

Effects of ATDE Teaching Mode during Online Teaching on Creative Thinking Ability of Learners

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Xinwei Lv¹(✉), Yamin Wu², Xiuli Cui²

¹Civil Engineering and Transportation Engineering, Yellow River Conservancy Technical Institute, Kaifeng, China

²School of Architectural Engineering, Zhengzhou University of Industrial Technology, Zhengzhou, China
2013840263@yrcti.edu.cn

Abstract—Online teaching based on computer and network technology has become a vital teaching mode under the current situation of the overwhelming COVID-19 epidemic. Teachers and students who fully understand and master basic knowledge and skills of various information technologies in online learning can stimulate students' interest in learning information technology and train their ability in information collection, processing, and use. Given the lack of face-to-face communication and deep emotional exchange, online teaching has poor performance in improving the creative thinking ability of learners. During online teaching, teachers train the innovation consciousness quality of students in online courses successfully and improve the creative thinking ability of learners by using “asking,” “thinking,” “doing,” and “evaluation,” that is, the ATDE teaching mode. In this study, a teaching experiment was carried out on 41 undergraduates admitted in 2018 who majored in civil engineering at Zhengzhou University of Industrial Technology, Henan Province, China. Students were divided into the experimental group and the control group. The experimental group adopted the ATDE teaching mode for the course *Design of concrete structure*, while the control group applied the traditional teaching mode. A questionnaire survey of students' creative thinking ability was conducted for both groups. Results showed that university students' creative, emotional attitude under the ATDE teaching mode was far higher than that under the traditional ($F=6.490$, $p=0.015$). The creative thinking performance of university students under the ATDE teaching mode was higher than that under the traditional teaching mode ($F=7.468$, $p=0.009$). The Pearson correlation coefficient between creative, emotional attitude and creative thinking performance was 0.985 in the late test stage, which was higher than in the early test stage (0.480), which reveals that the ATDE teaching mode was conducive to improving abstract course learning effect of students majoring in civil engineering. Research conclusions can provide some references to investigate the feasibility of ATDE teaching mode in universities and offer a new choice and feasible path to train students' creative thinking ability.

Keywords—Online teaching, ATDE teaching mode, learners, creative thinking ability, variance test, paired-sample T test

1 Introduction

Online learning has become a way of spreading content and fast learning of students by taking advantage of information technology and Internet technology. Online learning has diversified interactive teaching activities, rich functions and plenty of games and supports multiple discipline tools such as asking questions by hands up, multi-person video and voice connection, and online answering, thus increasing teaching efficiency. However, online learning also has disadvantages, such as the lack of interaction. Online courses often adopt teaching activities through video. On the one hand, teachers cannot judge whether learners are concentrated in the class and learn something through their classroom performances. On the other hand, teachers cannot directly recognize whether online students are focused on the classroom. Learners without self-control are challenged to learn knowledge through online classes. The teaching objective of universities in China refers to the values, way of thinking, and students' ability level developed through classroom learning. Among them, creative thinking ability training is the key objective of core quality training disciplines in universities. Creative thinking ability is advanced thinking that uses multiple ways of thinking comprehensively and is the key component of individual innovation ability. However, teachers ignore training students' creative thinking in the online classroom. For example, problems designed by teachers during "classroom questioning" usually have fixed answers, and such questioning is against students' divergent thinking. Students with weak classroom initiatives and low participation can only seek answers in textbooks. Furthermore, students do not dare to try wrong answers because they strongly desire praise from teachers. The teaching experiences teachers have accumulated over a long period almost determine the process and way for students to accept knowledge. Teachers inculcate knowledge processed by the lesson preparation team and teaching and research team deeply and sometimes excessively into students directly, gradually standardizing and assimilating students' thinking activities. Consequently, students gradually lose the motivation for positive innovation and independent learning.

