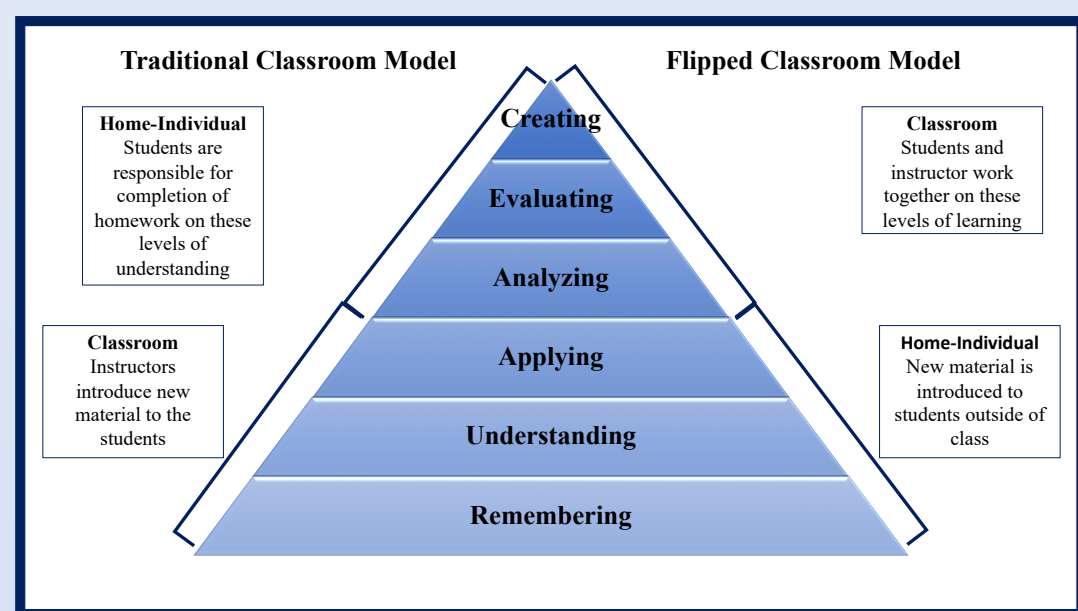
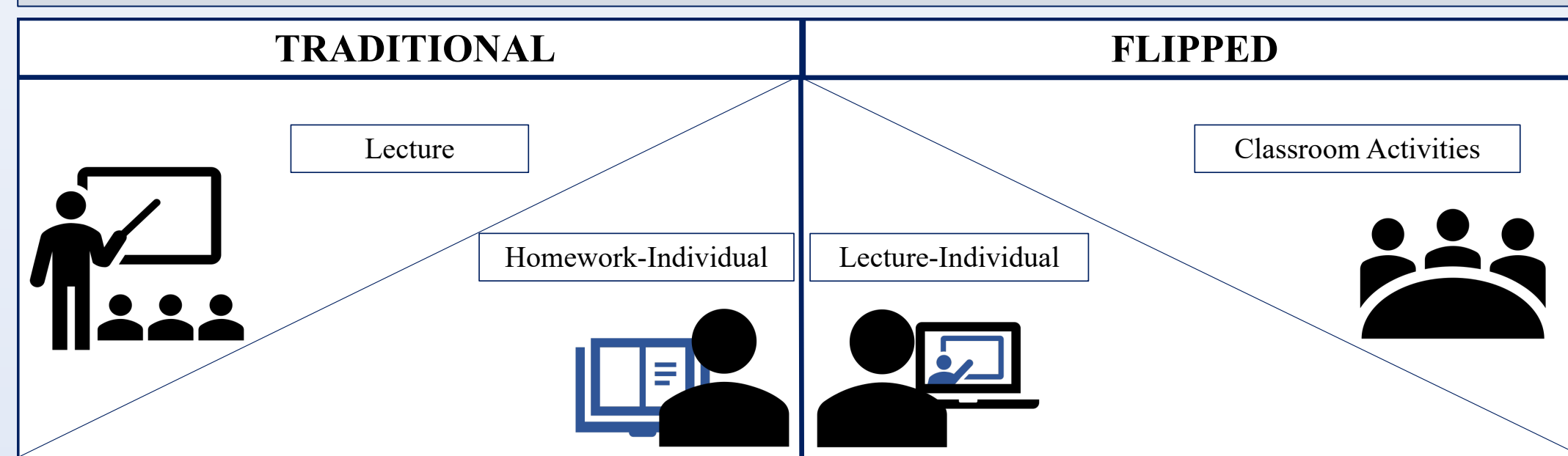


