

# Design of Classroom Teaching Model Based on Artificial Intelligence Technology Optimization for Promoting Students' Deep Learning in Convergent Environments

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**Abstract:** Deep learning is the inevitable point of deepening curriculum reform in Chinese primary and secondary schools and educational change in the age of intelligence, as well as one of the important channels for the development of core literacy. Based on this, the study is based on the development trend of artificial intelligence technology, guided by the theories of online-offline integrated teaching, deep learning and smart classroom, comprehensively adopting quasi-experimental research, independent samples t-test, covariance test and other methods, innovatively constructing a smart classroom (AI-DELC) model that promotes students' deep learning in the environment of online-offline integration, and carrying out the classroom teaching practice with an elementary school in Guangzhou City. The study shows that the AI-DELC teaching model under the online-offline integration environment can effectively enhance students' deep learning effect, implement the core literacy of disciplines, develop students' higher-order thinking, and cultivate students' abilities such as knowledge transfer, problem solving and reflection.

**Keywords:** artificial intelligence; deep learning; smart classroom; AI-DELC model; integrated environment

## 1. Introduction

With the deepening of the digital transformation of education, the requirements for the quality of smart classroom teaching in the field of higher education have been increasing. Wisdom education under the integration of technology and educational environment has become a new trend and inevitable trend leading the innovative development action of China's education informatization [1-2]. For the cultivation goal of comprehensive quality talents in higher education, classroom teaching not only helps students to acquire knowledge and improve their skills, but also needs to cultivate students' higher-order thinking skills such as innovative consciousness, critical thinking, communication and cooperation, and problem solving, and to guide students to establish positive will qualities and correct values [3-7]. From the perspective of learning science, students' deep learning is relative to superficial learning, mechanical learning and meaningless learning. Deep learning is a continuous learning process that focuses on developing higher-order thinking skills and promoting the formation of positive emotions, attitudes, and values [8]. In this process, students master the core knowledge of the subject, develop positive intrinsic motivation, social-emotional, attitudes, and values, and become excellent learners who are both independent, critical, creative, and cooperative with a solid foundation [9-12].



Compared with the traditional classroom, the technology-enabled smart classroom breaks the limitation of time and space, effectively supports teaching and learning interaction, and at the same time can pay attention to the needs of students' individualized learning [13-14]. In the smart classroom, the way of knowledge presentation, student learning and evaluation are diversified, which can fully mobilize the enthusiasm of learners, promote their spontaneous to explore the problem, communication and collaboration, and provide a high-quality intelligent teaching environment for deep learning [15-17]. The promotion effect of smart classroom on deep learning is not inevitable, as illustrated by the phenomenon of no significant difference. Therefore, in order to make the smart classroom play a real effectiveness to promote the comprehensive development of higher vocational students, it is necessary to understand and analyze the academic situation, learning characteristics and habits of higher vocational students, and to systematically design the smart classroom teaching mode under the guidance of deep learning theory [18-21].

In the context of the wide application of the smart classroom education model, some scholars have studied the optimal design of classroom teaching based on artificial intelligence. Ilgun Dibek, M. et al. showed that students' higher-order thinking ability is one of the important educational goals in the current era, and the integration of artificial intelligence technology to optimize the teaching settings can effectively enhance students' learning of popular skills [22]. Lu, K. et al. used the 3P (foresight-process-product) model to study the link between college students' AI literacy and higher-order thinking skills, emphasizing the full integration of the cultivation of AI literacy and other indicators in curriculum design to promote the further improvement of students' higher-order thinking skills [23]. Xu, Y. et al. explored the impact of a digital game-based AI chatbot system on students' behavioral patterns, and applied it to the teaching of the curriculum, which can stimulate students' motivation to learn and assist in the construction of the knowledge system, and moreover promote the cultivation of students' higher-order thinking skills [24]. Borge, M. et al. established chat-based Generative Artificial Intelligence (GenAI), which has a wide range of applications in curriculum teaching and learning as a collaborative human-computer interaction tool that creates learning environments that help learners explore skill practice and debate practice [25]. Liu, J. et al. investigated the factors and mechanisms influencing the development of students' higher-order thinking skills in a smart curriculum environment and found that the use of smart devices and the enhancement of self-efficacy strengthened students' learning experience and motivation, which in turn facilitated the improvement of students' higher-order thinking skills [26].

Mayasari, N. et al. investigated that AI learning tools with customized educational content significantly enhanced students' critical thinking skills, providing valuable insights into the instructional design of courses that develop students' higher-order thinking skills [27]. Baskoro, G. et al. emphasized the effectiveness of AI in the classroom on students' critical thinking skills, which are based on the development of higher-order thinking skills, as well as demonstrated that the misuse of AI apps can lead to a decrease in students' creativity and critical inquiry skills [28]. Ma, X. et al. developed a structural model of teacher-student interaction in a smart classroom environment, which not only improves the quality of teaching by smart teachers and develops students' hot skills, but also plays an important role in the development of students' higher-order thinking skills [29]. Hadzhikolev, E. et al. proposed a hierarchical multivariate evaluation model oriented to the educational format of online courses, which provides a comprehensive assessment of the level of higher-order thinking skills and practical skills of students, quantifies the subjective logic of the evaluator, and promotes the development of high quality of teaching and learning [30]. In summary, in order to solve the problem that the current smart classroom teaching lacks "depth", which is not enough to support the connotative development of smart classroom teaching in higher education, and it is difficult to trigger students' "deep learning", it is of great significance to study the optimization of classroom teaching mode based on artificial intelligence technology. It is of great significance to study the optimization of classroom teaching mode based on artificial intelligence technology.

Based on the online-offline integrated learning environment, this study carries out the design and practice of a smart classroom with artificial intelligence technology to promote students' deep learning through theoretical and quasi-experimental research, with a view to implementing the core literacy of the discipline, developing students' critical thinking, cultivating students' higher-order abilities, and enhancing students' sense of reflection, so as to provide primary and secondary school teachers with the opportunity to carry out the practice of online-offline integrated classroom that promotes students' deep learning. Theoretical reference and practical reference for primary and secondary school teachers to carry out the practice of online-offline integrated classroom to promote students' deep learning.

