowledge, and knowledge regarding learning strategies.

• Adaptive Learning Environments: These systems deliver educational curricula by recommending content tailored to each learner based on their preferences, progress, and learning style. They utilize academic data to monitor and guide learners and to represent knowledge through concept maps. Furthermore, they leverage this data to track learner progress, identify weaknesses (providing appropriate supporting content), and recognize strengths (offering suitable material). Operating on the principle that a "one-size-fits-all" approach is ineffective, these systems adapt to learners based on their proficiency levels, responses, preferences, and behaviors during the learning process.

• Learner Performance Prediction (Profiling and Prediction): This involves decisions regarding enrollment and subsequent actions—such as course scheduling, determining dropout and attendance rates, defining learner profiles and academic achievement patterns, and providing appropriate support.

• AI-Powered Virtual Reality Teaching: Virtual reality integrated with artificial intelligence offers multisensory visual stimulation that supports learners and fosters engagement. Through the virtual environment, learners gain a deeper understanding of the subject matter within an interactive setting that enables them to explore and continue learning freely and independently, in a dynamic and energetic manner.

• Smart Content: Smart content is gaining significant importance in AI-driven educational applications. AI can generate digital content with a level of proficiency comparable to that of human creators; furthermore, it enables the digitization of textbooks and the development of functional, interactive digital interfaces.

• Educational Robots: Educational robots possess the ability to perform educational tasks with capabilities that surpass human limits. They can leverage and integrate human knowledge across various fields using a suite of advanced, simultaneously integrated technologies. These robots facilitate both assisted and autonomous teaching and infuse learner activities with an intelligent dimension, making them highly effective tools for training learners in new skills and advanced knowledge.

• Administrative Task Automation: AI can efficiently and effectively handle multiple tasks, enabling the automation and acceleration of administrative processes within educational institutions. It also automates teaching-related duties, such as the automated grading of homework and exams, while chatbots provide learners with instant answers to their inquiries at any time.

Using Artificial Intelligence Applications in Mathematics Teaching and Learning:
Learning mathematics through artificial intelligence technologies fosters an atmosphere of enjoyment, vitality, and innovation; students approach learning with enthusiasm and engage in a wonderful, enriching experience. AI technologies enable students to

participate in active, interactive, and experimental activities, thereby boosting their desire to learn, stimulating creativity and engagement, and yielding excellent educational outcomes. Consequently, learning shifts from merely studying a subject to truly grasping and internalizing the content (Casey, 2022).

Artificial intelligence can be applied to mathematics teaching and learning in the following ways (Wael Mohamed, 2021):

• Collecting student feedback within an integrated learning environment and processing it to generate insights that allow the learning environment to be adapted to the learner's capabilities.

• Utilizing smart learning environments to individualize mathematics instruction through personalized learning settings.

• Coordinating the roles of the mathematics teacher and probabilistic educational robots.

• Analyzing various datasets, statistics, probabilities, and statistical models related to diseases and epidemics.

• Focusing on the study of mathematical modeling and fuzzy mathematics.

• Employing educational robotics in mathematics teaching and learning, and analyzing interactions—both between teachers and students and among students themselves.

• Using educational robotics for the continuous professional development of mathematics teachers.

• Utilizing dynamic mathematics learning software such as MATHia, Math XP, Maple, and Mathematica.

Artificial intelligence has the potential to revolutionize mathematics education by providing students with personalized, adaptive, and engaging learning experiences; teachers can leverage these tools to support their instruction and deliver more effective teaching.

The use of AI technologies in mathematics education offers numerous advantages, most notably (Bilal Rabia, 2023; Gherhes, 2018):

• AI assists mathematics teachers in delivering lessons in diverse ways. By analyzing student data—including performance, behavior, and engagement—AI algorithms can provide tailored guidance based on individual learning needs, abilities, and interests. This enables the identification of areas requiring further attention and support, as well as the provision of personalized feedback and guidance to enhance understanding.

