# STATISTICAL ANALYSIS ON THE INFLUENCE OF FLIPPED CLASSROOM TEACHING DURING COVID-19 PANDEMIC

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(Received 17th February 2021; accepted 19th April 2021)

**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.
**Keywords**: *statistical analysis, flipped classroom teaching, students learning effect, coronavirus, theoretical knowledge*

## 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 (He, 2014a). 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 (Zhao et al., 2020). 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 (Zhao et al., 2019).

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 (Xia, 2016). 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; and (c) there is no significant difference between flipped classroom and traditional classroom in improving students' academic performance.

### *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 et al. (2017) took the second-year "invertebrate" course as an example to carry out experimental research, where 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 (Thai et al., 2017). The research of Kostaris et al. (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 (Xing and Dong, 2015). Domestic scholars Xing and 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 (Xing and Dong, 2015).

***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 et al. (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 (Ma et al., 2013). 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 (He, 2014b). Foreign scholars Pi and Do (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 (Pi and Do, 2017).

***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. 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 (Ojennus, 2016). 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 (Smallhorn, 2017). Aidinopoulou and 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 performance. The conclusion shows that there is no difference between the flipped classroom and the traditional classroom in improving students' memory of historical content (Aidinopoulou and Sampson, 2017).

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.

## Materials and 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 (Luo and Leng, 2013). 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 (Cui and Ning, 2010). 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 excluded. The provided data meets one of the following conditions to calculate the effect value (mean value, standard deviation SD and sample size N of experimental group and control group; mean, t-value and sample size N of experimental group and control group; mean, p-value and sample size N of experimental group and control group; and difference in means, common standard deviation Common SD and sample size N of the experimental group and the control group); and (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.

***Table 1.*** *Document coding information.*

| No. | Author (Year) | Sample size | Subject | Subject code | School section | Knowledge type |
|---|---|---|---|---|---|---|
| 1 | Long (2014) | T: 33<br>C: 29 | Information literacy education | Others | University | Theoretical |
| 2 | Xing (2015) | T: 101<br>C: 107 | College physics | Science | University | Theoretical |
| 3 | Ma (2013) | T: 30<br>C: 30 | Informatuon technology | Others | Universiy | Theoretical/practical |
| 4 | He (2014) | T: 30<br>C: 30 | C-Language programming | Science | University | Theoretical/practical |
| 5 | Sun (2014) | T: 48<br>C: 46 | Mathematics | Science | Middle school | Theoretical |
| 6 | Yin (2016) | T: 39<br>C: 30 | English language | Liberal Arts | University | Theoretical |
| 7 | Hu (2017) | T: 22<br>C: 22 | English language | Liberal Arts | Middle school | Theoretical |
| 8 | Pan (2014) | T: 43<br>C: 42 | Design and production of multimedia courseware | Others | University | Practical |
| 9 | Hu (2016) | T: 59<br>C: 55 | 2D Animation | Otrhers | University | Theoretical/practical |
| 10 | Ye (2016) | T: 40<br>C: 42 | JAVA Language programming | Scinece | University | Practical |
| 11 | Yang (2013) | T: 40<br>C: 39 | "Modern Educational Technology" experimental course | Others | University | Practical |
| 12 | Liang (2016) | T: 40<br>C: 42 | Web production | Others | Middle school | Practical |
| 13 | Cai (2014) | T: 53<br>C: 56 | Information technology | Others | Middle school | Theoretical |
| 14 | Sun (2015) | T: 50<br>C: 50 | Teaching Chinese As foreign language | Liberal Arts | University | Theoretical |
| 15 | Vasiliki (2017) | T: 26<br>C: 23 | History | Liberal Arts | Primary school | Theoretical |
| 16 | Bhagat (2016) | T: 41<br>C: 41 | Mathematics | Science | Middle school | Theoretical |
| 17 | Jensen (2015) | T: 55<br>C: 53 | Biology | Science | University | Theoretical |
| 18 | Cieliebak (2016) | T: 13<br>C: 23 | Algorithms and data structures | Science | University | Theoretical |
| 19 | Thai (2017) | T: 23<br>C: 22 | Invertebrates | Science | University | Theoretical |
| 20 | Kostans (2017) | T: 23<br>C: 23 | Information and communication technology | Others | Middle school | Theoretical |
| 21 | Sun (2016) | T: 91<br>C: 90 | Physics | Others | University | Theoretical |
| 22 | Leo (2016) | T: 49<br>C: 29 | Biology | Others | Middle school | Theoretical |
| 23 | Pi (2017) | T: 24<br>C: 26 | English grammar and writing | Liberal Arts | University | Theoretical |
| 24 | He | T: 334 | College | Science | University | Theoretical |

| | | | | | | |
|---|---|---|---|---|---|---|
| | (2016) | C: 343 | chemistry | | | |
| 25 | Dahike (2016) | T: 24 C: 29 | Biochemistry | Science | University | Theoretical |
| 26 | Smallhorn (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*

### *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) (Zheng and Wen, 2011). 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 (Zheng and Wen, 2011). Therefore, Hedges (1981) 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 (Cohen, 1969).

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 (Eq. 1);

$$g = d * J \quad \text{(Eq. 1)}$$

$$d = \frac{M_1 - M_2}{S} \quad \text{(Eq. 2)}$$

In Eq. 2, $M_1$ is the average of the experimental group (flipped classroom teaching), $M_2$ is the average of the control group (traditional classroom teaching), and S is the combined standard deviation.

$$S = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 1}} \quad \text{(Eq. 3)}$$

In Eq. 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.