## **2. Smart classroom design for deeper student learning in an inclusive environment**

### *2.1. Rationale*

#### **2.1.1. Artificial Intelligence**

Artificial Intelligence, abbreviated as AI, is a new technological science that researches and develops the theories, methods, technologies and application systems used to simulate, extend and develop human intelligence. Artificial Intelligence is a branch of computer science, and AI has research areas such as natural language processing, image recognition, and expert systems. From the nineteen sixties, the theory and technology of artificial intelligence is becoming more and more mature, and the artificial intelligence products are more and more, and also carry human intelligence. Artificial Intelligence can simulate human thinking, and can simulate human consciousness and thinking process. Artificial intelligence is not human intelligence, but can think like a human being and may also exceed human intelligence.

With the increasingly wide application of artificial intelligence in the field of education, this paper analyzes the latest artificial intelligence technology, combines artificial intelligence with classroom teaching, lands in the actual teaching work, and analyzes the behavior of teachers and students, so as to effectively promote students' deep learning.

#### **2.1.2. Deep Learning Process Model**

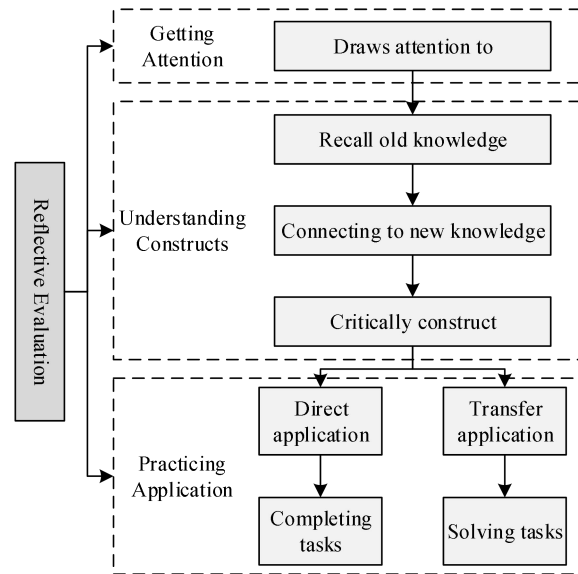
From the perspective of learning science, deep learning is relative to surface learning, mechanical learning and meaningless learning. Deep learning not only focuses on learning results, but also on the learning process, especially the experience and feelings of learners in real problem situations. Deep learning has four significant features:

First, focus on the development of critical thinking. Deep learning requires learners to be able to learn knowledge critically in the process of constructing their own knowledge system, so as to form their own understanding.

Second, it emphasizes the transfer and application of knowledge. Deep learning requires learners to apply relevant knowledge and skills to different learning situations on the premise of critically understanding what they have learned, so as to be able to integrate and apply what they have learned.

Third, real-life-oriented problem solving. Deep learning requires learners to be able to skillfully apply what they have learned to solve complex problems in real life.

Fourth, the cultivation of reflective consciousness is emphasized. Deep learning requires students to reflect on the learning process, construct a complete knowledge structure in the process of reflection, and discover their own deficiencies and defects and make improvements. In this study, according to the connotation and characteristics of deep learning, based on the deep learning (DELIC) route, we constructed a 1 deep learning process model as shown in Figure 1. Specifically, it includes four stages: drawing attention, understanding and constructing, practicing and applying, and reflecting and evaluating.



**Figure 1.** Deep learning process model

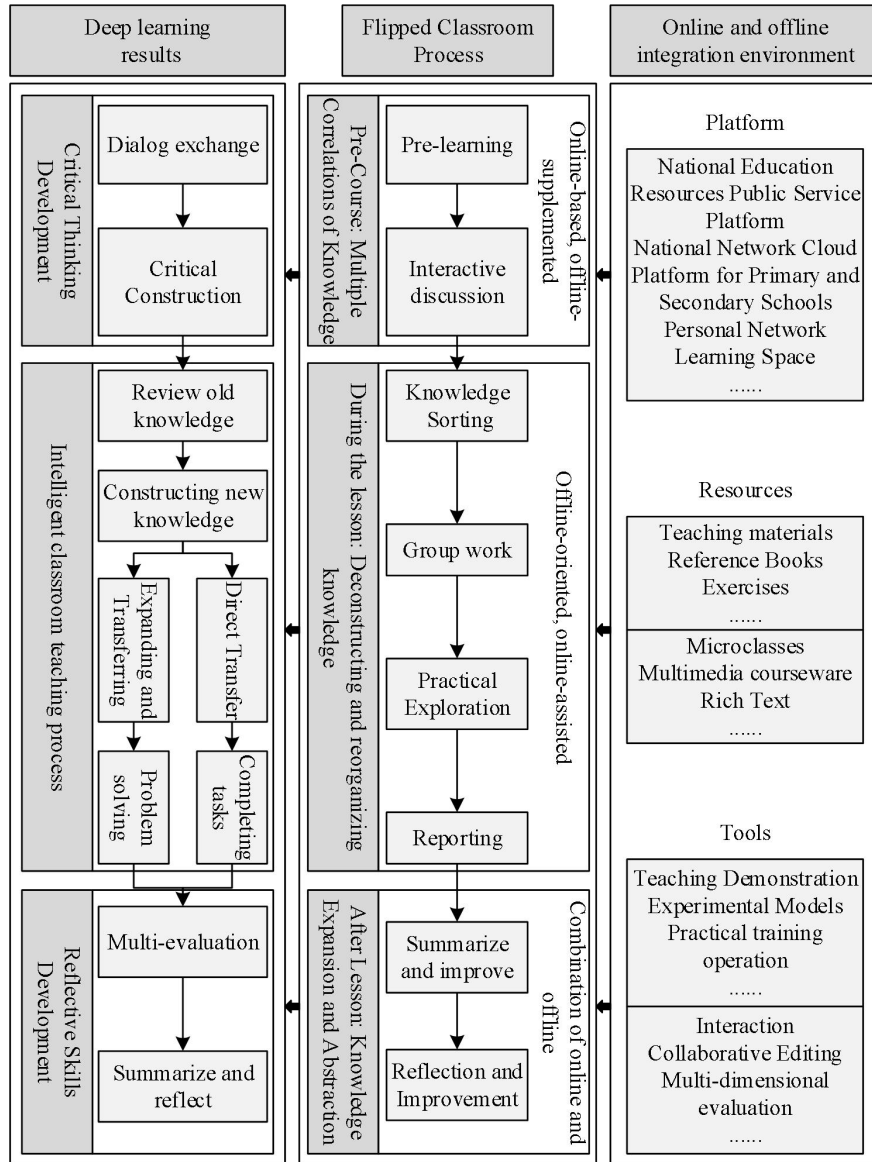
### 2.1.3. Online and offline integration of teaching and learning environments

Online-offline integrated teaching refers to the organic integration of online teaching practice and offline teaching practice with new information technology such as big data analysis and artificial intelligence as innovative elements, so as to effectively maximize the benefits of teaching and learning. Online and offline integrated teaching is not only a simple addition of "online teaching" and "offline teaching" to produce a "physical reaction", but also a "chemical reaction" between the two interdependence and mutual integration, which in turn gives birth to a new teaching ecology.

