

APPLYING ARTIFICIAL INTELLIGENCE IN THE DESIGN OF EDUCATIONAL GAMES TO ENHANCE THE EFFECTIVENESS OF SCIENTIFIC EXPLORATION FOR CHILDREN AGED 4-5 YEARS

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ABSTRACT

This study aims to assess the current state of artificial intelligence (AI) applications in designing educational games to organize science exploration activities for 4-5-year-old children and to propose a process and measures to improve the effectiveness of AI applications in preschool education. The study uses survey, statistical, literature review, and expert consultation methods with 47 teachers at two preschools, Trung Khanh and Duc Hong, in Cao Bang province. The results show that teachers initially used AI tools such as ChatGPT, Gemini, and Canva AI to design learning materials and games, but their use was limited by digital literacy, command-building skills, and technological infrastructure. Based on this, the study proposes a five-step process for designing AI-powered educational games and three implementation measures. Experimental results show that these measures are feasible and help improve the effectiveness of organizing science exploration activities for preschool children.

Keyword: *Artificial intelligence; scientific exploration activities; learning games; early childhood education; 4-5 year olds.*

1. INTRODUCTION

In the context of digital transformation and the Fourth Industrial Revolution, artificial intelligence (AI) is creating many opportunities for innovation in education. Tools such as ChatGPT, Gemini, Copilot, and Canva AI help teachers create learning materials, design lessons, and organize teaching activities in a visual, creative, and personalized way. According to UNESCO (2023), AI has the potential to improve the quality of education if used responsibly and always with the learner at the center.

In Vietnam, digital transformation in education is identified as a key task to improve the quality of teaching and learning. The Preschool Education Program (2021) encourages the application of technology in organizing educational activities, creating a foundation for AI to be gradually researched and implemented in practice.

Scientific exploration activities are an important content of preschool education, contributing to the formation of observation skills, thinking, problem-solving abilities, and a love of discovery in 4-5 year old children. Among these, learning games are considered a suitable form of organization, helping children acquire knowledge

through experience. However, designing quality learning games still requires teachers to invest a lot of time and creativity. AI can support teachers in quickly building content, designing images, learning materials, and games, contributing to improving the effectiveness of organizing scientific exploration activities.

Although AI has been widely researched and applied in education, current studies mainly focus on primary and higher education. Research on the application of AI in designing educational games for preschool children, especially for scientific exploration activities, is limited and has not yet proposed a practical implementation process.

This study aims to assess the current state of AI application in designing educational games for 4-5 year olds, supplement the theoretical basis, provide practical evidence, and support preschool teachers in effectively utilizing AI in the context of digital transformation in education.

2. OVERVIEW OF THEORY

2.1. Artificial intelligence in early childhood education

Artificial intelligence (AI) is a scientific field that develops systems capable of simulating certain

human intellectual functions such as learning, reasoning, language processing, and decision-making. With the development of big data and large language models (LLMs), AI is increasingly being applied in education to support individualized learning, build digital learning materials, and improve the efficiency of management and teaching.

In early childhood education, AI primarily plays a supporting role for teachers in designing learning materials, building visual learning environments, and diversifying educational activities. Utilizing AI-generated tools like ChatGPT, Gemini, and Canva helps teachers save preparation time, increase creativity, and improve the quality of activities for children.

However, AI does not replace teachers; it is merely a supporting tool. Teachers still retain the decisive role in selecting content, organizing activities, and evaluating children's development. According to UNESCO (2023), the application of AI in education needs to ensure the principles of learner-centeredness, transparency, safety, and accountability. Besides the benefits, the application of AI also places demands on teachers' digital competence, content reliability, data security, and ethical use of technology.

2.2. The role of learning games in scientific exploration activities for 4-5 year old children

Educational games are a characteristic form of early childhood education, combining play activities with learning objectives. For children aged 4-5, this is a suitable method to help them acquire knowledge through experience, exploration, and interaction with the environment.

