Can the Flipped classroom teaching model really improve students' high-level thinking ability?

——Meta analysis based on 34 experimental or quasi experimental studies

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Abstract. Cultivating students' higher-order thinking is one of the basic needs of current social development for education. However, the experimental or quasi experimental studies on the impact of Flipped classroom on students' higher-order thinking at home and abroad are quite different, and have not reached a consistent conclusion. This study utilized meta-analysis methods, utilizing CMA software and Review Manager software to conduct an in-depth analysis of 34 relevant literature both domestically and internationally from 2013 to 2023. The results show that the overall Effect size (SMD) of Flipped classroom on students' higher-order thinking is 0.619, and reaches a significant level. Flipped classroom teaching mode has a positive effect on students' higher-order thinking, In terms of learning stages, Flipped classroom has a significant difference in the impact on students' advanced thinking, especially on students' advanced thinking, There is no significant difference in the impact of Flipped classroom on students' advanced thinking in terms of regions and subject types at home and abroad and in terms of class size, there are significant differences in the impact of Flipped classroom teaching mode on higher-order thinking. Flipped classroom teaching improves students' higher-order thinking more significantly when the class size is smaller. Therefore, it is feasible to use the Flipped classroom teaching model to promote the development of students' high-level thinking, and the impact of class size should be taken into account.

Keywords: Flipped classroom, High order thinking, Meta-analysis

1 Introduction

With the continuous progress and development of economy and technology, the educational demand for cultivating students' high-level thinking is becoming increasingly strong in current society. Whether the Flipped classroom teaching mode can improve students' higher-order thinking has not yet formed a unified conclusion. There are two

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diametrically opposed views on the impact of Flipped classroom teaching mode on students' higher-order thinking in the domestic and foreign education field: First, compared with traditional classroom, flipped classroom can significantly improve students' higher-order thinking, Second, there is no significant difference between Flipped classroom and traditional classroom in the impact of students' higher-order thinking. The specific comparison of teaching experimental research is as follows: View 1 (significant difference): Abdulrahman M Al Zahrani scholars show that the Flipped classroom teaching model is more conducive to cultivating students' high-level thinking ability through quasi experimental research [1], Yang Xiao-Jun and other scholars found that Flipped classroom is more obvious than traditional teaching in cultivating students' Critical thinking in high-level thinking [2],Zhou Ping found that Flipped classroom is more effective than traditional classroom in the experimental research on cultivating high-level thinking of English majors [3], The teaching experiment research of Liu Shuang and other scholars in computer courses shows that Flipped classroom teaching has a greater effect on cultivating students' high-level thinking than traditional classroom teaching [4]. Viewpoint 2 (no obvious difference): Di Gong and other scholars found no obvious difference in the impact of Flipped classroom teaching and traditional classroom teaching on the promotion of students' high-level thinking in the teaching of computer courses [5], Sezer, a Türkiye scholar, found that there is no obvious difference between Flipped classroom teaching and traditional classroom teaching in cultivating students' high-level thinking through quasi experimental research [6], Chi Mei-Xuan scholar found that when learning medical courses, there was no significant difference between Flipped classroom teaching and traditional classroom teaching in cultivating students' high-level thinking [7].

To sum up, given that there is a big dispute among scholars on whether the Flipped classroom teaching model can improve students' high-level thinking ability, it is very necessary to conduct an effective meta-analysis on this issue, so as to explore the following two main issues: first, compared with traditional classroom teaching, can Flipped classroom teaching improve students' high-level thinking ability? Secondly, if flipped classroom teaching can enhance students' higher-order thinking, what are the main factors or variables that affect this process of improvement?

2 Research design

2.1 Document retrieval and screening

The first step is to identify: this research conducts Document retrieval on Chinese and English databases such as CNKI, VPCS, Wan Fang, Web of Science, EBSCO, Springer, etc., from January 2013 to June 2023. In order to ensure a comprehensive retrieval of literature, two rounds of retrieval were carried out successively: the first round: the Chinese database took "Flipped classroom", "High order thinking", "Critical thinking", "Creative thinking", "Problem solving thinking", "Decision making" as the theme words, and the English database took "Flipped Classroom", "High order thinking", "Creative thinking", "Critical thinking", "Problem solving thinking" Search for the subject word 'Decision making'. Second round: Using the method of "snowball"