The ATDE teaching mode was proposed by Long'an Chen, a famous educator from Taiwan, in 1990. The ATDE teaching mode is composed of asking, thinking, doing, and evaluating. It can train and improve the creative thinking level of students. In ATDE teaching mode, learners dare to doubt the textbook or teachers when they encounter questions in class and improve their ability in scenario migration, problem-solving, and analysis. Creative thinking of university students cannot be formed without intelligent activities and accumulation and representation of abundant specific knowledge. ATDE teaching mode helps students improve these abilities and train their creative thinking ability. By transforming "the classroom" into a "learning environment", teachers must master textbook knowledge and prepare for the next class. Teachers shall prepare for problems that students may propose in class, show respect and patience to different ideas of students, offer them an inclusive and harmonious classroom environment, and encourage them to "imagine" within a reasonable range. Furthermore, teachers shall be able to use ATDE teaching mode flexibly, train and improve students' core qualities by combining actual classroom situations, and enhance their creative thinking ability.

2 Theoretical basis and hypotheses development

2.1 Theoretical basis

The ATDE teaching mode emphasizes that students produce and understand associated new knowledge and do divergent thinking positively according to existing disciplinary knowledge, learning experiences, and psychological structure. It is mainly based on the thought of constructivism. As a branch of cognitive psychology, constructivism is another important education theory by Piaget, J [1] after behavioral cognitivism. It is developed based on the “construction” in the original cognitive learning theory. Constructivism argues that students are the subjects of cognition and learning, whereas teachers are responsible for guiding and organizing teaching activities and helping students in meaningful learning and building the knowledge framework. Students are no longer passive receivers of knowledge from teachers but take the initiative to understand knowledge, build knowledge structure, verify hypotheses proposed during learning, and process a knowledge construction framework with existing knowledge experiences and psychological structures. Such a mode has some requirements on students’ knowledge and ability level. Students have to be strongly interested in the contents they will learn. Meanwhile, teachers shall provide students appropriate learning environment and encourage students to make meaningful construction to enrich their knowledge system. Constructivism deems that the process in which learners construct internal psychological characterization positively is learning. In this process, learners must make existing knowledge structures in their brains interact with factors in the natural environment to complete the learning task. The whole learning process is open. Teachers have to organize students to participate in various activities, and students learn by doing, complete positive learning, and acquire knowledge.

2.2 Hypotheses development

America was the first country that proposed and was concerned with training students’ creative thinking. America has offered relatively mature research fruits and relevant mechanisms. ATDE teaching mode was proposed by Long’an Chen, an educator from Taiwan, based on the summary of empirical laws after reviewing the teaching theories of European and American educators. ATDE teaching mode particularly emphasizes students’ existing knowledge and accumulated experience. It offers students opportunities for divergent thinking and develops their potential to the maximum extent, which is conducive to implementing the ATDE teaching mode and creative thinking successfully.

Influencing factors of creative thinking ability have been studied. Hong, E et al. [2] pointed out that creative thinking ability is closely related to school education. Strom, R. D et al. [3] believes that school and home education provides greater support to creative behaviors and suggests improving the creative thinking ability of learners by improving teacher training, learning evaluation methods, and technological tools. Middleton, H [4] pointed out that a good course design is important to enhance creative thinking. He discussed a series of creative thinking strategies and their possible application in design. Webster, P. R [5] believed innovative thinking is vital in improving music education quality. Sitorus, J et al. [6] demonstrated that improving creative thinking

ability is closely related to teaching design in five stages: orientation, preparation, incubation, initiation, and verification. Students can find innovative mathematical solutions by recalling previous knowledge and learning experiences. Borodina, T et al. [7] reported that students formed creative thinking under subjective and objective conditions of higher education, but the created conditions in higher education are not enough to develop high-level creativity. It must further investigate and improve education quality level. Alzoubi, A et al. [8] pointed out that creative thinking education could improve creative self-efficacy and cognitive motivation. He suggested embedding creative thinking education into learning courses. Sener, N et al. [9] proved that a project-based teaching mode could effectively improve students' attitudes to science and creative thinking. Moreover, different learning environment could stimulate their interest in science learning and produce positive effects on their science learning. Al-Zahrani, A. M [10] demonstrated that flipped classroom has obvious effects in promoting the creative thinking of students and can facilitate the creativity of students, especially in smoothness, flexibility, and novelty. Wahyudi, W et al. [11] found out the effect of teaching implementation of scientific creativity in inquiry learning to promote the critical thinking (CT) ability of prospective teachers. The results shown that inquiry creative process learning model had a significant effect on the improvement of CT ability of prospective teacher of physic.