In scientific exploration activities, educational games provide opportunities for children to observe, experiment, compare, classify, and explain familiar phenomena. This process contributes to the formation of initial scientific concepts, develops thinking skills and problem-solving abilities, while also cultivating communication, cooperation, and self-confidence.

For teachers, educational games are an important means of realizing educational goals oriented towards competency development. The quality of the game depends on correctly identifying objectives, selecting appropriate content, designing open-ended situations, and organizing

activities that meet the developmental characteristics of children.

2.3. Application of Artificial Intelligence in Designing Educational Games for Organizing Science Exploration Activities for 4-5 Year Old Children

The development of AI creates many innovative opportunities in designing educational games in preschools. Unlike the general role of AI in education, AI in educational game design focuses on supporting teachers in developing ideas, designing content, creating visual learning materials, and perfecting the components of games to support science exploration activities.

During the design process, AI can assist teachers in identifying themes, developing rules, designing illustrations, flashcards, videos, stories, and question systems suitable for educational goals. At the same time, AI helps adjust content according to children's cognitive levels, contributing to increased visual appeal, attractiveness, and reduced preparation time for learning materials.

However, the effectiveness of AI application depends on teachers' technological capabilities, especially their skills in developing prompts, evaluating, and adjusting AI-generated products. Teachers need to verify the accuracy of the content, ensuring its scientific validity, pedagogical soundness, and suitability to children's developmental characteristics before implementation.

Although many studies have addressed AI in education, research on the process of applying AI to design learning games for scientific exploration activities for 4-5 year old children in Vietnam is still limited. This provides a basis for research proposing a process for designing AI-powered learning games suitable for the practical conditions of preschools.

3. RESEARCH METHODS

3.1. Method of surveying the current situation

This study uses a survey method combining questionnaires, observation, and semi-structured interviews to assess the current state of artificial intelligence (AI) application in designing educational games for organizing science exploration activities for 4-5 year old preschool children.

The survey subjects included 47 teachers directly teaching 4-5 year old children at Trung Khanh Preschool and Duc Hong Preschool (Cao Bang province). The survey focused on: (1) teachers' awareness of AI; (2) the level and purpose of using AI; (3) the effectiveness and difficulties of applying AI; (4) influencing factors; and (5) the need for training in AI application skills.

Data was collected from May to December 2025 through direct and online methods. The data were processed using Microsoft Excel through descriptive statistical indicators, including frequency, percentage, mean, and standard deviation; Simultaneously, the average Likert score was used to assess the necessity and feasibility of the proposed measures.

.3.2. Experimental Pedagogical Method

The experimental pedagogical method was used to verify the feasibility and effectiveness of applying AI in designing learning games for organizing science exploration activities for 4-5 year old preschool children.

The experimental subjects included 10 teachers currently teaching 4-5 year old preschool classes at two surveyed schools. Teachers received training on the AI-based learning game design process before the experiment was implemented.

The experiment was conducted over 8 weeks with science exploration topics from the Preschool Education Program. Teachers used AI generation tools such as ChatGPT, Gemini, and Canva AI to design learning games according to the five-step process proposed by the study.

The effectiveness of the process was evaluated through observation, teacher evaluation forms, post-experiment interviews, and learning game products. Data were analyzed using descriptive statistics to assess the feasibility and effectiveness of the process.

4. RESULTS OF THE CURRENT SITUATION SURVEY

Based on survey data from 47 teachers, the study analyzes the current state of AI application in learning game design according to the following aspects: awareness, level of use, application effectiveness, and influencing factors. The results serve as a basis for proposing a process and measures to improve the effectiveness of AI applications in preschool education.

4.1. Current status of teachers using AI tools to design learning games used in organizing science exploration activities for 4-5 year old children in preschools

To assess the current state of artificial intelligence (AI) application in designing learning games to serve the organization of science exploration activities for 4-5 year old children, the research team surveyed teachers about the content in which they have used AI to support the design and organization of activities. The results are presented in Table 1.