tracking references. In the end, a total of 854 articles were retrieved from the Chinese and English databases. Step 2, screening: Firstly, eliminate duplicate literature, review literature, meeting minutes, and other related literature from the first reading topic and abstract, 436 remaining references. Secondly, conduct a second reading and eliminate non experimental or empirical research literature, leaving 224 papers remaining. Step 3, Inclusion: Read the entire 224 articles and select them based on the following inclusion criteria: The research results show the impact on students' higher-order thinking, There must be an experimental group (Flipped classroom) and a control group (traditional classroom), Must have the required values for research: mean, standard deviation, and sample size (N), The research object is students, Step 4, including: In summary, a total of 32 articles were included as samples in this study.

2.2 Document retrieval and screening

According to the research needs, the literature is uniformly coded, and the main classification items (variables) for coding are as follows: literature author, publication year, sample size (experimental group, control group), experimental stage, experimental subject, subject type, experimental scale, and experimental results. Among them, when the author appears duplicate, the author and serial number method is used to distinguish them, Number of participants: Under 60 participants are small-scale, 60-150 participants are medium-sized, and over 150 participants are large-scale, The academic stage is divided into three types: primary school, middle school (middle school, high school), and university (junior college, undergraduate, graduate), Experimental subjects mainly include: English, physics, computer science, medicine, history, and other subjects, The experimental results were classified as improved or no significant difference.

3 Analysis of research results

3.1 Publication bias test

From Figure 1, it can be seen that the majority of the sample effects included in the study are located within the upper effective region of the funnel plot. In this study, the rank Factor of safety (Nfs) test was conducted through CMA software, and Nfs=3102>5 * 34+10, indicating that the data bias of the selected literature is small, there is no publication bias on the whole, and the selected research literature samples are reliable and effective.

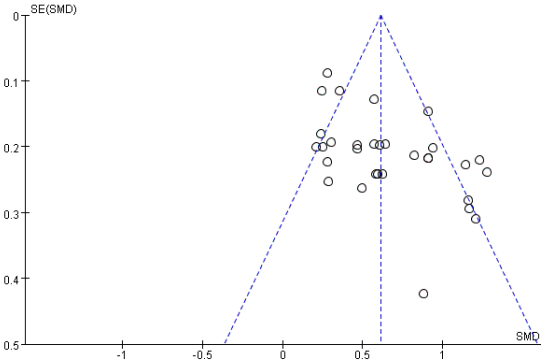

Fig. 1. Funnel Diagram of Effect size Distribution

3.2 Heterogeneity test

Scholar Higgins mentioned: When the heterogeneity test I^2 is less than 25%, it indicates that there is slight heterogeneity in the research, When $25\% < I^2 \leq 50\%$, it shows that there is moderate heterogeneity in the study, When $I^2 > 50\%$, it shows that the research has high heterogeneity[8]. This study has I^2=81% (as shown in Table 1), indicating a high degree of heterogeneity in the study. Therefore, a random effects model needs to be used for subsequent research analysis.

Table 1. Heterogeneity Test Results

effect model	SMD	95% confidence interval		heterogeneity test		
		lower limit	upper limit	I^2	df	P
Fixed	0.591	0.526	0.656	81%	31	0.000
Random	0.734	0.574	0.893			

3.3 The Overall Influence of Flipped classroom Teaching Mode on the Development of Advanced Thinking

According to the theory proposed by scholar Cohen, when the research merger effect SMD is less than 0.2, it indicates a small impact, When 0.2<SMD<0.8, it indicates a moderate impact ,When SMD>0.8, it indicates a significant impact[9]. In this study, the combined effect amount SMD=0.734, of which (95% CI [0.574,0.893], p<0.05) reached a statistically significant level, indicating that Flipped classroom teaching has a medium to upper impact on the development of higher-order thinking, that is, flipped classroom teaching mode can promote the development of students' higher-order thinking.

3.4 The Influence of Flipped classroom Teaching Mode on the Development of High-level Thinking of Students in Different Stages

Due to the small number of primary and secondary school stages included in the literature, this paper focuses on the analysis of the impact of Flipped classroom teaching on the development of higher-order thinking of middle school students and college students, in order to test the difference of the impact of Flipped classroom teaching mode on the development of higher-order thinking of students in different stages. It can be seen from Table 3 that Chi^2=0.08, P=0.78>0.05, and there is no significant difference in the impact of Flipped classroom teaching on the development of high-order thinking of middle school students and college students. According to the size of specific Effect size (SMD), middle school (SMD=0.71) and university (SMD=0.66) show that Flipped classroom teaching has a positive effect in both learning stages, and it has significantly improved the development of students' higher-order thinking in middle school than in university.