• AI helps automate the grading of assignments and tests, saving teachers time and allowing them to focus on providing feedback and assisting students who struggle to understand or solve mathematical problems. It also helps ensure consistency and fairness in grading.

• Artificial intelligence has the ability to adjust the difficulty level of mathematical problems to match students' learning progress, ensuring they face challenges without becoming overwhelmed. It also fosters deep learning and enhances student engagement. AI-powered intelligent tutoring systems can provide students with immediate feedback, guidance, and support; these systems adapt to the student's pace and level of understanding, offering conceptual explanations, answers to questions, homework assistance, additional examples when needed, and supplementary learning resources.

• AI-driven systems can analyze and interpret student responses to open-ended questions, providing more detailed and personalized feedback. This helps students better understand their strengths and weaknesses while improving their critical thinking and communication skills.

• Artificial intelligence can be used in mathematics education to make the subject more engaging and enjoyable for students. For instance, AI algorithms can create personalized educational games or simulations that help students learn mathematical concepts interactively, challenge them to solve complex problems, and facilitate collaborative learning experiences.

Advantages of using artificial intelligence applications in mathematics teaching and learning:

Using artificial intelligence (AI) applications in mathematics education offers several advantages, including (Abdullah Mousa & Ahmed Bilal, 2019; Walaa Hosni, 2021; Mohamed Badawi, 2022):

• AI technologies infuse the mathematics learning experience with enjoyment, vitality, and novelty, fostering the student's enthusiasm for learning and creating a wonderful, enriching experience.
• AI technologies enable students to engage in active, interactive, and experimental mathematics activities—both inside and outside the classroom—thereby boosting their desire to learn and stimulating their creativity and participation.
• They assist mathematics teachers in delivering lessons in diverse ways by providing personalized guidance to students—based on an analysis of their individual learning needs, abilities, and interests.
• AI algorithms can analyze student performance, behavior, and interaction to identify areas requiring further attention and support, while offering tailored feedback and guidance to improve future performance in mathematics.
• They facilitate the grading of tasks and tests, saving time for mathematics teachers and allowing them to focus on providing feedback and assisting students who struggle to understand or solve mathematical problems.
• They offer the ability to adjust the difficulty level of mathematical problems to match student progress, ensuring that students face a challenge without becoming overwhelmed.
• It contributes to enhancing learning and a deep understanding of mathematics, and to fostering positive engagement—both among students themselves and between students and the teacher.
• Intelligent tutoring systems can provide students with immediate feedback, guidance, and support during various mathematics teaching and learning situations.
• They contribute to analyzing and interpreting student responses to open-ended questions, thereby helping to identify their strengths and weaknesses and enhancing their critical thinking and mathematical communication skills.

Examples of artificial intelligence applications in mathematics teaching and learning:

Intelligent mathematics instruction employs various machine learning techniques and self-learning algorithms to collect and analyze big data; these technologies determine the type of content delivered to the learner based on their abilities, requirements, and needs. One example is *iTalk2Learn*, an application for teaching fractions; it utilizes a learner model that stores data regarding the student's mathematical knowledge (both conceptual and procedural), cognitive needs, emotional state, and reactions and responses to feedback. Another example is the *Brainly* platform, an AI-driven social networking site focused on classroom-related questions; it uses machine learning algorithms to allow students to ask homework questions and receive automated answers, while also facilitating peer collaboration to arrive at correct solutions independently (Ping, 2019).