Kindergarten Substance	Kindergarten Trung Khanh		Kindergarten Hong Duc	
	Number of votes	Percentage	Number of votes	Percentage
Educational Game Design	23	69,7	13	92,9
Illustration design	25	75,8	14	100
Create questions and lesson content.	17	51,5	12	85,7
Create video or audio	24	72,7	13	92,9
Evaluating children's learning outcomes	9	27,3	5	35,7
Other opinions...	0	0	0	0

Table 1. Current status of teachers using AI design tools in science exploration activities for 4-5 year old children

The survey results show that teachers in both schools have initially applied AI to many stages of the design and organization of science exploration activities; however, the level of use differs across different areas. AI was most frequently used for designing illustrations, followed by creating videos or audio, and designing educational games. This indicates that teachers primarily utilize AI to create visually engaging and lively learning materials, contributing to enhancing the attractiveness of science exploration activities.

For question and lesson content development, the percentage of teachers using AI was lower, reflecting a difference in the ability to utilize AI tools to support educational content design between the two schools. In particular, assessing children's learning outcomes had the lowest usage rate. This result suggests that teachers still prioritize traditional assessment methods based on direct observation and remain cautious about using AI in assessing preschool children.

Overall, AI is currently used by teachers primarily as a tool to support the design of learning materials and educational games, while its functions in supporting the creation of in-depth content and evaluating children's learning outcomes have not been effectively exploited. This indicates the need to enhance the development of AI application skills, especially in the areas of prompting, selecting appropriate tools, and quality control of AI-generated products, in order to improve the effectiveness of its application in organizing science exploration activities for 4-5 year old children.

4.2. Level of Use and Effectiveness of AI Application in Educational Game Design

To assess the level of use and effectiveness of artificial intelligence (AI) application in designing educational games for organizing science exploration activities for 4-5 year old children, the research team surveyed teachers about the frequency of AI use in practice and the effectiveness of AI-designed educational games. The results are presented in Tables 2 and Tables 3.

Kindergarten Substance	Kindergarten Trung Khanh		Kindergarten Hong Duc	
	Number of votes	Percentage	Number of votes	Percentage
Very often	0	0	0	0
Often	12	36,4	5	35,7
Rarely implemented	20	60,6	7	50,0
unfulfilled	1	3,0	2	14,3

Table 2. Level of AI use in designing educational games in science exploration activities for 4-5 year old children

The results in Table 2 show that the application of AI in designing educational games by teachers is still limited. The majority of teachers reported using AI only occasionally in the design and organization of science exploration activities, while the percentage of teachers who use it regularly is low, and none use it very frequently. Furthermore, some teachers have never used AI to design educational games. This indicates that AI is still in its early stages of adoption and application and has not yet become a regular tool to support the professional activities of preschool teachers.

Kindergarten Substance	Kindergarten Trung Khanh		Kindergarten Hong Duc	
	Number of votes	Percentage	Number of votes	Percentage
Very effective	0	0	0	0
Quite effective	8	24,2	5	35,7
Ineffective	25	75,8	9	64,3
Inefficient	0	0	0	0

Table 3. Effectiveness of AI-designed learning games.

The results in Table 3 show that the majority of teachers rate learning games designed with AI as only slightly effective, while the rate of assessment as quite effective is still low, and there is no opinion on choosing the very effective level. This result reflects that although AI has supported teachers in building learning materials and designing learning games, the effectiveness of practical applications has not yet met expectations.

It can be seen that the level of use and effectiveness of AI applications has a close relationship. The fact that teachers have not used AI regularly leads to limited experience in exploiting AI tools, especially in building commands, choosing appropriate tools, and verifying content created by AI. This directly affects the quality of learning games as well as the effectiveness of organizing scientific discovery activities for children.

Overall, the survey results show that AI has initially supported teachers in designing learning games, but the level of use and application effectiveness is still not high. This is the basis for researching and proposing measures to foster AI application capacity and build appropriate learning game design processes to improve the effectiveness of organizing scientific discovery activities for 4–5-year-old children.

