

Statistical Analysis on the Influence of Flipped Classroom Teaching on Students' Learning Effect During the Coronavirus Disease 2019 Epidemic

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Abstract

Currently, many educational practitioners do not agree on how flipped classroom affects students' learning effect. In order to further explore the impact of flipped classroom on students' learning effect, this paper conducts a quantitative analysis of some flipped classroom experimental and quasi-experimental studies systematically by means of meta-analysis method. The study finds that the random effect model shows that the combined effect is 0.373, reaching the statistical significance level, which indicates that flipped classroom has moderate positive effect on improving students' learning effect. There is no significant difference in the effect of flipped classroom on the learning effect of different subjects and stages, but the effect on primary school students is weaker. Significant differences in the effect on learning outcomes among different knowledge types have been found, and specifically, the flipped instruction is good for the study of practical knowledge, but has less influence on theoretical knowledge learning. Therefore, in the application of flipped classroom, it is necessary to pay attention to the characteristics of different learning objects and types of knowledge, and flipped classroom teaching cannot be used too much in primary school and the teaching of theoretical knowledge during the coronavirus disease 2019 epidemic.

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Introduction

The flipped classroom originated from Woodland Park High School in the Rocky Mountains, Colorado, USA. Initially, the school's chemistry teachers Jon Bergmann and Aaron Sams, in order to solve the problem that some students were absent from their courses and could not keep up with the progress, recorded the content of the lectures and uploaded them to the Internet for the absent students to study at home. This form of teaching practice was also widely welcomed among the students who were not absent. Later, many teachers began to apply this new teaching model to their classrooms[1]. The flipped classroom is a mixed learning environment. Course teachers provide teaching videos as the main form of learning resources. Students complete the viewing and learning of teaching videos and other learning resources before the class. Teachers and students complete homework questions and collaboration together in the classroom a new type of teaching model for activities such as inquiry and interactive communication[2]. The flipped classroom reverses the teaching process of the traditional classroom. The teaching of knowledge is placed under the class, and the internalization of knowledge is placed in the class; the role of teachers and students has changed, and the teacher has changed from the original imparter of knowledge to the guide of knowledge. In the study, the passive position is changed to the active position, students use short and powerful micro video resources to learn in advance before class, and the class solves problems under the guidance of teachers. The flipped classroom teaching model has been widely recognized by researchers and practitioners because of its advanced educational concepts that focus on the central position of students, the improvement of classroom teaching efficiency and the internalization of knowledge. At the same time, various forms of open educational resources such as Khan Academy, TED, Yale University Open Classes, MOOC and National Quality Courses have promoted the blowout development of flipped classrooms[3].

No matter in the field of academic research or teaching practice, flipped classroom has become a hot issue of concern in the domestic and international education circles. Scholars at home and abroad have conducted rich research on flipped classrooms, mainly

focusing on the connotation, essence, teaching model and design of flipped classrooms. At the same time, domestic and foreign educators have also carried out a lot of practical research in different disciplines in universities, primary and secondary schools, and even set off a practice boom to flip the classroom in China, from university to elementary school, carrying out full-time training of "micro-curricular"; Some teacher training activities with the theme of "flipped classroom" are endless, and so on. The upsurge of flipped classroom across the country is partly due to the promotion of local administrative forces, and partly because teachers use this teaching mode blindly[4]. The question of "how effective", "suitable teaching situation" and "applicable to all disciplines, school segments and types of knowledge" of this teaching model has become a confusion that current policy makers and front-line educators urgently need to answer. In response to this practical problem, this study uses Meta-Analysis to systematically analyze the existing research to explore how the flipped classroom has an impact on students' learning effects. What is the influence of the learning effect of students under the knowledge type, so as to further reveal what circumstances are more suitable to adopt the flip classroom teaching model, in order to provide a reference for the current application and further development of the flip classroom teaching model during the coronavirus disease 2019 epidemic.

Literature Review

Regarding the impact of flipped classroom on student learning, there are three conclusions in the current research: a. Compared with traditional classroom teaching, flipped classroom teaching can significantly improve students' academic performance; b. In the transmission of theoretical knowledge such as concepts and principles, the effect of traditional classroom teaching is significantly better than flipped classroom; c. There is no significant difference between flipped classroom and traditional classroom in improving students' academic performance.

a. Flipped Classroom is Significantly Better than Traditional Classroom

Many scholars believe that flipped classroom can significantly improve the learning effect of students, and conducted corresponding empirical research. Thai, De Wever and Valcke (2017) took the second-year

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"invertebrate" course as an example to carry out experimental research. 45 participants were randomly assigned to the experimental group (23 people) and the control group (22 people) for learning.

After the experiment, the learning effects of the two groups of students were tested. The results showed that the students who used the flipped classroom teaching method had significant test results higher than the traditional classroom teaching group[5]. The research of Kostaris, Sergis and Sampson (2017) also supports the above point of view.

The researchers selected the middle school "Information and Communication Technology" course for quasi-experimental research. The experimental group (23 people) and the control group (22 people) tested the students' computer hardware components and the relationship between them, the basic software design principles and the knowledge of information processing and other knowledge points, the results show that flipped classroom can significantly improve students' academic performance[6].