Specifically, online-offline integrated teaching is characterized by strong systematicity, flexibility, interactivity and innovativeness. On-line and off-line integrated teaching emphasizes diversified information technology means as innovative elements to reorganize the teaching content, retune the form of interaction, reconfigure the teaching mode and reshape the evaluation method.

### 2.2. Smart Classroom Teaching Model Design

This study is guided by the theory of online-offline fusion teaching, based on the deep learning process model and the application process of artificial intelligence technology in the field of education, combined with the real needs of teaching in the intelligent era, to construct a smart classroom design model that promotes students' deep learning under the online-offline fusion environment as shown in Figure 2. The model mainly consists of three parts, including the online-offline fusion environment, the smart classroom teaching process and the deep learning results. The online-offline integration environment is the basis of the design model, which can effectively support the flipped classroom teaching practice that promotes students' deep learning.



**Figure 2.** Smart classroom design model for promoting deep learning in integrated environment

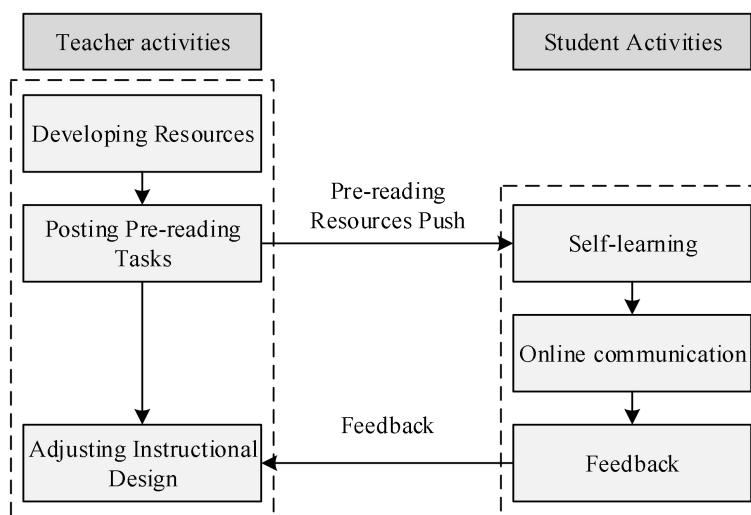
It should be noted that the online-offline integration environment includes not only offline physical places but also online virtual spaces. Specifically, it includes applicable learning platforms, rich teaching resources and practical teaching tools. Among them, the learning platform mainly provides students with the convenience of online learning. Teaching resources include not only offline resources such as textbooks, reference books and supporting exercises, but also online resources such as microclasses, multimedia courseware and rich texts. Teaching tools support offline teaching demonstrations, experimental simulations and hands-on training operations, etc., and also help online interactive exchanges, collaborative editing and multidimensional evaluation.

The teaching process of a smart classroom that promotes students' deep learning in an online-offline integration environment is a core part of the instructional design. This study divides the teaching process of the smart classroom into three stages: pre-class preview, in-class teaching and post-class consolidation, each of which contains teacher activities and student activities. The specific contents are as follows:

### 2.2.1. Pre-course preparation phase

The specific flow of the pre-course pre-study stage is shown in Figure 3. The pre-course preparation is mainly focused on the completion of online, first, the teacher with the teaching content and with the results of the pre-analysis of the preliminary teaching design and development of pre-study resources,

and then through the online teaching platform of the teacher's side of the pre-study tasks issued to the students, push pre-study resources. After receiving the pre-study tasks, students need to do independent pre-study to complete the pre-study tasks, and if they don't understand anything in the process of completing the tasks, they can communicate with teachers and classmates in real time by using the online teaching platform as a medium. Teachers can adjust and improve the teaching design based on the completion of students' pre-study collected by the online teaching platform.



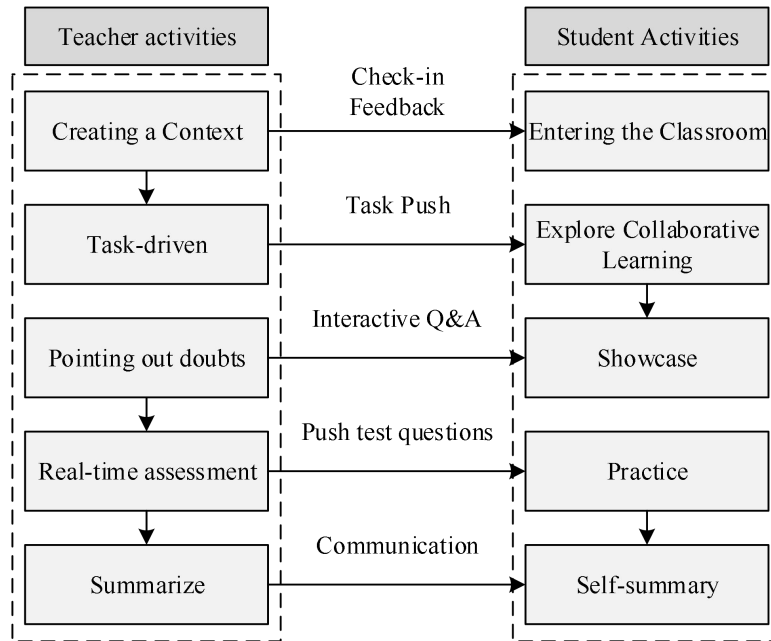
**Figure 3.** Activity design in the pre-class preview stage

### 2.2.2. Teaching phase in the classroom

Teaching in the classroom is the core stage of the smart classroom, where teachers will teach according to the optimized teaching design before class. Traditional classroom teaching is usually in the form of teachers teaching and students listening or teachers demonstrating and students practicing, with a lack of effective interaction between teachers and students. However, in the smart classroom, teachers and students can utilize the online teaching platform for full and effective interaction. In the middle of the classroom teaching stage, the main online and offline integration of teaching, guiding students to internalize the content of knowledge.