4.3. Factors influencing the application of AI in educational game design

To identify factors influencing the application of artificial intelligence (AI) in designing educational games for science exploration activities for 4-5 year olds, the research team surveyed teachers about factors related to personal competence, facilities, and the supportive environment at school.

The survey results showed that all factors assessed by teachers influenced the AI application process, with the most prominent being the teacher's AI proficiency, professional support and exchange among colleagues, children's cognitive abilities, lesson preparation time, technological equipment availability, and school support. The majority of teachers chose the levels "Influencing" and "Very Influencing," indicating that the application of AI depends not only on the teacher themselves but also on many factors from the educational environment.

Among the surveyed factors, the teacher's AI proficiency was assessed as having the greatest influence. This shows that the ability to utilize AI tools, build prompts, select appropriate tools, and validate AI-generated content is crucial for the effectiveness of educational game design. Furthermore, peer and school support play a vital role in sharing experiences, providing guidance on tool usage, and promoting AI application in professional activities. Simultaneously, facilities, technological infrastructure, and lesson preparation time also directly impact the practical implementation of AI.

Overall, the survey results indicate that the application of AI in educational game design is simultaneously influenced by human factors, technical conditions, and the organizational environment. Therefore, to enhance the effectiveness of AI application, a comprehensive approach is needed, including training teachers in digital skills, increasing investment in technological infrastructure, building a professional sharing environment, and refining the process of applying AI in organizing science exploration activities for 4-5 year olds.

4.6. Proposing a process for designing learning games using AI to organize scientific discovery activities for 4–5-year-old children

Based on the results of a survey of the current situation and an overview of research on artificial intelligence applications in education, the study proposes a five-step AI learning game design process to support preschool teachers in effectively organizing scientific discovery activities for 4–5-year-old children.

Step 1: Determine goals and select activity content

Teachers determine educational goals to be achieved, such as recognizing animals, plants, natural systems, or senses. From that goal, teachers choose appropriate game types such as jigsaw puzzles, drag-and-drop, finding the correct answer, or group discovery games.

Step 2: Use AI to build ideas and design TCHT

Use ChatGPT, Gemini, or Claude to build game ideas, create game rules, game tasks, and question systems suitable for the KPKH theme.

After creating content, teachers use Canva, Adobe Express, or Microsoft Designer to design images, flashcards, and game interfaces. For custom-made illustrations, teachers can use Leonardo AI to create images of animals, trees, or computer systems suitable for preschool children.

Next, teachers use Wordwall, Baamboozle, or Kahoot! to design interactive games such as drag-and-drop, matching, secret doors, or group question-answering games.

Step 3: Edit and organize games for children

After completing the product, teachers check and edit the content, images, sounds, colors, and difficulty level of the game to ensure it is suitable for the physiological characteristics and cognitive abilities of 4-5 year old children.

Teachers organize games in KPKH activities, instruct children how to play, explain the rules of the game, and encourage children to participate in experiences and interactions during the activity.

Step 4: Evaluate and perfect the game

After organizing children to participate in the game, teachers observe the children's level of interest, ability to interact, and performance of tasks to evaluate the effectiveness of TCHT. On that basis, teachers continue to adjust the content, images, organizational form or difficulty level of the game to perfect and improve the effectiveness of use in KPKH activities for 4-5 year old children.

The proposed process aims to promote the role of AI as a tool to support teachers, while affirming that teachers are still the decisive subject in choosing, adjusting, and organizing educational activities suitable to children's developmental characteristics.

5. SOME MEASURES FOR APPLYING ARTIFICIAL INTELLIGENCE IN DESIGNING EDUCATIONAL GAMES TO ORGANIZE SCIENCE EXPLORATION ACTIVITIES FOR 4-5 YEAR OLD CHILDREN IN PRESCHOOLS

Based on the results of the survey on the current situation, analysis of influencing factors, and the process of designing AI-powered educational games, this study proposes and develops three measures to improve the effectiveness of applying artificial intelligence in designing educational games to organize science exploration activities for 4-5 year old children in preschools.