Domestic scholars Xing&Dong (2015) applied flipped teaching and traditional teaching to the two parallel classes of the "University Physics" course. The study found that the class score using flipped classroom teaching increased significantly higher than the class using traditional teaching, the effect value is 0.68[7].

b. Traditional Classroom is Significantly Better than Flipped Classroom

Some scholars believe that the traditional classroom is significantly better than the flipped classroom in teaching certain knowledge points. Domestic scholars Ma&Zhao (2013) applied the flipped classroom teaching model to the "university information technology" course to test the students' academic performance in the "computer common sense", "Win application", "word processing" and "network application" modules. The study found that in the "computer common sense" module, students in the traditional classroom group score higher than the flipped classroom group, indicating that in the "computer common sense" module that emphasizes knowledge and concepts, the effect of the traditional teaching model is better than the flipped classroom[8]. Also supporting this view is the research of He (2014), who selected two parallel classes of the Software Vocational and Technical College of

Henan Normal University as the experimental class (30 people) and the control class (30 people), in the course of "C Language Programming" carry out experimental research on flipped classroom teaching and test the learning achievements of students in the "C language knowledge concept", "analysis program", "debug program" and "write program" modules. The research results show that in the "C language knowledge concept" module, traditional classroom groups the student's academic performance is higher than the flipped classroom group, indicating that in terms of emphasizing conceptual knowledge, flipped classrooms are not as effective as traditional classrooms[9]. Foreign scholars Su-Young and others (2017) selected students who participated in the two classes of "English Grammar and Writing for College Students" as the experimental object, including 24 in the experimental group and 26 in the control group. An independent sample t test was conducted, and the study found that the students in the flipped classroom teaching group had lower post-test scores than the pretest, while the students in the traditional teaching group had improved scores and reached a statistically significant level. The overall teaching effect of the "writing" course is not as good as the traditional classroom[10].

c. No Difference Between Flipped Classroom and Traditional Classroom

Some studies have found that there is no significant difference between the two on the effect of learning. Dahlke&Ojennus (2016) selected two parallel classes in the course "University Biochemistry" to use flipped classroom teaching (25 people) and traditional classroom teaching (29 people). The final grades showed that the two teaching methods did not improve the students' academic performance and significant differences[11]. Smallhorn (2017) applied flipped classroom teaching to the "university biology" course, and selected the core knowledge points of genetics, evolution and biodiversity to explain. The experimental results show that flipped classroom improves student participation and positive learning attitude. However, there is no significant improvement in academic performance[12]. Aidinopoulou&Sampson (2017) selected 49 11-year-old students and divided them into an experimental group and a control group to teach historical content and test the students' memory

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performance. The conclusion shows that there is no difference between the flipped classroom and the traditional classroom in improving students' memory of historical content[13].

These show that the question of whether flipped classroom can significantly improve students' academic performance has not yet reached a unified conclusion. In view of this, this study attempts to explore the following questions: Compared with the traditional teaching model, is the flipped classroom teaching more helpful for improving the learning effect of students because of its focus on advanced concepts such as knowledge internalization? If the answer is yes, what are the conditions for the effective application of flipped classroom teaching? Does its impact have the same applicability in different academic stages, different disciplines and different learning contents? In response to the above problems, we searched and retrieved a large number of documents, and used meta-analysis methods to analyze and discuss 37 experiments and quasi-experiments at home and abroad, and studied the overall impact of flipped classrooms on students' learning effects, as well as different disciplines, school segments and knowledge types. The impact of learning effect, which further reveals the conditions for the effective application of flipped classroom teaching, and gives suggestions for improving the effectiveness of flipped classroom applications.

Methods

Meta-analysis was first proposed by British educational psychologist Gene V. Glass. It is a statistical method for systematic quantitative synthesis of previous research results[14]. For the same research theme, due to the research object, funding, the impact of various environmental factors and the researchers themselves, there are often inconsistent conclusions. However, the traditional descriptive literature reviews are mostly descriptions without comments, and these results cannot be analyzed quantitatively[15]. The meta-analysis method makes up for this shortcoming. It carries out quantitative comprehensive analysis of multiple studies with the same research theme. The basic process is: asking questions, comprehensively searching relevant research literature, formulating strict inclusion and exclusion criteria, description basic information and quantitative statistical analysis. In view

of the fact that there are many empirical studies on the effect of flipped classroom and traditional classroom on learning effects, and the conclusions of each research are different, this study uses a meta-analysis method to quantitatively analyze it.

Literature Search and Screening

For the retrieval of Chinese documents, the CNKI full-text database is selected for accurate retrieval. The subject words are set to "flipped classroom" or "inverted classroom" or "reversed classroom" and contain "positive research" or "experimental research". For reliability considerations, only the core journals and CSSCIs are selected for the source of the journal, including: "Education Research", "Distance Education", "Open Education Research", "Chinese Medical Education Technology", "Fudan Education Forum" and "Language Teaching and Research". At the same time, the search time was limited to 2007-2017, a total of 76 Chinese documents were retrieved. For the retrieval of foreign language documents, select the main databases of Web of Science, Elsevier Science Direct, ERIC and JSTOR for accurate search, with "flipped classroom", "flipped learning", "inverted classroom", "flipped instruction", "learning outcomes", "Learning achievement" and "academic performance" are the subject terms for searching. The search time is limited to 2007-2017, and a total of 185 English documents have been retrieved.