How the ATDE teaching mode influences learners' learning motivations, learning strategies, and creative thinking ability has been investigated. Lou, S. J et al. [12] conducted a comparative experiment on 46 sophomores majoring in preschool education in a vocational high school and found that students had positive feedback and acceptance of the ATDE teaching mode. Moreover, the ATDE teaching mode is conducive to strengthening teacher-student interaction and peer interaction, thus improving learning effectiveness. Ku, Y. L et al. [13] pointed out that the ATDE teaching mode improved the creativity and self-perception ability of eight students significantly after finishing the course of the nursing peak project, and such improvement has statistical significance ($p < 0.01$), without influences on creativity features, ability, and motivation. Henriksen, K et al. [14] analyzed the influences of the ATDE teaching mode on the academic performances of sports students through a case study. Results showed that ATDE mode enhances sports students' cohesion, offsets resource shortages with strong organizational culture, and improves personal responsibility and academic performance. Debbag, M et al. [15] analyzed the relationship between the ATDE teaching mode and classroom management mode. Results showed a significant correlation between the ATDE teaching mode and the academic performances of learners. Nikander, J. A. O et al. [16] believed that the ATDE teaching mode provides good learning resources, develops a balanced life for young athletes in Finland, and improves sports performances of young athletes. Pegu, B [17] reported that the ATDE teaching mode facilitates the systematic transformation from passive learning to positive learning and trains professional students to build confidence and accept more knowledge. Chen, C. C et al. [18] implemented an astronomy teaching experiment in a preliminary school in central Taiwan by combining a quasi-experimental method and qualitative analysis. The control group used traditional classroom narration teaching, and the experimental group used AR teaching. According to the results, the AR-based teaching mode improves students' performance in learning efficiency, motivation, and experiences more than students in the control group. Chuang, C. F et al. [19] experimented with ATDE teaching mode on

46 sophomores majoring in preschool education in a vocational high school. Results showed that the ATDE teaching mode could be implemented in six stages, help teachers produce the idea of textbook design, and facilitate patent application. Students have positive feedback and acceptance of the hybrid innovative teaching mode. Chen, H. L et al. [20] investigated the influences of ATDE teaching on the creative thinking of learners in a nine-week innovative course. Students in the experimental group achieved significant scores and presented high creative thinking ability in all aspects. The creative thinking course has achieved positive effects and has some enlightenment to study engineering education or creative thinking. TSENG, Y. C et al. [21] carried out an experimental study on a costume design course for pet dogs and found that ATDE teaching could improve creativity. Liu, H. Y et al. [22] pointed out that creativity teaching advocates helping university students by enhancing their problem-solving ability and strengthening their professional ability. Teachers can improve university students' creativity effectiveness by using good teaching strategies.

According to studies concerning influencing factors of creative thinking ability, students' creative thinking ability manifests intelligence features, personality characteristics, and mental states. Students cannot develop creative thinking without intelligent activities and the accumulation and presentation of abundant specific knowledge. It is closely related to the teaching behaviors of teachers. According to studies concerning the influencing paths of ATDE teaching mode on learning outcomes of learners, TDE teaching mode is a teaching mode that stimulates learning creativity. Teachers can stimulate students' thinking using the ATDE teaching mode and integrate knowledge points, principles, application formulas, and practical operations into a complete knowledge system. Students can form relatively systematic learning and thinking habits and improve their creative thinking ability. Hence, this study lays a good theoretical foundation to investigate the influences of ATDE teaching mode on the creative thinking ability of learners and provides some enlightenment to education.