5.1. Training the AI Application Capacity of Preschool Teachers

The survey results show that the ability of teachers to use artificial intelligence (AI) is the biggest influencing factor on the effectiveness of designing educational games to serve science exploration activities. Although most teachers have accessed and used some AI tools such as ChatGPT, Gemini, and Canva AI, their exploitation is still mainly limited to creating images, videos, or suggesting ideas; The skills in constructing prompts, verifying, and adjusting AI-generated content are limited. Therefore, developing teachers' AI application capabilities is a fundamental measure.

The training content should aim to simultaneously develop knowledge, skills, and attitudes for using AI in early childhood education. Teachers need to be equipped with knowledge about AI generation, principles of safe and responsible AI use, and guidance on exploiting AI tools appropriate to the characteristics of early childhood education. The focus of the training program should be on the skills of constructing prompts, selecting and evaluating AI-generated products, and editing them to ensure accuracy, pedagogical effectiveness, and suitability for the developmental characteristics of 4-5 year old children.

The training should be organized in the form of workshops combined with practical exercises, professional development activities based on lesson study, and experience sharing within the professional team. The school needs to create conditions for teachers to regularly update their knowledge of new AI tools, participate in online courses, and build a learning community to support each other in the application of AI.

Implementing this measure effectively will contribute to improving teachers' digital skills, increasing their ability to effectively utilize AI, and laying the groundwork for innovating science exploration activities in line with digital transformation in preschool education.

5.2. Building a digital learning materials system and prompt bank for designing learning games

One of the difficulties teachers reflected in the survey was not knowing how to build effective prompts and spending a lot of time searching for and editing AI-generated learning materials. Therefore, building a digital learning materials system combined with a prompt bank is a necessary measure to support teachers in effectively utilizing AI tools in designing learning games for science exploration activities for 4-5 year old children.

The digital learning materials system should be organized according to themes in the Early Childhood Education Program, such as plants, animals, water, air, weather, and natural phenomena. Each theme should include images, videos, audio, flashcards, sample games, and visual materials that have been scientifically and pedagogically validated by teachers. In addition, a prompt bank should be developed for each purpose, such as generating game ideas, designing illustrations, creating game rules, generating open-ended questions, or designing worksheets. The prompts should be standardized in structure, have usage instructions, and be illustrated with output products to facilitate teacher selection, adjustment, and application in practice.

Building and using a shared digital learning materials system along with a prompt bank will not only save teachers time in designing materials but also improve the quality of AI-generated products and reduce errors during use. At the same time, this also serves as a basis for enhancing expertise sharing, forming a shared digital learning resource repository within the school, and contributing to promoting the effective, unified, and sustainable application of AI in preschool education.

5.3. Strengthening the conditions supporting AI application in schools

The effectiveness of AI applications in designing learning games depends not only on the teacher's capabilities but also on the physical infrastructure, technological infrastructure, and supportive environment of the school. Survey results show that factors such as technological equipment, support from colleagues, school attention, and lesson preparation time all significantly impact the AI application process. Therefore, it is necessary to strengthen the conditions to ensure that AI is effectively implemented in practice.

First, schools need to invest in digital equipment systems, stable internet connections, and software to support the design of learning materials, creating conditions for teachers to access and use AI tools in their professional activities. In addition, it is necessary to build a shared digital learning resource repository, storing educational games, images, videos, and validated prompt systems so that teachers can refer to, share, and further develop them.

Besides ensuring the technical conditions, the school needs to build a positive professional learning environment.