Since the retrieved documents do not all meet the requirements, the documents need to be screened, and the criteria for inclusion are as follows:

- (1) The research is experimental research or quasi-experimental research, review articles and theoretical articles are excluded;
- (2) This article studies the learning effect of the flipped classroom, so the article should report the learning effect index (study score or work evaluation), and the article with no learning effect is excluded;
- (3) This article wants to compare the effects of flipped classroom and traditional classroom on learning effects, so the literature should have an experimental group and a control group, and the literature without a control group is excluded;
- (4) The literature provides sufficient data to calculate the experimental effect value, and the literature that cannot calculate the effect value is

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excluded. The provided data meets one of the following conditions to calculate the effect value:

- (a) Mean value, standard deviation SD and sample size N of experimental group and control group;
- (b) Mean, t value and sample size N of experimental group and control group;
- (c) Mean, p-value and sample size N of experimental group and control group;
- (d) Difference in means, common standard deviation Common SD and sample size N of the experimental group and the control group;
- (5) Duplicate documents are excluded. If the same document is published in different journals or in different forms, only one of them is selected.

After the sample screening was completed, a total of 37 documents that met the standard were included, including 14 Chinese documents and 23 English documents.

Literature Coding

After the literature search and screening are completed, in order to facilitate later analysis and statistics and to calculate the effect value, this article encodes the feature values of the original documents participating in the calculation, and counts the author, year, subject, sample size, school period, and knowledge type of the document.

The original document coding information is shown in Table 1. This study divides the syllabus into three stages: primary school, middle school and university; divides the discipline into liberal arts and science, and sets other disciplines that cannot be classified as liberal arts or science as other subjects, such as multimedia courseware design and production, two-dimensional Animation, web production, etc.

The knowledge types are divided into theoretical and practical categories. Most of the theoretical categories teach concepts, rules, facts, and principles. The test papers are used to check the students' mastery of the knowledge they have learned.

The test papers are selected, filled in, Judgment, calculation, short answer and other types of questions. Most of the questions are objective questions with clear answers. Most of the practical classes teach skills, experience, and operation processes.

The focus is on the ability of students to apply the knowledge they have learned to practice. The test type is generally work display or computer operation.

Calculation of Effect Value

The effect value is an indicator to measure the intensity of the experimental effect or the correlation strength of the variable, and it is not affected by the size of the sample size (or the impact is small)[16]. Each study can draw one or more independent effect values. In the medical field, RD, OR, RR, RRR, ARR and NNT, etc. are commonly used as research effect values, and the effect values in education are based on their statistical significance. It can be divided into three categories: difference class, related class and group overlap. Among them, the effect value of the difference class is generally used to compare the mean of two or more groups in experimental research, including Cohen's d, Glass' and Hedges's g. In the case of a large sample size, the three effect values of Cohen's d value, Glass' value, and Hedges's g value are almost the same.

However, for small sample studies, Cohen's d will seriously overestimate the effect value[16]. Therefore, Hedges&Olkin proposed to use the standardized mean difference (d) times the correction factor (J) to correct the d value, which is the Hedges's g value[17].

Due to the small sample size and number of studies in this study, Hedges's g (hereinafter referred to as g value) was used as the final effect value.

The calculation step of the effect value g value is: first calculate the standardized mean difference (d), and then multiply by the correction factor (J), the calculation formula is as follows:

$$g = d \times J \tag{1}$$

$$d = \frac{M_1 - M_2}{S} \tag{2}$$

In formula (2), M1 is the average of the experimental group (flipped classroom teaching), M2 is the average of the control group (traditional classroom teaching), and S is the combined standard deviation.

Table 1. Document coding information

Number	Author (Year)	Sample Size	Subject	Subject Code	School Section	Knowledge Type
1	Long (2014)	T: 33 C: 29	Information Literacy Education	Others	University	theoretical
2	Xing (2015)	T: 101 C: 107	College Physics	Science	University	theoretical
3	Ma (2013)	T: 100 C: 89	Information Technology	Others	University	theoretical/ practical
4	He (2014)	T: 30 C: 30	C Language Programming	Science	University	theoretical/ practical
5	Sun (2014)	T: 48 C: 46	Mathematics	Science	Middle School	theoretical
6	Yin (2016)	T: 39 C: 30	English Language	Liberal Arts	University	theoretical
7	Hu (2017)	T: 22 C: 22	English Language	Liberal Arts	Middle School	theoretical
8	Pan (2014)	T: 43 C: 42	Design and Production of Multimedia Courseware	Others	University	practical
9	Hu (2016)	T: 59 C: 55	2D Animation	Others	University	theoretical/ practical
10	Ye (2016)	T: 40 C: 42	JAVA Language Programming	Science	University	practical
11	Yang (2013)	T: 40 C: 39	"Modern Educational Technology" Experimental Course	Others	University	practical
12	Liang (2016)	T: 40 C: 42	Web Production	Others	Middle School	practical