In the process of offline teaching, teachers first sort out the knowledge content on the online teaching platform, then set up learning tasks, let students form learning groups, carry out practical exploration, and finally report and display the results of learning. In this process, students deconstruct and reorganize their knowledge, solve multiple related problem chains, and then continuously improve their knowledge system. In terms of the results of deep learning, students review old knowledge, construct new knowledge, and then utilize the learned knowledge and content to complete the learning tasks and solve problems in real situations, thus cultivating higher-order abilities such as knowledge transfer and problem solving.

The specific flow of the teaching stage in the classroom is shown in Figure 4, the teacher attracts students' attention by creating a situation and poses questions in the situation to guide students' thinking, and teachers and students can interact and communicate with each other on the basis of the questions; at the same time, the teacher continues to explore the issues in depth, introduces the learning tasks and pushes them to the students with the help of the platform, so that the students receive the tasks and carry out inquiry and collaborative learning, and the teacher can also monitor the students' task completion in real time through the platform data. Teachers can also monitor students' task completion through the platform data in real time. After students complete the task through inquiry and cooperation, the teacher invites students to present their results and explain their ideas, and teachers and students can interact with each other to answer questions.

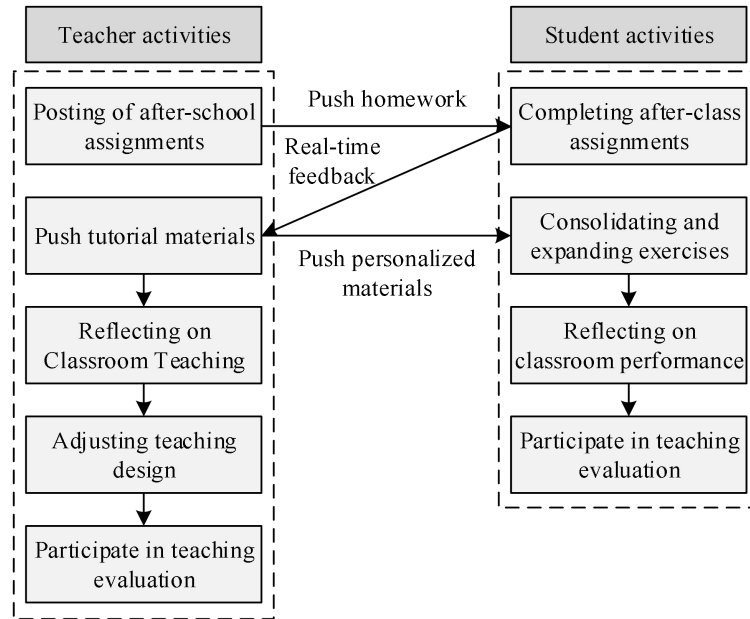


**Figure 4.** Activity design of the teaching stage in the course

Afterwards, the teacher summarizes the students' problems in the presentation and provides detailed and in-depth explanations to enable students to form a clear and systematic knowledge system. After the problems are explained, the teacher can further push the accompanying test questions to the students through the online teaching platform to understand the students' knowledge mastery, so as to adjust the teaching. Finally, teachers and students can summarize the classroom through interactive communication to help students consolidate what they have learned in the classroom.

### 2.2.3. Post-course consolidation phase

The specific flow of the after-class consolidation stage is shown in Figure 5. First, the teacher pushes homework to the students through the online teaching platform, and the students complete the after-class homework on the student side, and then the teacher pushes diversified tutoring materials to the students through the platform as a medium according to the students' classroom performance and homework completion. For students who have a deeper understanding of knowledge, more in-depth learning resources can be pushed to him, and for students who do not have a good command of knowledge, some simple learning resources can be pushed to him, so that he can be targeted to break through one by one, and thoroughly master the knowledge.



**Figure 5.** The activity design of after-school consolidation phase

Afterwards, teachers and students will reflect on the lesson to adjust their teaching and learning, teachers can improve the teaching tasks and adjust the teaching design to prepare for the future teaching, and students can adjust their learning strategies and methods to face the future learning in a better state of mind. Finally, teachers and students conduct online and offline teaching evaluation together, including teacher's evaluation of students, students' mutual evaluation and students' self-evaluation. Teachers can design certain evaluation scales for more reasonable and effective evaluation.

### 3. Practical research on intelligent classroom teaching models

#### 3.1. Experimental preparation

##### 3.1.1. Purpose of the experiment

The experimental purpose of this study is to carry out a smart classroom teaching practice that promotes students' deep learning with the unit content of Parallelograms and Trapezoids in the fourth grade of elementary school of the Humanistic Version of Mathematics. The effectiveness of the Smart Classroom Model for Promoting Students' Deep Learning in Convergent Environments (hereinafter referred to as, AI-DELC model) constructed in this study was verified through the method of quasi-experimental research in terms of the four aspects of critical thinking in deep learning, the ability to transfer knowledge, the ability to solve problems, and the awareness of reflection.

##### 3.1.2. Subjects

This study takes the fourth grade of an elementary school in Guangzhou City as the practice object, 104 students in the fourth grade of the school were randomly selected as the experimental subjects, 52 in the experimental group and 52 in the control group. Before the experiment, the experimental group and the control group were simultaneously tested in four aspects: critical thinking, knowledge transfer ability, problem solving ability and reflective consciousness. During the experiment, the experimental group was taught in AI-DELC mode and the control group was taught in traditional teaching mode. After the experiment, the experimental group and the control group were tested on four aspects of critical thinking, knowledge transfer ability, problem solving ability and reflective consciousness at the same time.