Table 2. The influence of Flipped classroom teaching on higher-order thinking of students in different stages

period	Effect number	SMD	95% confidence interval		Double tailed test			
			lower limit	upper limit	Z	P		
middle school	2	0.71	0.42	0.99	4.89	0.000	Chi^2=0.08 P=0.78	Z=9.56 P<0.0001
university	30	0.66	0.52	0.81	9.00	0.000		

Due to the limited number of primary and secondary school segments included in the literature, the focus is on analyzing the impact of flipped classroom teaching on the development of higher-order thinking among middle and university students, in order to test the differences in the impact of flipped classroom teaching mode on the development of higher-order thinking among students of different age groups. From Table 2, it can be seen that the inter group effect test Chi^2=0.08, P=0.78>0.05, indicating that flipped classroom teaching has an impact on middle school students.There is no significant difference in the development of higher-order thinking between college students and college students. Based on the specific effect value (SMD), it can be seen that flipped classroom teaching has a positive effect in both stages of high school (SMD=0.71) and university (SMD=0.66), and the improvement in students' higher-order thinking development is more significant in the middle school stage than in the university stage.

3.5 The Influence of Flipped classroom Teaching Mode on the Development of Advanced Thinking of Students at Home and Abroad

Table 3. The Influence of Flipped classroom Teaching on Advanced Thinking of Students at Home and Abroad

area	Effect number	effect value	95% confidence interval		Double tailed test			
			lower limit	upper limit	Z	P		
domestic	14	0.78	0.49	1.07	5.23	0.000	Chi^2=0.11 P=0.74	Z=9.11 P< 0.0001
abroad	18	0.72	0.55	0.89	8.49	0.000		

According to research practice, regional variables can generally be divided into two moderators, domestic and foreign, to test the difference of the impact of Flipped classroom teaching on students' higher-order thinking development in different regions. It can be seen from Table 3 that Chi^2=0.11, P=0.74>0.05, which indicates that there is no significant difference in the impact of Flipped classroom teaching on the development of higher-order thinking of domestic and foreign students. According to the size of the specific Effect size (SMD), the Effect size of the domestic region (SMD=0.78) and the Effect size of the foreign region (SMD=0.72) indicate that Flipped classroom teaching has a positive effect in both domestic and foreign regions, and it has significantly improved the development of students' higher-order thinking in domestic regions than in foreign regions.

3.6 The Influence of Flipped classroom Teaching Mode of Different Types of Disciplines on the Development of Students' Advanced Thinking

Table 4. The Impact of Flipped Classroom Teaching with Different Disciplinary Types on Higher Order Thinking

Discipline type	Effect number	effect value	95% confidence interval		Double tailed test			
			lower limit	upper limit	Z	P		
natural science	22	0.71	0.53	0.89	7.81	0.000	Chi^2=0.08 P=0.78	Z=9.39 P< 0.0001
social science	10	0.77	0.41	1.12	4.27	0.000		

From the perspective of subject type, the included literature is divided into social science and natural science to explore whether the influence of Flipped classroom teaching on the development of students' higher-order thinking is affected by subject type factors. It can be seen from Table 4 that Chi^2=0.08, P=0.78>0.05, which indicates that there is no significant difference in the impact of Flipped classroom teaching on students' higher-order thinking in different types of disciplines. According to the specific Effect size (SMD), natural science (SMD=0.71) and social science (SMD=0.77) show that Flipped classroom teaching has a positive effect in both types of disciplines,

and in the social science category, Kobe Bryant has significantly improved the development of students' high-level thinking in natural science disciplines.