13	Cai (2014)	T: 53 C: 56	Information Technology	Others	Middle School	theoretical
14	Sun (2015)	T: 50 C: 50	Teaching Chinese As Foreign Language	Liberal Arts	University	theoretical
15	Vasiliki (2017)	T: 26 C: 23	History	Liberal Arts	Primary School	theoretical
16	Bhagat (2016)	T: 41 C: 41	Mathematics	Science	Middle School	theoretical
17	Jensen (2015)	T: 55 C: 53	Biology	Science	University	theoretical
18	Cieliebak (2016)	T: 13 C: 23	Algorithms and Data Structures	Science	University	theoretical
19	Thai (2017)	T: 23 C: 22	Invertebrates	Science	University	theoretical
20	Kostans (2017)	T: 23 C: 23	Information and Communication Technology	Others	Middle School	theoretical
21	Sun (2016)	T: 91 C: 90	Physics	Others	University	theoretical
22	Leo (2016)	T: 79 C: 24	Biology	Others	Middle School	theoretical
23	Pi (2017)	T: 24 C: 26	English Grammar and Writing	Liberal Arts	University	theoretical
24	He (2016)	T: 334 C: 343	college chemistry	Science	University	theoretical
25	Dahike (2016)	T: 24 C: 29	Biochemistry	Science	University	theoretical

26	Small-horn (2017)	T: 195 C: 168	Biology	Science	University	theoretical
27	Clark (2013)	T: 42 C: 40	Mathematics	Science	University	theoretical
28	Guo (2015)	T: 45 C: 45	Mathematics	Science	Primary School	theoretical
29	Spilka (2014)	T: 27 C: 27	Mathematics	Science	Primary School	theoretical
30	Elmandaway (2017)	T: 29 C: 29	Electronic Course Design	Science	University	practical
31	Mohanty (2016)	T: 45 C: 45	Science	Science	Middle School	theoretical
32	Cashin (2016)	T: 82 C: 81	Read	Liberal Arts	Primary School	theoretical
33	Tsai (2015)	T: 50 C: 46	E-book Making	Others	Primary School	practical
34	Tsai (2017)	T: 47 C: 39	Applied Information Technology: office software	Others	University	practical
35	Ahmed (2016)	T: 65 C: 32	Introduction to Engineering Design	Science	University	practical
36	Duffy (2016)	T: 44 C: 43	Earth Science	Liberal Arts	Middle School	theoretical
37	Lee (2016)	T: 36 C: 56	sociology	Liberal Arts	University	theoretical

Note: T represents the number of the experimental group, C represents the number of the control group

$$S = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 1}}$$

In formula (3), n_1 is the sample size of the experimental group, n_2 is the sample size of the control group, S_1 is the standard deviation of the experimental group, S_2 is the standard deviation of the control group, and S is the combined standard deviation.

$$J = 1 - \frac{3}{df} \quad (4)$$

$$df = n_1 + n_2 - 2 \quad (5)$$

Comprehensive Meta-Analysis 2.0 software was used to calculate the effect value in this study.

Results Analysis and Discussion

The overall Influence of Flipped Classroom Teaching on Learning Effect

Three of the 37 documents report the experimental results of both theoretical and practical. For these studies, two independent effect values can be obtained. Therefore, 40 effect values were finally obtained for analysis. Table 2 shows each sample's effect value.

According to the statistical principle of meta-analysis, only data with good homogeneity can be merged. Therefore, the heterogeneity test needs to be conducted on the results of multiple studies in order to select the appropriate effect model according to the heterogeneity analysis results. When the research heterogeneity is large, the random effect model is used for analysis; when the research heterogeneity is small, the fixed effect model is used for analysis.

The commonly used methods of heterogeneity test are Q test and I^2 test. The test level of the Q test is usually set to 0.10, and when $p < 0.10$, there is heterogeneity between studies. The calculation formula of Q statistic is as follows:

$$Q = \sum_{i=1}^k \frac{(g_i - \bar{g})^2}{se_i^2} \quad (6)$$

In equation (6), g_i is the effect value of the i -th study (the value of g in this study), \bar{g} is the average effect value of all studies, and se_i is the standard error of the i -th study.

The I^2 statistic reflects the proportion of heterogeneity in the total variation of the effect value. The value of I^2 is between 0 and 100. The greater the value of I^2 , the greater the heterogeneity. When $0 < I^2 < 40$, there is low degree of heterogeneity; when $40 < I^2 < 60$, there is moderate heterogeneity; when $60 < I^2 < 75$, there is large heterogeneity; when $75 < I^2 < 100$, there is great heterogeneity. The calculation formula of I^2 is as follows:

$$I^2 = \frac{Q - K}{Q} \times 100\% \quad (7)$$

In equation (7), Q is the chi-square value of the heterogeneity test, and K is the number of studies included in the meta-analysis[14].

Table 3 shows the combined effect values of 37 studies. The sample heterogeneity test results show that $Q = 162.382$, $P = 0.000 < 0.10$, $I^2 = 75.983$, indicating that there is a large heterogeneity between samples, so the random effect model should be used For analysis.