##### 3.1.3. Practical content

Teaching practices that promote deep student learning are carried out with the unit content of Parallelograms and Trapezoids in the fourth grade of the Humanistic Version of Mathematics. The unit teaching of Parallelograms and Trapezoids is mainly carried out in an on-line and off-line integrated

environment, and the unit teaching content is mainly to help students establish geometric concepts, spatial concepts, and experience abstract ideas. At the same time, in the course of unit teaching, teachers require students to be able to abstract parallelograms and trapezoids according to the characteristics of common objects in life, and to be able to imagine the actual objects described according to parallelograms and trapezoids; at the same time, students should be able to consciously utilize the concepts of parallelism and perpendicularity, and the principles and methods of drawing perpendicular lines to critically solve real-life problems. They should be able to abstract real-life problems into problems related to parallelograms and trapezoids, understand them using mathematical ideas, and solve them through mathematical methods.

In this study, the unit of Parallelograms and Trapezoids was designed according to the design method of “large unit, task group”, and the specific contents are shown in Table 1. The practical content consists of 7 hours, including parallel and perpendicular (T1), drawing perpendicular lines (T2), definition of parallelogram (T3), definition of trapezium (T4), drawing parallelograms (T5), drawing trapezoids (T6), and review of the unit on parallelograms and trapezoids (T7).

**Table 1.** Teaching design of "Parallelogram and Trapezoid" unit

Class hour	Learning content		Learning task	
1	Parallel and vertical	Before class	T1-1	Discuss the definition, connotation and detection of parallel and vertical.
		In class	T1-2	Explore the position relationship of two lines on the same plane.
			T1-3	Explore the type of intersection of two lines.
			T1-4	Illustrate common parallel and vertical cases in life.
		After class	T1-5	Use parallel and vertical knowledge to build graphs and think about the shortcomings of the learning process.
1	Draw perpendicular lines	Before class	T2-1	The common methods of drawing vertical lines are discussed and the detection exercises are completed.
		In class	T2-2	Explore a point on the line to draw the vertical line of the line.
			T2-3	Look beyond the line and draw the vertical line of the line.
			T2-4	Use vertical knowledge to draw rectangles and squares.
		After class	T2-5	Use the knowledge of drawing vertical lines to find the shortest distance and think about the shortcomings in the learning process.
...	...	...	...	
1	Review of parallelogram and trapezoid units	Before class	T7-1	Explore the relationship between parallelograms and trapezoids, rectangles and squares and complete testing.
		In class	T7-2	Sorting out vertical, vertical, parallelogram and trapezoid knowledge.
			T7-3	Recognize and abstract the parallelogram and trapezoid in life.
		After class	T7-4	Complete the parallelogram and trapezoid comprehensive exercises and summarize the learning methods and share the perception.

### 3.2. Deep Learning Effectiveness Analysis

#### 3.2.1. Independent samples t-test

Compared with shallow learning, deep learning has a unique role to play in the implementation of disciplinary core literacy and the development of students' higher-order thinking skills. Deep learning focuses on the development of students' critical thinking, emphasizes the transfer and application of knowledge, is oriented to real-life problem solving, and attaches importance to the cultivation of

reflective consciousness. Based on this, this study mainly evaluates the effect of deep learning from four aspects: critical thinking, knowledge transfer ability, problem solving ability and reflective consciousness.

The author first compares the differences between the experimental group and the control group in the four dimensions of critical thinking, knowledge transfer ability, problem solving ability and reflective consciousness in deep learning, and conducts independent samples *t* tests on the pre-tests and post-tests of the experimental group and the control group respectively by using spss21.0 software, in order to analyze the influence of different teaching modes on the effect of deep learning.

The statistical results of the pre-test of the evaluation of the deep learning effect of the experimental group and the control group are shown in Table 2, which shows that the difference between the means of the two groups in the four dimensions of the evaluation of the deep learning effect is 0.05, 0.05, 0.04, and 0.06, which is a small difference, respectively.

**Table 2.** Pre-test statistical results of deep learning effect evaluation

Experimental control		N	Mean	Standard deviation	Mean standard error
Critical thinking level	Experiment group	52	3.06	0.415	0.036
	Control group	52	3.11	0.327	0.042
Knowledge transfer ability	Experiment group	52	3.34	0.483	0.041
	Control group	52	3.39	0.509	0.039
Problem solving ability	Experiment group	52	3.47	0.448	0.056
	Control group	52	3.43	0.473	0.062
Reflective consciousness	Experiment group	52	3.08	0.606	0.057
	Control group	52	3.14	0.589	0.055

Next, the pre-test results of the deep learning level of the experimental group and the control group were subjected to the independent samples *t* test, and the results are shown in Table 3. It can be seen that the value of “Sig. (two-sided)” is 0.165, which is greater than the significance level of 0.05, indicating that there is no difference in the level of deep learning between the experimental group and the control group before the experiment, which indicates that the level of deep learning of the two groups is at the same level, and the subsequent teaching experiment can be carried out.

**Table 3.** Independent sample T-test of deep learning pre-test results

Levene and T-test			Pretest mean of critical thinking level	
			Assume equal variance	Suppose the variances are not equal
Levene test of variance equation	F		3.008	-
	Sig.		0.183	-
	<i>t</i>		1.015	1.026
	Df		183	153.32
	Sig. (both sides)		0.165	0.165
Levene test of variance equation	Mean difference value		0.03	0.03
	Standard error value		0.033	0.031
	95% confidence interval of the difference	Lower limit	0.035	0.34
		Upper limit	0.337	0.337

After the two classes went through different teaching modes and studied Parallelograms and Trapezoids for a total of seven lessons, the two groups of students were tested on their critical thinking levels and the posttest statistics were obtained as shown in Table 4. It can be seen that the difference between the means of the two groups in the four dimensions of deep learning is 0.26, 0.31, 0.24, and 0.17.