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

$$df = n_1 + n_2 - 2 \quad \text{(Eq. 5)}$$

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

## Results 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.

***Table 2.*** *Original document meta-analysis results.*

| No. | Author | n | Hedge'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 | 0.000 |
| 3 | Ma | 189 | -0.363 | 0.146 | 0.021 | -0.077, -0.650 | -2.484 | 0.013 |
| | | | 0.268 | 0.120 | 0.017 | 0.523, 0.013 | 2.062 | 0.039 |
| 4 | He | 60 | -0.077 | 0.255 | 0.065 | 0.423, -0.577 | -0.302 | 0.763 |
| | | | 0.602 | 0.151 | 0.023 | 0.898, 0.306 | 3.987 | 0.000 |
| 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 | 0.000 |
| 9 | Hu | 114 | -0.106 | 0.186 | 0.035 | 0.259, -0.471 | -0.568 | 0.570 |
| | | | 0.151 | 0.186 | 0.035 | 0.516, -0.215 | 0.807 | 0.420 |
| 10 | Ye | 82 | 0.863 | 0.248 | 0.081 | 1.420, 0.306 | 3.039 | 0.002 |
| 11 | Yang | 79 | 0.630 | 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 | 0.000 |
| 14 | Sun | 100 | 0.617 | 0.144 | 0.021 | 0.899, 0.355 | 4.285 | 0.000 |
| 15 | Vasiliki | 49 | 0.000 | 0.282 | 0.079 | 0.552, -0.552 | 0.000 | 1.000 |
| 16 | Bhagat | 82 | 0.508 | 0.240 | 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 | 0.340 | 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 | 0.000 |
| 21 | Sun | 181 | 0.434 | 0.150 | 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 | 0.210 | 0.044 | 0.674, -0.149 | 1.248 | 0.212 |
| 29 | Spilka | 58 | 0.740 | 0.278 | 0.077 | 1.254, 0.196 | 2.667 | 0.008 |
| 30 | Elmandaway | 58 | 2.097 | 0.324 | 0.105 | 2.732, 1.462 | 6.470 | 0.000 |
| 31 | Mohanty | 90 | 0.308 | 0.210 | 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 | 1.270 | 0.204 |
| 34 | Tsai | 86 | 0.007 | 0.215 | 0.046 | 0.427, -0.414 | 0.030 | 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 | 0.210 |
| 37 | Lee | 92 | 0.272 | 0.213 | 0.045 | 0.689, -0.145 | 1.280 | 0.201 |

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;

$$Q=\sum_{i=1}^{n}\left(\frac{\theta_i-\overline{\theta_i}}{se_i}\right)^2 \quad \text{(Eq. 6)}$$

In Eq. 6, i is the effect value of the i-th study (the value of g in this study), $\overline{\theta_i}$ 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;

$$I^2=\frac{Q-(K-1)}{Q}\times 100\% \quad \text{(Eq. 7)}$$

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 (Luo and Leng, 2013). *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.

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

| Model | Sample size | Effect size value | 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 | 162.382 | 39 | 0.000 | 75.983 |

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 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.

***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 | |

### *The effect of flipped classroo 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 are 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.

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

| School section | 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 | |

### *The effect of flipped classroo 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 class. The basic concepts and principles are well understood, and even deviations occur.

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

| School section | 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 |
| Practical | 12 | 0.618 | 0.898 | 0.338 | 4.328 | 0.000 | (P=0.028) |

### *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 (Luo and Leng, 2013).

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.

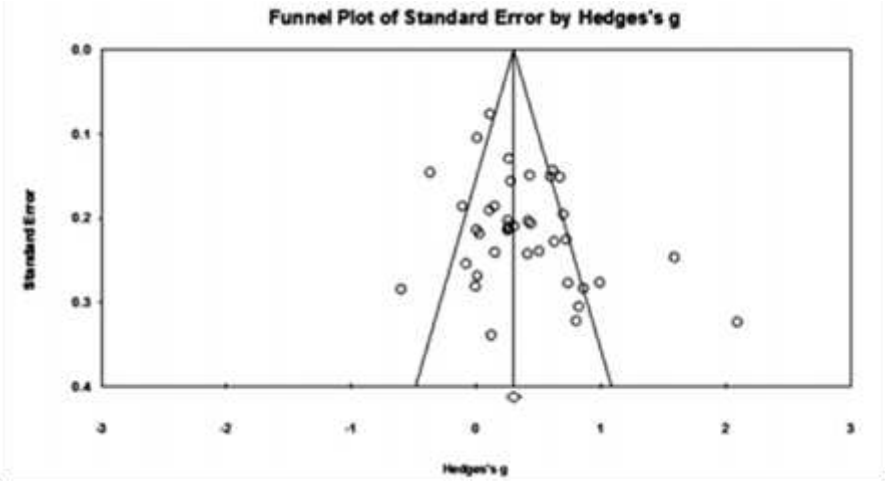


***Figure 1.*** *Funnel chart of flipped classroom learning effect.*

### *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 (Liu and Wu, 2015). 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 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 (Zhong et al., 2013).

### *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 (Zhang et al., 2012). 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.

## 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 student's 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.

## Acknowledgement

This work was supported by the Philosophical and Social Sciences Research Project of Hubei Education Department (19Y049), and the Staring Research Foundation for the Ph.D. of Hubei University of Technology (BSQD2019054), Hubei Province, China.

## Conflict of interest

Author(s) confirm that all have no conflict of interests to disclose and the manuscript has been read and approved by all named authors.

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