6. PEDAGOGICAL EXPERIMENT

6.1. Objectives and Subjects of the Experiment

The pedagogical experiment was conducted to verify the feasibility and effectiveness of applying artificial intelligence (AI) in designing educational games to support the organization of science exploration activities for 4-5 year old preschool children. Specifically, the study evaluated the ability of the process to support teachers in designing educational games suitable for educational goals, reducing the time spent preparing learning materials, and improving the quality of organizing science exploration activities.

The subjects of the experiment included 10 teachers currently teaching 4-5 year old preschool classes at Trung Khanh Preschool and Duc Hong Preschool, Cao Bang province. The teachers had equivalent professional qualifications, voluntarily participated in the study, and received training on using the AI-powered educational game design process before the experiment was implemented.

The experiment was conducted over 8 weeks with scientific exploration topics suitable for the

Preschool Education Program, such as plants, animals, water, air, and natural phenomena.

6.2. Experimental Content and Procedure

During the experiment, teachers used AI generation tools such as ChatGPT, Gemini, and Canva AI to design learning games according to the five-step process proposed in the study: (1) identifying the goals and content of the activity; (2) selecting the AI tool and building the prompt; (3) designing, editing, and perfecting the learning game; (4) organizing the scientific exploration activity; and (5) evaluating, adjusting, and storing the learning materials.

The effectiveness of the process was evaluated through the following criteria: (i) the suitability of the game to the educational goals; (ii) its attractiveness and ability to engage children; (iii) the level of support for teachers in designing learning materials; (iv) the ability to foster children's active participation and exploratory interest; and (v) the level of teacher satisfaction with the use of AI.

Data were collected using observation forms, teacher evaluation forms, post-experiment interviews, and teacher-designed learning game products. Results were processed using descriptive statistics to compare before and after the experiment.

6.3. Experimental Results and Discussion

The experimental results show that the process of applying AI in designing learning games is feasible and effective in the practical conditions of the preschools participating in the study. After the application period, teachers became more proficient in using AI tools to develop ideas, design images, create learning materials, and complete learning games. The time spent preparing learning materials was shortened, while the quality and visual appeal of the games were significantly improved.

AI-powered learning games make scientific exploration more engaging, creating more opportunities for children to observe, experience, exchange ideas, and solve problems. Teachers noted that children participated more actively, were more interested in learning activities, and demonstrated better observation, comparison, prediction, and expression skills.

Besides the positive results, the experiment also revealed some limitations. The quality of AI-generated products still depends significantly on the teacher's command-building skills. Some content needs to be modified to ensure accuracy and suitability for educational goals and children's developmental characteristics. Furthermore, technological infrastructure and teachers' digital skills remain factors affecting the effectiveness of AI implementation in practice.

Overall, the experimental results confirm that the proposed process can be effectively applied in early childhood education. AI serves as a tool to assist teachers in designing learning materials and innovating methods for organizing science exploration activities, but it does not replace the professional role of teachers in selecting content, adapting products, and organizing educational activities suitable for children.

7. CONCLUSION

This study assessed the current state of artificial intelligence (AI) application in designing educational games for organizing science exploration activities for 4-5 year old preschool children in two preschools in Cao Bang province. The results showed that teachers had initially used AI-generated tools such as ChatGPT, Gemini, and Canva AI to design learning materials, images, and educational games. However, the level of application was limited and affected by many factors such as teachers' AI proficiency, technological infrastructure conditions, school support, and lesson preparation time.

Based on the survey results and theoretical overview, the study proposed a five-step process for designing AI-powered educational games along with three measures to improve the effectiveness of AI application in organizing science exploration activities. The results of the pedagogical experiment show that the proposed process and measures are feasible, contributing to improving teachers' AI application capabilities, enhancing the quality of learning game design, and increasing children's interest and active participation in scientific exploration activities.

The research contributes to supplementing the theoretical and practical basis for AI application in preschool education, while also providing a reference for teachers and administrators in the process of implementing digital transformation. However, due to the limited scope of the survey in

two preschools with a small sample size, further studies need to expand the scope, increase the sample size, and continue to evaluate the effectiveness of new AI generation tools in different educational contexts.

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