**Table 4.** Post-test results statistics of four dimensions of deep learning

Experimental control		N	Mean	Standard deviation	Mean standard error
Pretest mean of critical thinking level	Experiment group	52	3.39	0.407	0.050
	Control group	52	3.13	0.473	0.044
Knowledge transfer ability	Experiment group	52	3.72	0.583	0.061
	Control group	52	3.41	0.411	0.049
Problem solving ability	Experiment group	52	3.65	0.485	0.043
	Control group	52	3.41	0.461	0.055
Reflective consciousness	Experiment group	52	3.29	0.572	0.054
	Control group	52	3.12	0.554	0.061

The results of the independent samples *t* test on the posttest of the level of deep learning in the experimental group and the control group are shown in Table 5. It can be seen that the value of “Sig. (Bilateral)” is 0.003, which is less than the significance level of 0.05. It can be shown that there is a significant difference in the level of critical thinking posttest between the experimental group and the control group, and the results of the pre and posttests are higher for the experimental group than for the control group. Since the control variable in this experiment is caused by the mode of instruction, it can thus be determined that the level of deep learning of the students in the experimental group has been significantly increased by the AI-DELC mode of instruction.

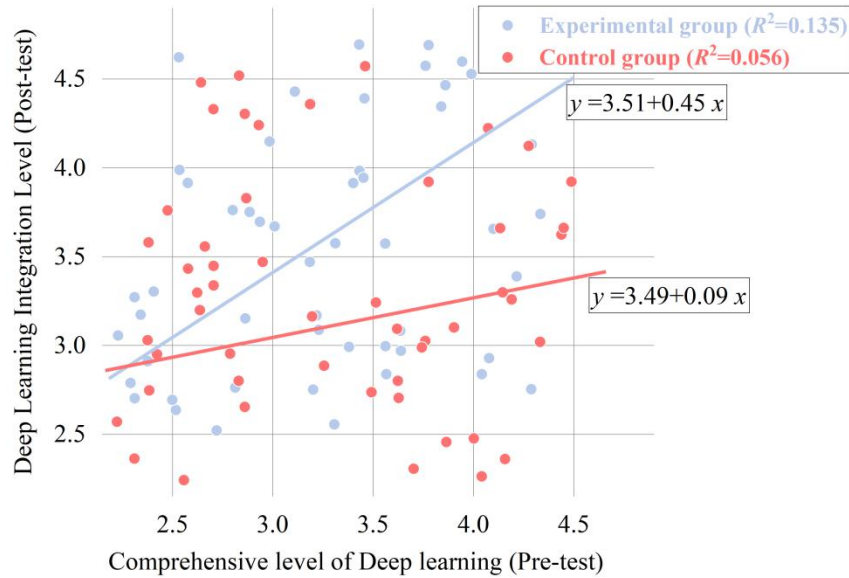
**Table 5.** Independent sample T-test of post-test results of critical thinking level

Levene and T-test		Pretest mean of critical thinking level		
		Assume equal variance	Suppose the variances are not equal	
Levene test of variance equation	F	3.874	-	
	Sig.	0.031	-	
	<i>t</i>	3.744	3.745	
	Df	167	161.66	
Levene test of variance equation	Sig. (both sides)		0.003	0.003
	Mean difference value		0.245	0.245
	Standard error value		0.065	0.065
	95% confidence interval of the difference	Lower limit	0.131	0.132
		Upper limit	0.485	0.485

### 3.2.2. Analysis of covariance

This study continues to use analysis of covariance to further examine the effect of the AI-DELC model on students' level of deep learning in order to increase the credibility of the study. The pre-test mean of the composite level of deep learning (the mean of the four dimensions of the evaluation of deep learning effects) was the covariate, the post-test mean was the dependent variable, and the teaching mode was the independent variable. Before conducting the analysis of covariance, the author checked whether the data met the prerequisites for the analysis of covariance.

First, the scatter of the two groups of students' comprehensive level of deep learning was plotted as shown in Figure 6. It can be seen that the  $R^2$  of the two groups of data are 0.135 and 0.056 respectively, indicating that there is a linear relationship between the covariates and the dependent variable, which can be tested for covariance.



**Figure 6.** Deep learning integrated horizontal scatter plot

Next, the between-subjects effect of the comprehensive level of deep learning was tested, and the results are shown in Table 6. The significance value of the interaction term of the control factors and covariates “teaching mode\*deep learning comprehensive level pre-test mean” is 0.252, which is greater than 0.05, indicating that the interaction effect between the control factors and covariates is statistically insignificant, and in summary, the covariates and control factors satisfy the conditions for the analysis of covariance.

**Table 6.** The effect test between subjects at the comprehensive level of deep learning

Dependent variable: Comprehensive level of deep learning					
Source	Class III sum of squares	Degree of freedom	Mean square	F	Sig.
Corrected model	5092.87 <sup>a</sup>	4	2074.81	7.251	0.002
Intercept	50785.05	1	60972.83	185.78	0.000
Group	15.060	1	15.845	0.037	0.734
Comprehensive level of deep learning	4938.52	1	4816.23	18.543	0.000
Teaching mode* Comprehensive level of deep learning	455.83	1	406.83	1.706	0.252
Mistake	57331.18	166	309.28		
Total	708424.00	173			
Total variation after correction	59060.41	172			

a: R squared =0.118 (Adjusted R squared =0.091)

After the covariance analysis, the effect between subjects of the integrated level of deep learning is obtained as shown in Table 7, and its covariance analysis results are shown in Table 8. According to the between-subjects effect test results in the teaching mode row of the Sig. value of 0.017, which is less than 0.05. Root covariance analysis results, it can be found that, after eliminating the effect of the experimental pre-test, the experimental group and the control group post-test of the depth of the learning integrated water mean adjusted to 3.5184, 3.2669, and the deviation of  $\eta^2$  is 0.028.

**Table 7.** Test of inter-subject effects after covariance analysis

Dependent variable: Comprehensive level of deep learning						
Source	Class III sum of squares	Degree of freedom	Mean square	F	Sig.	Partial Eta squared
Corrected model	4635.06 <sup>a</sup>	3	2838.05	8.543	0.000	0.081
Intercept	51834.78	1	61182.34	185.52	0.000	0.534
Deep learning comprehensive level of pre-test value	4535.08	1	4535.75	13.758	0.000	0.081
Teaching mode	1783.68	1	1570.74	5.438	0.017	0.025
Mistake	53447.91	165	382.46			
Total	738452.00	173				
Total variation after correction	58969.93	172				

a: R squared =0.098 (Adjusted R squared =0.082)

**Table 8.** Deep learning comprehensive level covariance analysis results (Post-test)

Group	N	Mean	SD	Adjusted mean	SE	F	$\eta^2$
Experiment group	52	3.5125	0.425	3.5184	2.05	5.72	0.028
Control group	52	3.2675	0.504	3.2669	2.00		

The above results show that after completely eliminating the influence of the comprehensive level of deep learning pre-test on the level of post-test, there is still a significant effect of different teaching modes on the final level of deep learning. This is consistent with the results of the previous test and analysis, i.e., the smart classroom teaching mode based on AI technology optimized to promote students' deep learning in the convergence environment constructed in this paper can significantly improve students' deep learning compared with the traditional teaching mode.