From the random effect model in Table 3, it can be seen that the combined effect value of the flipped classroom is 0.373, and it reaches a statistically significant level ($P < 0.001$), which shows that the flipped classroom has a positive positive effect on the learning effect of students. According to the effect size standard proposed by Cohen, when the effect value $ES < 0.2$, it is a small effect; when $0.2 < ES < 0.8$, it is a medium effect, and when $ES > 0.8$, it is a large effect[18], which can be seen, flipped classroom has a moderate positive impact on improving students' learning effectiveness.

The Influence of Flipped Classroom on the Learning Effect of Different Stages

In order to further explore the impact of flipped classrooms on the learning effect of students in different school stages, we divided the included literature into

Table 2. Original document meta-analysis results

Number	Author	n	Hedges' s g	Standard error	Residual	95%CI (Upper, Lower)	Z value	P Value
1	Long	62	0.422	0.204	0.042	0.822, 0.022	2.069	0.039
2	Xing	208	0.676	0.152	0.023	0.974, 0.378	4.448	0
3	Ma	189	-0.363 0.268	0.146 0.12	0.021 0.017	-0.077, -0.65 0.523, 0.013	-2.484 2.062	0.013 0.039
4	He	60	-0.077 0.602	0.255 0.151	0.065 0.023	0.423, -0.577 0.898, 0.306	-0.302 3.987	0.763 0
5	Sun	94	0.444	0.207	0.043	0.850, 0.038	2.144	0.032
6	Yin	69	0.416	0.243	0.059	0.850, -0.059	1.715	0.086
7	Hu	40	0.807	0.323	0.104	1.440, 0.174	2.499	0.012
8	Pan	85	1.593	0.247	0.061	2.077, 1.108	6.441	0
9	Hu	114	-0.106 0.151	0.186 0.186	0.035 0.035	0.259, -0.471 0.516, -0.215	-0.568 0.807	0.57 0.42

10	Ye	82	0.863	0.248	0.081	1.420, 0.306	3.039	0.002
11	Yang	79	0.63	0.228	0.052	1.077, 0.182	2.757	0.006
12	Liang	82	0.727	0.226	0.051	1.170, 0.284	3.214	0.001
13	Cai	108	0.704	0.196	0.038	1.088, 0.319	3.588	0
14	Sun	100	0.617	0.144	0.021	0.899, 0.355	4.285	0
15	Vasiliki	49	0	0.282	0.079	0.552, -0.552	0	1
16	Bhagat	82	0.508	0.24	0.058	0.978, 0.038	2.117	0.034
17	Jensen	108	0.112	0.191	0.037	0.487, -0.263	0.584	0.559
18	Cieliebak	36	0.128	0.34	0.115	0.793, -0.538	0.376	0.707
19	Thai	45	0.827	0.306	0.093	1.427, 0.228	2.707	0.007
20	Kostans	46	0.994	0.277	0.077	1.537, 0.451	3.588	0
21	Sun	181	0.434	0.15	0.022	0.727, 0.140	2.896	0.004
22	Leo	69	0.156	0.242	0.058	0.627, -0.035	0.645	0.519
23	Pi	50	-0.597	0.285	0.081	0.541, -0.513	-2.094	0.036
24	He	677	0.116	0.077	0.006	0.219, -0.193	1.508	0.131

25	Dahike	54	0.014	0.269	0.072	0.462, -0.396	0.052	0.958
26	Smallhorn	363	0.013	0.105	0.011	0.674, -0.149	0.123	0.902
27	Clark	82	0.033	0.219	0.048	1.284, 0.196	0.152	0.879
28	Guo	90	0.262	0.21	0.044	0.674, -0.149	1.248	0.212
29	Spilka	58	0.74	0.278	0.077	1.254, 0.196	2.667	0.008
30	Elmanda- way	58	2.097	0.324	0.105	2.732, 1.462	6.47	0
31	Mohanty	90	0.308	0.21	0.044	0.720, -0.104	1.465	0.143
32	Cashin	163	0.281	0.157	0.025	0.588, 0.026	1.792	0.073
33	Tsai	96	0.258	0.204	0.041	0.657, -0.140	1.27	0.204
34	Tsai	86	0.007	0.215	0.046	0.427, -0.414	0.03	0.976
35	Ahmed	97	0.255	0.215	0.046	0.676, -0.167	1.185	0.236
36	Duffy	87	0.268	0.214	0.046	0.686, -0.151	1.254	0.21
37	Lee	92	0.272	0.213	0.045	0.689, -0.145	1.28	0.201

Note: T represents the number of the experimental group, C represents the number of the control group

Table 3. The effect of flipped classroom on students' learning effect

Model	Sample size	Effect size value (ES)	95% confidence interval		Z test		Heterogeneity test			
			Upper	Lower	Z value	P value	Q	df	P	I ²
Fixed effect	40	0.302	0.359	0.244	10.273	0.000	162.382	39	0.000	75.983
Random effect	40	0.373	0.497	0.250	5.926	0.000				