Introduction



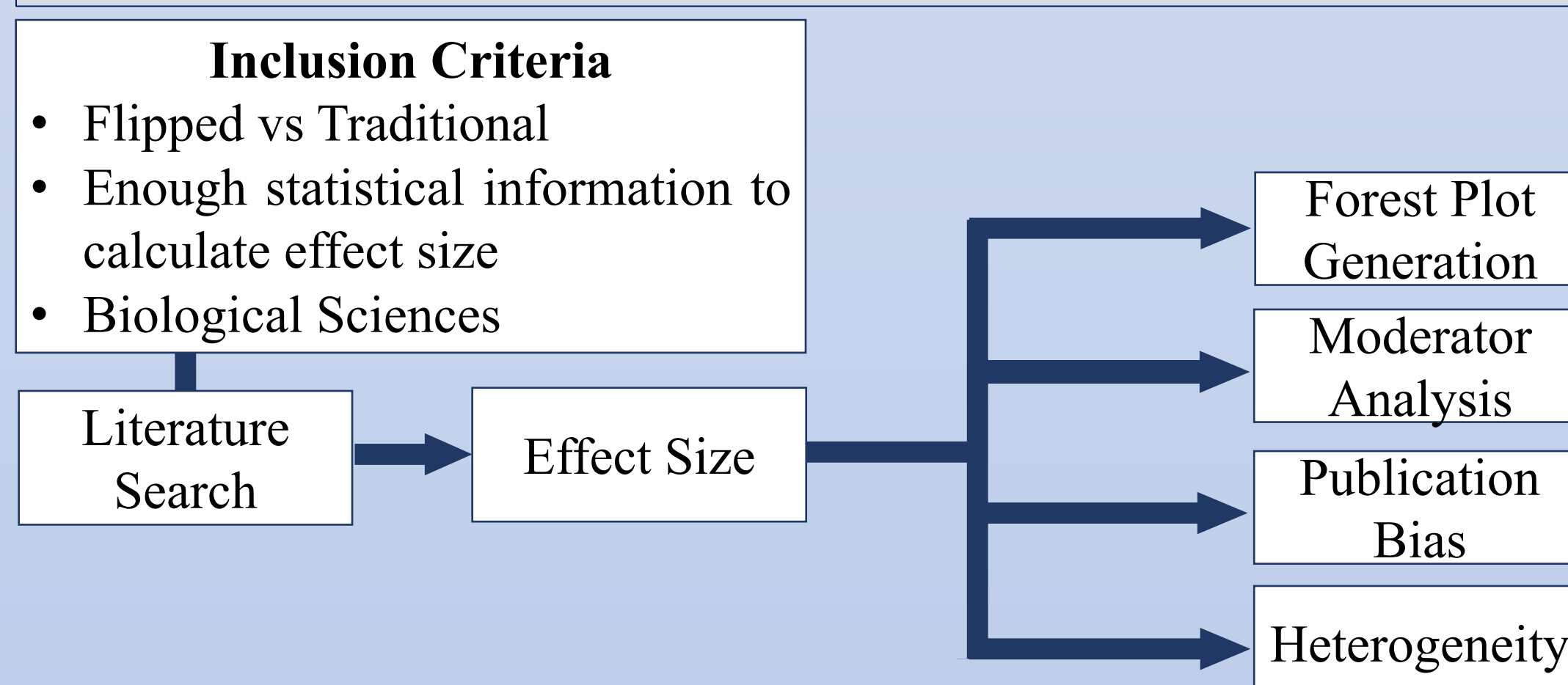
The flipped classroom approach is becoming more popular among the educators [1]:

- Gives instructors greater insight into student's gaps
- Gives instructors an opportunity to address the challenges that students might miss due to illness or other personal issue

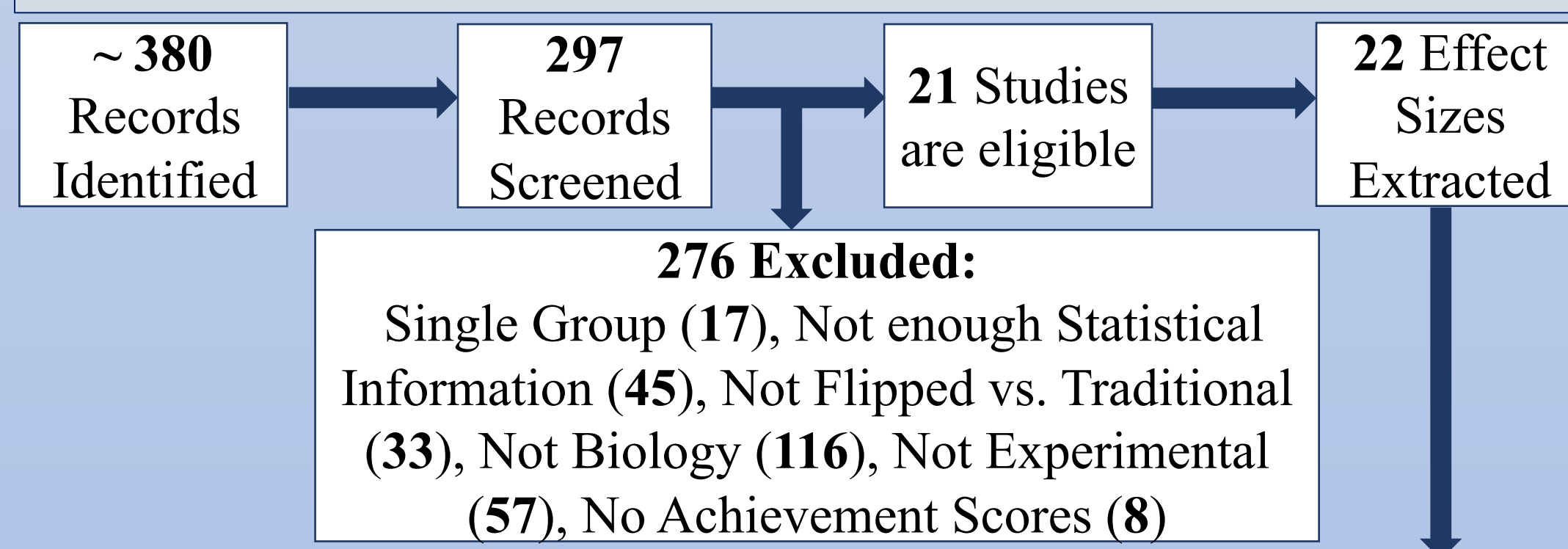
Bloom's taxonomy is a set of principals used to identify the complexity of learning objectives. In flipped environment, out-of-class time is spent on the lower levels, while in-class-time is spent on the higher levels.

Previous meta-analyses of the flipped classroom effect on student achievement concluded a positive relationship between academic achievement and flipped environment across multiple disciplines [2] [3], for exceptions see [4].