3.7 The Influence of Flipped classroom Teaching Models with Different Class Sizes on the Development of Students' High-level Thinking

Table 5. The impact of Flipped classroom teaching in different class sizes on higher-order thinking

Class Size	Effect number	effect value	95% confidence interval		Double tailed test			
			lower limit	upper limit	Z	P		
small-scale	5	0.97	0.68	1.26	6.50	0.000	Chi^2=8.36 P=0.02	Z=9.04 P< 0.0001
Medium-sized	22	0.70	0.54	0.97	6.83	0.000		
large-scale	5	0.46	0.24	0.67	4.15	0.000		

In order to explore whether the influence of Flipped classroom teaching on students' higher-order thinking development is affected by different class size factors, the included literature is divided into three categories according to the number of people: small, medium and large. According to Table 5, the inter group effect Chi^2=8.36, P<0.0001, indicating that Flipped classroom teaching has a significant difference in the impact on the development of higher-order thinking of students of different class sizes. The small-scale Effect size (SMD=0.97) is greater than 0.8 and reaches a significant level (P<0.05), which indicates that Flipped classroom has a high impact on advanced thinking in small-scale teaching. The medium scale Effect size (SMD=0.70) and the large-scale Effect size (SMD=0.46) are both between 0.2-0.8, indicating that the Flipped classroom has a moderate impact on higher-order thinking in large-scale class teaching.

4 Research conclusions and recommendations

4.1 Research conclusion

Through the meta-analysis of 34 teaching experiments or quasi experimental studies related to Flipped classroom teaching and higher-order thinking development in the past decade (2013-2023), it is found that Flipped classroom teaching, compared with the traditional classroom teaching model, can produce a positive effect on the development of students' higher-order thinking in general. There is no significant difference in the influence of Flipped classroom teaching on the development of higher-order thinking of students in different stages, but the effect is more significant for middle school students than for college students ,There is no significant difference in the impact of Flipped classroom teaching on students' higher-order thinking at home and abroad, but both have the same positive impact ,The impact of Flipped classroom teaching on

students' higher-order thinking development in different types of disciplines is not significantly different, but the application in social science courses has more obvious impact on students' higher-order thinking development, The application of Flipped classroom teaching in different class sizes has significantly different effects on the development of students' higher-order thinking. The overall improvement effect is small scale>medium scale>large scale. To sum up, the Flipped classroom teaching model will have a positive impact on the cultivation or development of students' high-level thinking, and this positive promotion is affected by such factors as learning period, subject type and class size.

4.2 Research suggestions

Firstly, higher-order thinking education should start with children, especially in addressing the shortcomings of primary school thinking education. Elementary school students are in an important period of enlightenment for their thinking development, and it is particularly important for them to cultivate higher-order thinking. At present, when scholars at home and abroad study the impact of Flipped classroom on students' higher-order thinking, the study period is concentrated in middle school and university, and the relevant research in primary school is still less. There is an urgent need for domestic educators to actively carry out research on higher-order thinking teaching in primary school, so that students can have good thinking skills and high-quality thinking tendencies from an early age.

Secondly, flipped classroom teaching can significantly improve students' higher-order thinking when the class size is small. In small-scale teaching, teachers can pay more comprehensive attention to each student's classroom learning effect, and more students can express their ideas in the class discussion link. Therefore, the number of students in the class is less than 60 to carry out Flipped classroom teaching to improve students' high-level thinking. In addition, to strengthen the teaching application of the Flipped classroom teaching mode, it is necessary to show obscure knowledge in the form of new media such as video animation before class, which can deepen students' understanding of knowledge, improve students' learning interest, trigger students' active thinking, and thus improve students' advanced thinking.

Thirdly, the Flipped classroom teaching model only provides an overall framework for the teaching design of modern courses, that is, the design framework of teaching activities after learning [10]. Flipped classroom consists of three parts: before class, during class and after class. How to play the best role in promoting students' high-level thinking in the three stages is the problem that teachers need to solve at present. In pre class self-study based on video resources, teachers should fully consider the characteristics of each student when recording teaching videos, try to distribute teaching videos of different levels to students at different levels, and guide students to expand their thinking and learn corresponding knowledge step by step in a procedural manner. In class, based on problem-based learning, teachers need to guide students to divergent thinking, propose problems that can enhance their higher-order thinking, and guide students to solve the problems raised. In the promotion based on homework after class, assigning tasks that are beneficial for enhancing higher-order thinking by teachers is

not the only choice. Teachers can allow students to use their own thinking to create works that are beneficial for enhancing higher-order thinking.

Finally, building a new classroom teaching model oriented to the development of students' high-level thinking is not an easy task, but a huge and complex project, which often requires the joint efforts of teachers, students and parents. The specific subject curriculum application of the Flipped classroom teaching model still needs systematic and in-depth analysis and research.

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