3 Methodology

3.1 Research objects

A questionnaire survey was conducted on 41 undergraduates admitted in 2018 who majored in civil engineering at Zhengzhou University of Industrial Technology to understand whether students' creative emotional attitudes and creative thinking performance have been developed effectively after using ATDE teaching mode.

3.2 Research methods

The questionnaire survey of students' creative thinking ability was designed with references to Williams S. D' [23] questionnaire. The questionnaire was proven to have high reliability and validity by many studies, and it could be used to assess students' creative thinking. Specifically, creative thinking ability could be measured by changes in students' creative emotional attitude and thinking performance. Scores of choice questions reflect their emotional attitude toward creativity. Scores of gap-filling

questions reflected the creative performance of students. Example enumeration and graph-based imagination tested the quantity and perspective of concepts students produced when facing problems, reflecting smoothness and flexibility of thinking. The uniqueness level of thinking was reflected by the novelty of students’ answers. First, the creative emotional attitude was measured by 20 questions with scores of 1 to 5. Second, creative thinking performance was measured by ten questions with scores of 1 to 10 scores. Scores of creative emotional attitude and thinking performance were transformed to a score interval of 0 to 100.

3.3 Research process

To assure scientificity and effectiveness of research data, a small-scaled test was performed in the early stage for learners before the official creativity thinking pre-test to the experimental group and control group to avoid disturbances of irrelevant factors on test results to the maximum extent. Later, the questionnaire measured students’ creative emotional attitudes and thinking performance. Finally, 21 students were included in the experimental group, and 20 students were included in the control group. In the experimental stage, learners of two groups were determined as homogeneous research objects after the pre-test. The author carried out an ATDE teaching experiment in the experimental group for *Design of concrete structure* for one semester, whereas the control group was provided with traditional education activities according to the textbook. In the late test stage, the creative thinking abilities of the experimental group and the control group were tested again.

4 Results analysis and discussion

4.1 Pre-test analysis

The creative emotional attitude and thinking performance of all university students in the experimental and control groups were tested before having lessons on *Design of concrete structure*. Questionnaires were sent and then recovered. A statistical analysis of scores of creative emotional attitude and thinking performance was carried out. Scores are listed in Table 1.

Table 1. Pre-test analysis

Names	Pair (mean±SD)		Difference (Pair 1–Pair 2)	t	p
	Pair 1	Pair 2			
Pre-test results of the creative emotional attitude of the experimental group vs the control group	49.50±5.10	45.95±8.14	3.55	1.667	0.112
Pre-test results of creative thinking performance of the experimental group vs control group	50.45±4.71	47.50±8.16	2.95	1.355	0.191

Notes: * p<0.05 ** p<0.01.

Table 1 shows no obvious difference between the experimental and control groups regarding creative emotional attitude and thinking performance. In other words, university students of control and experimental groups can be viewed as homogenous research objects, assuring no significant difference between the two groups regarding creative emotional attitude and thinking performance, and protecting the objectivity of research results.

4.2 Comparative analysis of post-test results between the experimental and control groups

Table 2. Method analysis results

	Groups (mean±SD)		F	p
	Control Group (n=20)	Experimental Group (n=21)		
Post-test of creative emotional attitude	57.65±5.40	61.52±4.30	6.49	0.015*
Post-test of creative thinking performance	64.43±6.65	69.75±5.77	7.468	0.009**

Notes: * p<0.05 ** p<0.01.

Table 3. Middle process value of variance analysis

Items	Difference	Quadratic Sum	Degree of Freedom	Mean Square
Post-test of creative emotional attitude	Inter-group	153.724	1	153.724
	Intra-group	923.788	39	23.687
	Total	1077.512	40	
Post-test of creative thinking performance	Inter-group	290.083	1	290.083
	Intra-group	1514.893	39	38.843
	Total	1804.976	40	

Table 4. Deep analysis-effect size index

Analysis Term	SSB (Inter-Group Difference)	SST (Total Deviation)	Partial η^2	Cohen's f Value
Post-test of creative emotional attitude	153.724	1077.512	0.143	0.408
Post-test of creative thinking performance	290.083	1804.976	0.161	0.438

Tables 2 and 3 show that ATDE teaching mode causes obvious differences in post-test performances between the experimental and control groups. The difference in post-test creative emotional attitude under different teaching modes is significant at the 0.05 level (F=6.490, p=0.015). According to a specific comparison of differences, the mean of the traditional teaching mode (57.65) is significantly lower than the mean of ATDE teaching mode (61.52). The difference in post-test creative thinking performance under different teaching modes is significant at the 0.01 level (F=7.468, p=0.009).