Table 4. The Influence of Flipped Classroom on the Learning Effect of Different Stages

School section	Sample size	Hedges's g	95% confidence interval		Z test		QBET
			Upper	Lower	Z value	P value	
University	25	0.351	0.522	0.181	4.040	0.000	QBET=1.880 (P=0.391)
Middle school	10	0.471	0.653	0.289	5.075	0.000	
Primary school	5	0.294	0.478	0.109	3.124	0.002	

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three groups: university, middle school, and elementary school according to the school stage. The combination and effect value of each class are shown in Table 4. The combined effect value of universities is 0.351, 0.471 for secondary schools and 0.294 for primary schools, and the combined effect values of the three have reached statistically significant levels, of which universities and secondary schools are significant at 0.001 level ($P < 0.001$), and primary schools are at 0.01 level ($P < 0.01$), indicating that the flipped classroom has a moderately positive effect on the learning effect of the students in the three stages, and the effect on the learning effect of the primary school students is slightly weaker. The reason may be that the autonomous learning ability of primary school students is still relatively weak. In the absence of teacher supervision, the consciousness is poor, and the pre-class knowledge cannot be learned well, resulting in less effective internalization of knowledge in the class. From the perspective of the effect between groups, $QBET = 1.880$, $p = 0.391 > 0.05$, indicating that there is no significant difference in the effect of flipping the classroom on the learning effect of students of different school levels.

The Effect of Flipped Classroom on the Learning Effect of Different Subjects

Different disciplines have their own disciplinary characteristics. For example, the knowledge points of science courses are clear. Teachers often only need to make clear the use of formulas, the derivation of calculation processes or the experimental procedures and principles. The liberal arts courses involve a wide range of relevant knowledge and often require Teachers use various means to mobilize students' emotions and cause students to think. Other courses like web design require students to have good aesthetic abilities and innovative abilities to make good works. So is the flipped classroom suitable for all disciplines? Does it have the same impact on different disciplines? In order to solve this problem, this study divides the included literature into science, liberal arts and other three categories. The analysis results are shown in Table 5. The combined effect of science is 0.390, the liberal arts is 0.278, and the other is 0.417. The combined effect of the three reaches statistical significance level, of which the science is significant at 0.001 level ($P < 0.001$), and the liberal arts is at 0.05 level ($P < 0.05$), others are

significant at the 0.01 level ($P < 0.01$), indicating that flipped classroom has a moderate positive impact on different disciplines. $QBET = 0.694$, $P = 0.707 > 0.05$, indicating that there is no significant difference in the effect of flipped classroom on the learning effect of different subjects. In other words, although different disciplines have their own disciplinary characteristics, the effect of flipped classrooms is similar.

The Effect of Flipped Classroom on the Learning Effect of Different Types of Knowledge

This study also explored the impact of flipped classrooms on the learning effect of different types of knowledge. The analysis results are shown in Table 6. The combined effect value of theoretical knowledge is 0.274, practical knowledge is 0.618, and both theoretical and practical knowledge are significant at the 0.001 level ($P < 0.001$). From the perspective of the effect between groups, $QBET = 4.821$, $p = 0.028 < 0.05$, indicating that there is a significant difference in the effect of flipped classroom on the learning effect of different types of knowledge. Specifically, flipped classroom has a greater impact on the learning effect of practical operation courses, but has a smaller effect on theoretical courses. Further analysis of the literature reveals that most of the practical courses are works design or experimental exploration. For this kind of relatively operable courses, more time is required to practice the knowledge learned. Traditional teaching methods spend a lot of time on explaining the theory or operation steps of the classroom, leaving students little time for actual operation, resulting in students having no time to practice and obtain feedback, and flipped classroom to put theoretical knowledge and operation steps. Before the class, the task-driven teaching model is adopted, and the time in the class is used more for students to practice, solve problems, cooperate and communicate, group mutual evaluation, teacher evaluation, etc. These activities in the class can better help students recognize your own shortcomings, so as to improve in time to improve the learning effect. The theoretical courses involve the explanation of some basic concepts and principles. This knowledge is the basis for learning the follow-up courses. The flipped classroom has little effect on improving the learning effect of the theoretical courses. The reason may be that students do not change their knowledge before

Table 5. The effect of flipped classroom on the learning effect of different subjects

Subject	Sample size	Hedges's g	95% confidence interval		Z test		QBET
			Upper	Lower	Z value	P value	
Science	20	0.390	0.554	0.26	4.661	0.000	QBET=0.694 (P=0.707)
Liberal arts	8	0.278	0.525	0.032	2.213	0.027	
Others	12	0.417	0.699	0.135	2.900	0.004	

Table 6. The effect of flipped classroom on the learning effect of different types of knowledge

Knowledge type	Sample size	Hedges's g	95% confidence interval		Z test		QBET
			Upper	Lower	Z value	P value	
Theoretical	28	0.274	0.400	0.148	4.258	0.000	QBET=4.821 (P=0.028)
Practical	12	0.618	0.898	0.338	4.328	0.000	