## 4. Conclusion

### (1) Research Summary

With the purpose of promoting students' deep learning, taking artificial intelligence as the technical guidance and design principle, and taking the teaching content of the Humanities Teaching Edition of mathematics as an example, this study applies the designed smart classroom teaching model based on the fusion environment and the optimization of artificial intelligence technology to promote students' deep learning to the teaching of elementary school mathematics classroom through quasi-experimental research and other research methods. A quasi-experimental teaching study was conducted to analyze and verify the effectiveness of the teaching model on students' deep learning. We have solved the problem of deep learning in this study by shifting from traditional classroom “teacher-led + students' passive learning” to “teacher-led + students' active”, analyzed the teaching objectives of deep learning based on artificial intelligence and the objectives of multivariate evaluation, and explored the theoretical relationship between artificial intelligence technology and deep learning. It analyzes the teaching objectives and multiple evaluation objectives of deep learning based on artificial intelligence, explores the theoretical relationship between artificial intelligence technology and deep learning, designs the teaching mode according to the theory of online-offline integration, innovates the classroom teaching mode, and integrates the cultivation of disciplinary literacy and deep learning.

Focusing on a series of research questions such as whether the model is effective for students' deep learning, the research was carried out through quasi-experimental research, independent sample test, covariance test and other methods, and the following results were finally obtained:

First, the experimental class is higher than the control class in the four dimensions of critical thinking, knowledge transfer ability, problem solving ability and reflective awareness, and there is a significant difference. That is, under the new mode, in the four dimensions of deep learning level, which is more conducive to students' ability to enhance knowledge mastery, the experimental class is higher than the control class as a whole under the online-on-offline integrated teaching, which indicates that the students' deep learning level has been greatly improved.

First, after eliminating the influence of the experimental pre-test, the Sig. value of the test result of the between-subjects effect of the teaching mode is 0.017, which is less than 0.05. It indicates that there is a significant effect of different teaching modes on the level of deep learning. The AI-DELC model proposed in this paper can significantly improve students' deep learning compared with the traditional teaching model.

## (2) Research limitations and shortcomings

First, there may be differences in the teaching effect of different teaching materials, contents, adaptability of school segments, length of experiments, and research capabilities. The school section and subject considered in this study is the math subject in the fourth grade of elementary school, and the constructed AI-DELC model is applied to the real classroom teaching process to promote students' deep learning effect. However, the feasibility and practicality for other subjects and school segments, different teaching contents and subject contents need to be further confirmed and explored.

Secondly, there may be differences in teaching effects among different experimental durations and teaching abilities of the instructors. This study used the experimental class, the control class before and after the measurement of the quasi-experimental design mode, the control class used the traditional teaching mode, the experimental class used the designed AI-DELC teaching mode, both classes were taught by the same teacher, due to the time, teaching experience and other conditions of the limitations, and the author only participated in the auxiliary teaching, mainly in the capacity of classroom observers to participate in the experimental data, which may have some The data of the experiment may be affected. It is hoped that subsequently, if there is sufficient time and energy, the control of irrelevant variables and teaching hours can be strengthened in the research process to ensure that the objectivity and accuracy of the experimental data are enhanced.

Third, due to the limited experimental time and research capacity of this study, there are immature and imperfect parts of the research depth and process. For example, for this experiment due to time relations only did a round of teaching experiments, no revision and repeated observation and adjustment plan, for classroom teaching observation, management and other aspects of the need to continue to improve, for experimental data screening, collection and analysis there may be part of the omission, the follow-up to be verified and improved. For the theoretical construction of the teaching model of this experiment, due to the limited research capacity, time and experience, the universality of the law in the model theoretical argumentation level, practical application and other aspects, still need to be repeatedly verified.

## (3) Future outlook and research direction

The issue of deep learning has always been a hotspot of educational research, which is closely linked to the cultivation of core literacy and deepening reform of education, and is also one of the cultivation goals pointing to the learners in the new era. And the construction of deep learning teaching mode responds to the development trend of national education modernization and actively explores the new classroom teaching mode. Through literature combing, it can be seen that more and more scholars are studying the construction of deep learning teaching mode in China, which is enough to reflect that the research of deep learning teaching mode has gradually become one of the current research hotspots, and the depth of its research needs to be explored. As an educator, the author will continue to explore this research topic.

Subsequent research related to deep learning based on artificial intelligence technology can be thought and changed in the following two directions. First, this study will be followed up in the "degree of learning intelligent evaluation system and platform construction, deep learning teaching objectives and subject core literacy system construction and other theoretical research level, the application of theory, continue to explore research. Second, this study will continue to carry out in-depth empirical research on the deep learning teaching mode based on the theory of multiple intelligences in the future intelligent teaching environments such as "human-computer collaborative classroom", "5G multimodal smart classroom", and "multimodal + human-computer collaboration of MR experiments".

## References

1. Zheng, R., Xu, H., Wang, M., & Lu, J. (2024). The Impact of Artificial General Intelligence-assisted Project-Based Learning on Students' Higher Order Thinking and Self-efficacy. *IEEE Transactions on Learning Technologies*.
2. Yang, S., Huang, Y., Wang, Y., & Li, W. (2022). The classroom education model of artificial intelligence and information technology supported by wireless networks. *Wireless Communications and Mobile Computing*, 2022(1), 8797317.
3. Zhang, M., & Li, X. (2021). Design of smart classroom system based on Internet of things technology and smart classroom. *Mobile Information Systems*, 2021(1), 5438878.
4. He, G. (2020). Schema interaction visual teaching based on smart classroom environment in art course. *International Journal of Emerging Technologies in Learning (iJET)*, 15(17), 252-267.