According to a specific comparison of differences, the mean of ATDE teaching mode (69.75) is far higher than the mean of the traditional teaching mode (64.43), mainly because teachers designed relatively scientific problems requiring divergent thinking during the boring teaching process of *Design of concrete structure*. Helping students to think about abstract problems in familiar life contexts, such as responses and performances of engineering structures under dynamic loads and composition laws of truss structure, is better. Using a case study, teachers can easily stimulate creative thinking of students when analyzing problems, explore methods to solve problems in activities (e.g., role play, exhibition, modeling, group discussion, and experiments), and thereby promote the improvement of creative thinking. Teachers can improve the emotional attitudes of students and encourage them to practice “doing” and “evaluation” by designing the question scenario, which can arouse students’ interests and curiosity. On the one hand, ATDE teaching mode trains logicity and agility in their thinking. On the other hand, teachers encourage and appreciate different opinions proposed by students in class. It trains the uniqueness of students’ thinking and improves their creative thinking level effectively. Students’ creative thinking is developed more comprehensively under the education of ATDE mode.

4.3 Correlation analysis between creative emotional attitude and thinking performance of the experimental group

Table 5. Pearson correlation coefficients

Project	Pearson Correlation Coefficients	P-value
Pre-test results of creative emotional attitude and creative thinking performance of the experimental group	0.480*	0.028
Post-test results of creative emotional attitude and creative thinking performance of the experimental group	0.985**	0.000

Table 5 shows that the correlation coefficient between the post-test results of creative emotional attitude and creative thinking performance of the experimental group was 0.480, which was significant at the 0.05 level. The correlation coefficient between the pre-test results of creative emotional attitude and creative thinking performance of the experimental group was 0.985, which was significant at the 0.01 level. The Pearson correlation coefficient was 0.985 in the post-test stage, which was higher than that of the pre-test stage (0.480), and the significance level was higher. In other words, creative emotional attitude helps students do divergent thinking positively and analyze and solve problems using multiple novel perspectives, thus improving creative thinking performance. The correlation between creative emotional attitude and thinking performance was closer through the ATDE teaching mode. The reason is that, if creative emotional attitude is improved, students dare to put forward different opinions and insights. After adapting to ATDE teaching mode for a period, students assume the dominant role in class. It increases students’ interest in creativity, trains their habits of solving problems independently, seeks cooperation and exchange with others upon problems,

encourages students to accept new things, and makes the self-assessment of creativity level during the teaching process. As a result, students accept the ATDE teaching mode sincerely and dare to make innovations. Furthermore, their creative thinking performance is enhanced. Creative thinking is a kind of comprehensive thinking. The ATDE mode helps students do divergent thinking about the preset problem context as much as possible and produce multiple ideas in a short period to increase smooth thinking. It also encourages students to think and solve problems independently and create something new and original to improve their uniqueness of thinking. It trains students to seek different types of answers from different perspectives and using different methods, thus improving flexibility of thinking.