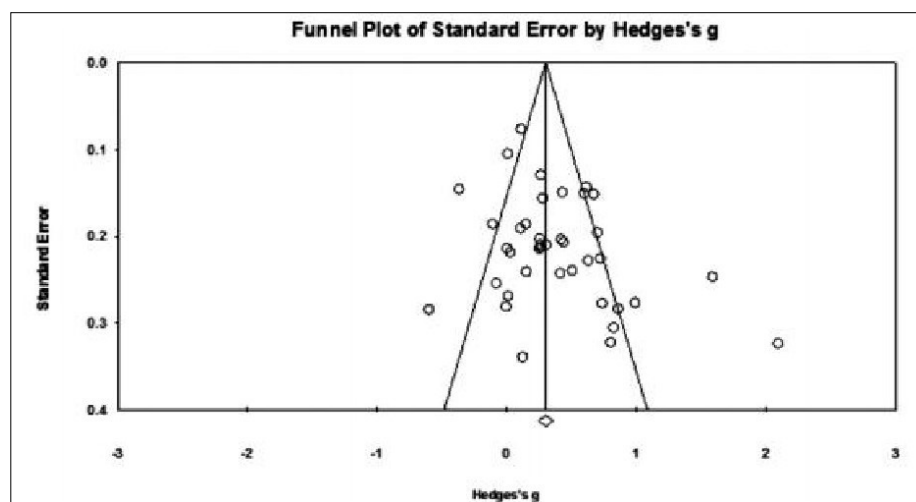


Figure 1. Funnel chart of flipped classroom learning effect

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class. The basic concepts and principles are well understood, and even deviations occur.

Publication Bias Test

Bias, also known as systematic error, refers to the deviation between the result of research or the inferred value and the true value. In the field of social science research, there is widespread reporting bias. Only when the degree of reporting bias is properly evaluated can its impact on the meta-analysis results be minimized as much as possible. Therefore, evaluating reporting bias is indispensable. Due to the small sample size in this study, a qualitative funnel chart and a quantitative Begg's test were used to detect publication bias.

The characteristic of the funnel chart is more intuitive. Researchers can judge whether the research results are biased by visual inspection, but there may be differences based on the visual inspection of the researcher alone. The Begg rank correlation method is a method of quantitatively identifying bias using the rank correlation test (Begg's test for short). The test is also suitable for small sample studies. If $Z > 1.96$, $P < 0.05$, there is bias, if $Z < 1.96$, $P > 0.05$, there is no bias[14].

As can be seen from Figure 1, the points on the funnel chart are basically symmetrically scattered around the combined effect value of 0.373, which initially shows that there is no publication bias. Begg's test results showed that $Z = 1.212 < 1.96$, $P = 0.226 > 0.05$, indicating that there is no publication bias, so the combined effect value obtained in this study is relatively stable.

Conclusion

Through the above research, it is found that in general, flipped classroom has a moderate positive effect on improving students' learning effect. There is no significant difference in the effect of flipped classrooms on the learning effect of different stages, and the improvement of the learning effect of primary school students is slightly weaker. The possible explanation is that the primary school students are young and have weak self-control. Therefore, the design and implementation of flipped classroom at the elementary stage need to be taken more reasonable model. There is no significant difference in the effect of flipped classroom on the learning effect of different

disciplines. At present, flipped classroom has more practice in science teaching and less liberal arts courses. This is because liberal arts courses require teachers and students, students and students Emotional communication takes place between the authors. Therefore, the flipped of the liberal arts curriculum requires teachers to design more comprehensively to help students improve their learning effects. This is also a challenge for teachers of the liberal arts curriculum. From the perspective of knowledge types, flipped classroom has a greater effect on the learning of practical courses and have less effect on theoretical courses. Therefore, courses with strong practical operation are more suitable for the use of flipped classroom teaching models. It can be seen that the flipped classroom teaching is not suitable for all courses and classrooms, and cannot be applied blindly, but should be scientifically and rationally designed according to the characteristics of students in different school segments and the characteristics of different knowledge points in different disciplines. We should proceed from the following aspects to gradually improve the flipped classroom teaching.

Strengthen the Cultivation of Students' Independent Learning Ability

The effect of flipped classroom on primary school learning is not significant, which is largely due to the weak autonomous learning ability of primary school students. The flipped classroom teaching has higher requirements for autonomous learning ability, and the cultivation of autonomous learning ability is a process from the training of self-management learning ability, the transformation of learning psychology to the formation of autonomous learning behavior[19]. For primary school students, their meta cognitive monitoring ability is still immature. At this time, teachers, parents and students are required to participate in multiple ways to improve their autonomous learning ability. With the help of the intelligent diagnosis system and the online test of knowledge points before class, teachers can monitor and understand the learning situation of students' knowledge points before class, so as to guide and explain them in the classroom in a targeted manner. The learning of knowledge points before class should consider the recent development area of the overall student, reduce the psychological burden of the

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student, let the student obtain a sense of self-efficacy, maintain learning motivation, and promote the formation of autonomous learning behavior.