There are numerous AI applications in mathematics education; examples include, but are not limited to (Widad Al-Shathri & Reem Al-Obaikan, 2016; Ibrahim Ajjam, 2018; Zahoor Al-Omari, 2019):

• Interactive Chatbots: Chatbots are a form of artificial intelligence application—software programs that encourage learning through conversational interaction. They automatically respond to chat messages and can be programmed to provide varied responses based on the interlocutor, the user's input, and the topic of discussion.
• Augmented Reality Technology: Augmented reality is a modern technology that integrates information technology into educational settings by combining the learning environment with digital learning objects. It transforms graphics into 3D models, enabling the teacher to hold and display the object so that students can view it with precision and clarity.
• Expert Systems: These are applications of artificial intelligence—specifically, computer programs that emulate the problem-solving methods of human experts. Expert knowledge is codified into these systems so that users can leverage them to solve complex problems. Functioning as knowledge-based information systems, they utilize specialized, complex domain knowledge to act as expert consultants for users; their primary purpose is to assist humans in the

reasoning process rather than merely providing information.

• Intelligent Tutoring Systems (ITS): These are computer systems designed to improve and enhance the learning process within a specific knowledge domain. They deliver automated lessons without requiring the presence of a human instructor, aiming to facilitate effective learning by utilizing various cloud computing and artificial intelligence technologies.

The Future of AI Applications in Mathematics Education and Learning:

AI applications hold significant importance for the future of mathematics education and learning. Examples include, but are not limited to, the following (Faten Al-Yajzi, 2019; Mahmoud Mukhtar, 2020; Hisham Al-Sunni et al., 2024):

• AI will play a pivotal role in the future of mathematics education through online digital textbooks and remote learning.

• A shift in school classrooms from traditional educational frameworks to the use of robots and AI applications tailored to the specific needs and requirements of various mathematics lessons.

• Large numbers of students will benefit from the use of robots and AI applications characterized by flexible, continuous operation; mathematics teachers will also benefit from AI technologies and applications.

• Assisting mathematics teachers in reducing the administrative and clerical tasks that often consume a significant portion of their time. This is achieved by automating most administrative duties, organizing paperwork, assessing learning styles, answering student questions, grading exams, and evaluating homework and supplementary mathematics activities.

• Adapting mathematics content to suit each student's individual capabilities, strengths, and weaknesses—regardless of their cognitive abilities, geographical location, or financial resources.

• Identifying mathematics topics requiring reassessment by analyzing them against each student's specific needs and addressing their knowledge gaps—thereby preventing them from falling behind their peers—based on their educational history and learning capabilities in the curriculum generally, and in mathematics specifically.

• Key artificial intelligence applications that can be utilized in the future of mathematics education and learning include: smart chatbots, intelligent tutoring systems, smart adaptive learning, augmented and virtual reality technologies, smart educational robots, smart educational games, and intelligent assessment.

Precautions regarding the use of artificial intelligence applications in mathematics education and learning:

There are several Precautions regarding the future use of artificial intelligence applications in mathematics education and learning, as outlined below (Ibrahim Ajjam, 2018; Walaa Hosni, 2021; Reda Al-Saeed, 2023):

•It may eliminate the need for direct, face-to-face mathematics instruction; since learners acquire knowledge independently of time and place, they lose personal and school-based connections, leading to a neglect of social interaction and resulting in isolation.

•Artificial intelligence cannot contribute to the development of the educational process without the availability of appropriate infrastructure, such as high-speed internet and other necessary requirements.

•AI language models can be used to generate fake news, hate speech, and other harmful content, potentially leading to social unrest, reputational damage, or even physical harm to individuals.

•The internal mechanisms and processes used by AI models are not sufficiently open or transparent to users, nor do they clearly explain how they operate.

•The successful adoption of artificial intelligence technology by educational institutions depends on the availability of digital infrastructure, the training and skill development of teachers and specialized technicians, and the security and protection of the data and applications used; consequently, these factors may pose obstacles to maximizing the benefits of AI applications in the teaching and learning of mathematics.

• Because artificial intelligence models rely heavily on Internet data, which may contain biases or anomalies, which may lead to producing unfair texts or results.
• Some models of artificial intelligence involve collecting and processing personal data from the Internet, which raises many concerns about privacy and data security.

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