4.4 Discussions

Given limitations in teaching time, school conditions, and other practical factors, online teaching in universities still emphasizes on teaching behaviors of teachers. Some teachers even apply video play, which fails to guide the training of students' creative thinking well (Songkram, N [24]). Only university students with creative thinking abilities can adapt to social development and facilitate social progress. However, contemporary university students spend most of their time in classes (Pesut, D. J [25]). Given the COVID-19 epidemic, online teaching has become an essential carrier, and improving the teaching effect of teachers is a crucial way to develop students' creative thinking. Teachers shall assume the responsibility of training the creative thinking of students (Zhu, W [26]). Fundamentally, university teachers' educational concepts and professional quality determine whether they can choose appropriate teaching strategies and strain students' creative thinking to a large extent (Siburian, J et al. [27]). First, university students have to change concepts, pay attention to training students' creative thinking, and implement it in the practical teaching process. Moreover, they shall improve their professional quality continuously, conduct deep studies on educational theory, understand laws of physical and psychological development as well as individual development characteristics of students, and observe the characteristics of creative thinking and training strategies to integrate training of students' creative thinking into daily classroom teaching (Alter, F [28]). This study concluded that after one-semester teaching experiment, the experimental group's creative emotional attitude and thinking performance improved significantly, indicating that the ATDE teaching mode could enhance the creative thinking ability of university students. Furthermore, to some extent, the traditional teaching mode is difficult to improve students' creative thinking ability with good thinking development levels in a short period. According to theoretical studies, the physical and psychological development theory of humans believes that human development has some stages and university students have strong curiosity and exploration desire. They have active thinking and like imagination and show obvious creativity and passion in many aspects (Su, Y. S et al. [29]).

In traditional classroom teaching, the objective is to accumulate knowledge and seek standard answers to problems but leave insufficient space and time for students' divergent thinking of students. Students' curiosity and imagination cannot be developed fully and further improved (Korhonen, N et al. [30]). Nevertheless, teachers create a

harmonious and mutual respecting classroom atmosphere in ATDE teaching mode and encourage the unique thinking of students. Students dare to imagine and express themselves in such an atmosphere. Additionally, teachers create question contexts that are appropriate for the divergent thinking of students by using various questioning skills of creative problems, such as “if-problem” and “imagine-problem,” which provide accurate guidance to creative thinking students (Rani Satyam, V et al. [31]). Thus, the experimental group’s emotional characteristics of creative thinking improved significantly after the one-semester experiment of ATDE teaching mode. Meanwhile, the relationship between creative emotional attitude and thinking performance becomes closer.

5 Conclusions

China’s higher education has entered into the age of information and intelligence. Teaching mode reform for university courses is an important means to improve learners’ creative thinking abilities. ATDE teaching mode trains the creative thinking ability of students and has been extensively applied. In this study, a teaching experiment was carried out on 41 undergraduates admitted in 2018 and majored in civil engineering at Zhengzhou University of Industrial Technology, Henan Province, China. Students were divided into experimental control groups. The experimental group adopted the ATDE teaching mode for *Design of concrete structure*, whereas the control group applied the traditional teaching mode. It concludes as follows: (1) Creative emotional attitude of the experimental group is far higher than that of the control group ($F=6.490$, $p=0.015$). The creative thinking performance of the experimental group is higher than that of the control group ($F=7.468$, $p=0.009$). (2) The Pearson correlation coefficient between creative emotional attitude and thinking performance is 0.985 ($0.000<0.01$), which is higher than that in the early test stage (0.480) ($0.028<0.05$). (3) ATDE teaching mode is conducive to improving the abstract course learning effect of students who majored in civil engineering. Deep studies on expanding the application range among students, controlling other disturbance factors produced by creative thinking, and enriching the ATDE teaching process by using modernized teaching technologies shall be carried out in the future.

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7 Authors

Xinwei Lv, Master's degree, is a lecture at Civil Engineering and Transportation Engineering, Yellow River Conservancy Technical Institute. Her research interests focus on Civil Engineering Inspection Technology and Teaching Research (email: 2013840263@yrcti.edu.cn).

Yamin Wu, Master's degree, is a lecturer at School of Architectural Engineering, Zhengzhou University of Industrial Technology. Her research interests focus on Concrete Structures, Building Materials Applications and Teaching Research (email: WUYamin@zzuit.edu.cn).

Xiuli Cui, Master's degree, is a lecturer at School of Architectural Engineering, Zhengzhou University of Industrial Technology. Her research interests focus on Vibration Reduction, Isolation Technology of Structures and Teaching Research (email: CUIxiuli@zzuit.edu.cn).

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