Practice and Study the Flipped Model Suitable for Different Disciplines

Regarding the current educational practice application of flipped classrooms, flipped classroom has obvious advantages for the abstract and logical teaching of science such as mathematics, physics and chemistry, while liberal arts courses such as Chinese and history have no obvious effect on the implementation of flipped classroom. The possible explanation is that the liberal arts courses need to create good situations, promote the exchange of students' emotions, and exchange ideas and collisions, so as to cultivate students' humanistic feelings. In this case, teachers can practice and study the flipped model for liberal arts courses through design team role-playing, achievement display, exchange of learning experience and experience, and adopting process evaluation and assessment to enhance the teaching effect of liberal arts courses[20].

According to the Characteristics of Knowledge Content

Although flipped classroom has a moderately positive impact on improving the learning effect of students, not all courses and all knowledge points are suitable for flipped, and the characteristics of different disciplines and different knowledge points must be considered when designing flipped. For example, different types of knowledge points should be different when the design is flipped. The theoretical knowledge class can be designed with more background knowledge of the advanced organizer class. The difficult points also need to be internalized and explained in the classroom, and practice The class knowledge can arrange all the operational knowledge before the class, and the class focuses on the study of deeper skills[21]. The design is targeted and can fully exploit the student's subjective initiative and creative inquiry activities, so that flipped classroom teaching and knowledge types are properly integrated during the coronavirus disease 2019 epidemic.

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References

1. He K K. From the essence of "flipped classroom", look at the future development of "flipped classroom" in our country[J]. e-Education Research, 2014, 35(7): 5-16.
2. Bin Zhao, Xia Jiang, Jinming Cao, Yichi Li. Biostatistical Analysis on the Consideration of Nutrition-Related Modules in the Higher Education Curriculum[J]. Journal of Infectious Diseases & Travel Medicine, 2020, 4(1): 1-7.
3. Bin Zhao, Wei Wang, Youxi Luo, Jinming Cao. Measurement that Influence Mathematics Teachers'Integration of Teaching Methods on Student Achievement in China[J]. Scholar Journal of Applied Sciences and Research, 2019, 2(9): 27-31.
4. Xia Y L. The Hot Phenomenon and Cold Thinking of "Flip Class"[N]. China Education Newspaper, 2016-04-19(009).
5. Thai N T T, De Wever B, Valcke M. The impact of a flipped classroom design on learning performance in higher education: Looking for the best "blend" of lectures and guiding questions with feedback[J]. Computers&education, 2017, 107: 113-126.
6. Kostaris C, Sergis S, Sampson D G, et al. Investigating the potential of the flipped classroom model in K -12 ICT teaching and learning: An action research study[J]. Educational technology&society, 2017, 20 (1): 261-273.
7. Xing L, Dong Z H. A Quasi-Experimental Study on the Flipped Classroom Strategies: The Case of Shanghai Jiao Tong University[J]. Fudan Education Forum, 2015, 13(1): 24-29.
8. Ma X L, Zhao G Q, Wu T. An Empirical Study on the Influence of Flipped Classroom Model on Information Technology Course Teaching[J]. Journal of Distance Education, 2013, 31(1): 79-85.
9. He W T. Research on the Flipped Classroom and the Teaching Practices[D]. Henan Normal University, 2014.
10. Pi S, Do S. The effectiveness of the flipped learning using the smart device[J]. Journal of digital convergence, 2017, 15(4): 65-71.

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11. Ojennus D D. Assessment of learning gains in a flipped biochemistry classroom[J]. *Biochemistry&molecular biology education*, 2016, 44(1): 20-27.
12. Smallhorn M. The flipped classroom: A learning model to increase student engagement not academic achievement[J]. *Student success*, 2017, 8 (2): 43-53.
13. Aidinopoulou V , Sampson D G. An action research study from implementing the flipped classroom model in primary school history teaching and learning[J]. *Educational technology&society*, 2017, 20(1): 237-247.
14. Luo J, Leng W D. Theory & Practice of Systematic Review/Meta-Analysis[J]. *Chinese Journal of Evidence-Based Cardiovascular Medicine*, 2013, 5 (2): 115.
15. Cui Z M, Ning Z K. Quantitative literature review method and meta-analysis[J]. *Statistics & Decision*, 2010(19): 166-168.
16. Zheng H M, Wen Z L. The Appropriate Effect Sizes and Their Calculations in Psychological Research[J]. *Advances in Psychological Science*, 2011, 19(12): 1868-1878.
17. [Hedges L V. Distribution theory for Glass's estimator of effect size and related estimators[J]. *Journal of educational statistics*, 1981, 6(2): 107-128.
18. Cohen J. *Statistical power analysis for the behavioral sciences*[M]. New York: Academic Press, 1969.
19. Liu Z X, Wu Q H. Cultivation of College Students' Learning Autonomy from the Perspective of "Flipped Classroom"[J]. *Modern Educational Technology*, 2015, 25(11): 67-72.
20. Zhong X L, Song S Q, Jiao L Z. Instructional Design Based on the Idea of the Flipped Classroom in ICT Environment[J]. *Open Education Research*, 2013, 19 (1): 58-64.
21. Zhang J L, Wang Y, Zhang B H. Introducing a New Teaching Model: Flipped Classroom[J]. *Journal of Distance Education*, 2012, 30(4): 46-51.