5. Huang, L. S., Su, J. Y., & Pao, T. L. (2019). A context aware smart classroom architecture for smart campuses. *Applied sciences*, 9(9), 1837.
6. Yang, J., Pan, H., Zhou, W., & Huang, R. (2018). Evaluation of smart classroom from the perspective of infusing technology into pedagogy. *Smart Learning Environments*, 5, 1-11.
7. Dai, Z., Xiong, J., Zhao, L., & Zhu, X. (2023). Smart classroom learning environment preferences of higher education teachers and students in China: An ecological perspective. *Heliyon*, 9(6).
8. Tian, X., Park, K. H., & Liu, Q. (2023). Deep Learning Influences on Higher Education Students' Digital Literacy: The Meditating Role of Higher-order Thinking. *International Journal of Engineering Pedagogy*, 13(6).
9. Hobbins, J. O., Murrant, C. L., Snook, L. A., Tishinsky, J. M., & Ritchie, K. L. (2020). Incorporating higher order thinking and deep learning in a large, lecture-based human physiology course: can we do it?. *Advances in Physiology Education*, 44(4), 670-678.
10. Lee, J., & Choi, H. (2017). What affects learner's higher-order thinking in technology-enhanced learning environments? The effects of learner factors. *Computers & Education*, 115, 143-152.
11. Wang, S., & Zhang, D. (2019). Student-centred teaching, deep learning and self-reported ability improvement in higher education: Evidence from Mainland China. *Innovations in Education and Teaching International*, 56(5), 581-593.
12. Lu, K., Pang, F., & Shadiev, R. (2023). How to deepen college students' approach to using technologies in T - O - IBL? Examining the mediating influence of deep approaches to using technologies between learning factors and higher order thinking skills. *Journal of Computer Assisted Learning*, 39(1), 182-193.
13. Wang, X., Li, M., & Li, C. (2019). Smart classroom: Optimize and innovative-based on compared with traditional classroom. *International Journal of Information and Education Technology*, 9(10), 741-745.
14. Yu, H., Shi, G., Li, J., & Yang, J. (2022). Analyzing the differences of interaction and engagement in a smart classroom and a traditional classroom. *Sustainability*, 14(13), 8184.
15. Wang, R., & Yang, W. (2022, September). The Design and Application of Smart Classroom Teaching Mode in Higher Vocational Education Based on Deep Learning. In *2022 International Conference on Education, Network and Information Technology (ICENIT)* (pp. 66-70). IEEE.
16. Ou, L., & Zhang, M. (2021, April). Project teaching method design and empirical study in smart classroom environment. In *2021 2nd International Conference on Big Data and Informatization Education (ICBDIE)* (pp. 441-444). IEEE.
17. Xie, S. (2018). Smart classroom and university classroom teaching innovation. *DEStech Transactions on Computer Science and Engineering*, 11245-11253.
18. Lee, H. Y., Chen, P. H., Wang, W. S., Huang, Y. M., & Wu, T. T. (2024). Empowering ChatGPT with guidance mechanism in blended learning: effect of self-regulated learning, higher-order thinking skills, and knowledge construction. *International Journal of Educational Technology in Higher Education*, 21(1), 16.
19. Gunawan, K. D. H., Liliyasi, L., Kaniawati, I., & Setiawan, W. (2021). Implementation of Competency Enhancement Program for science teachers assisted by artificial Intelligence in designing HOTS-based integrated science learning. *Jurnal Penelitian Dan Pembelajaran IPA*, 7(1), 55-65.
20. Meng, Q., Jia, J., & Zhang, Z. (2020). A framework of smart pedagogy based on the facilitating of high order thinking skills. *Interactive Technology and Smart Education*, 17(3), 251-266.
21. Wang, S., Sun, Z., & Chen, Y. (2023). Effects of higher education institutes' artificial intelligence capability on students' self-efficacy, creativity and learning performance. *Education and Information Technologies*, 28(5), 4919-4939.
22. Ilgun Dibek, M., Sahin Kursad, M., & Erdogan, T. (2024). Influence of artificial intelligence tools on higher order thinking skills: a meta-analysis. *Interactive Learning Environments*, 1-23.

23. Lu, K., Zhu, J., Pang, F., & Shadiev, R. (2024). Understanding the relationship between colleges students' artificial intelligence literacy and higher order thinking skills using the 3P model: the mediating roles of behavioral engagement and peer interaction. *Educational technology research and development*, 1-24.
24. Xu, Y., Zhu, J., Wang, M., Qian, F., Yang, Y., & Zhang, J. (2024). The Impact of a Digital Game-Based AI Chatbot on Students' Academic Performance, Higher-Order Thinking, and Behavioral Patterns in an Information Technology Curriculum. *Applied Sciences*, 14(15), 6418.
25. Borge, M., Smith, B. K., & Aldemir, T. (2024). Using generative ai as a simulation to support higher-order thinking. *International Journal of Computer-Supported Collaborative Learning*, 19(4), 479-532.
26. Liu, J., Liu, Z., Wang, C., Li, X., & Xu, Y. (2024). Key factors and mechanisms affecting higher-order thinking skills of primary and secondary school students in the smart classroom environment. *Current Psychology*, 43(11), 9651-9664.
27. Mayasari, N., Sastraatmadja, A. H. M., Suparman, T., Mutiara, I. I., & Poetri, A. L. (2024). Effectiveness of Using Artificial Intelligence Learning Tools and Customized Curriculum on Improving Students' Critical Thinking Skills in Indonesia. *The Eastasouth Journal of Learning and Educations*, 2(02), 111-118.
28. Baskoro, G., Mariza, I., & Sutapa, I. N. (2023). Innovation to Improve Critical Thinking Skills in the Generation Z using Peeragogy as a Learning Approach and Artificial Intelligence (AI) as a Tool. *Jurnal Teknik Industri: Jurnal Keilmuan dan Aplikasi Teknik Industri*, 25(2), 121-130.
29. Ma, X., Xie, Y., Yang, X., Wang, H., & Lu, J. (2024). Structural model construction and analysis for teacher-student interaction in smart classroom based on the development of higher-order thinking. *Education and Information Technologies*, 1-27.
30. Hadzhikolev, E., Hadzhikoleva, S., Yotov, K., & Orozova, D. (2020). Models for multicomponent fuzzy evaluation, with a focus on the assessment of higher-order thinking skills. *TEM Journal*, 9(4), 1656.