Methodology



Literature Search

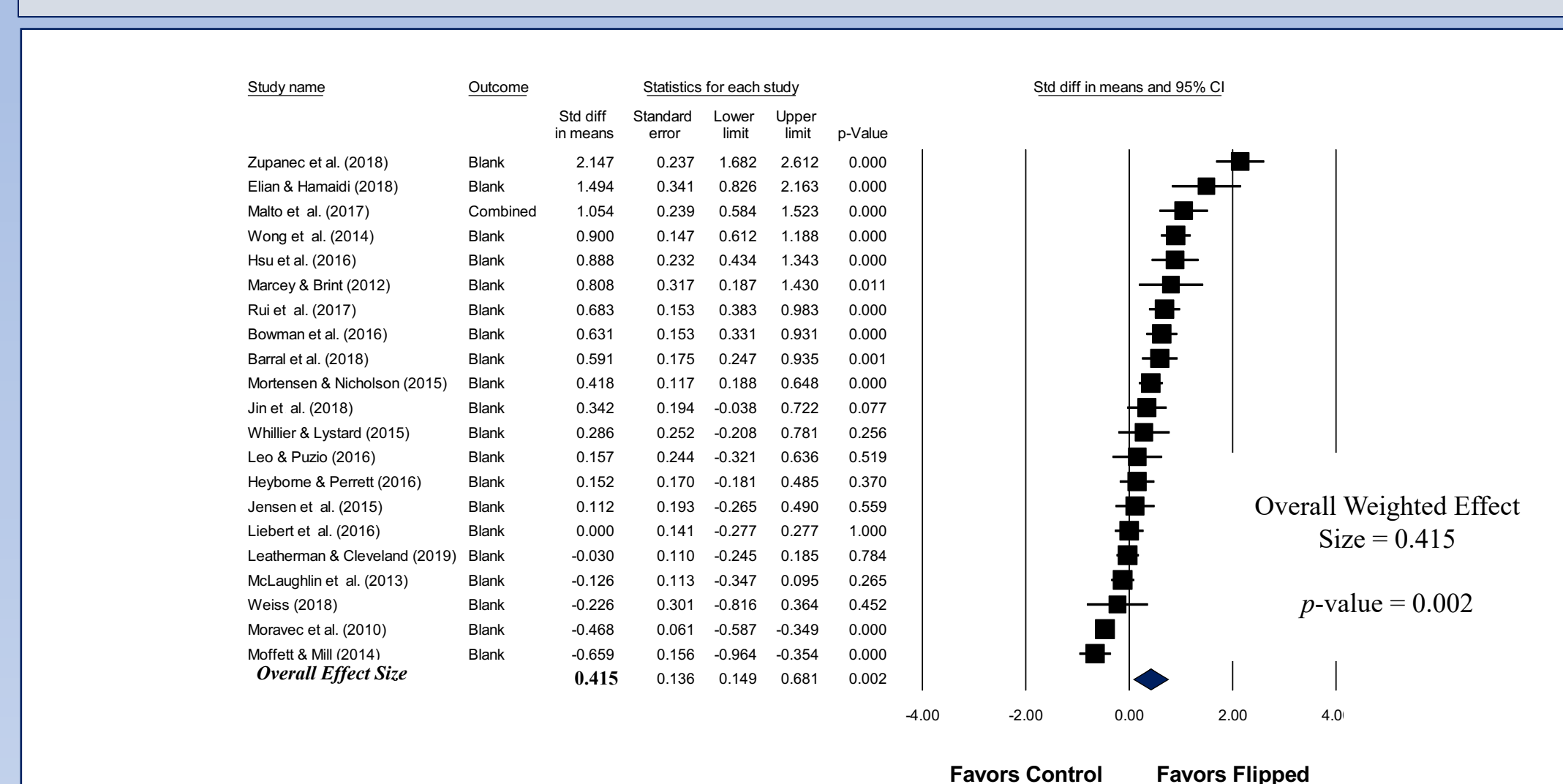


Effect Size

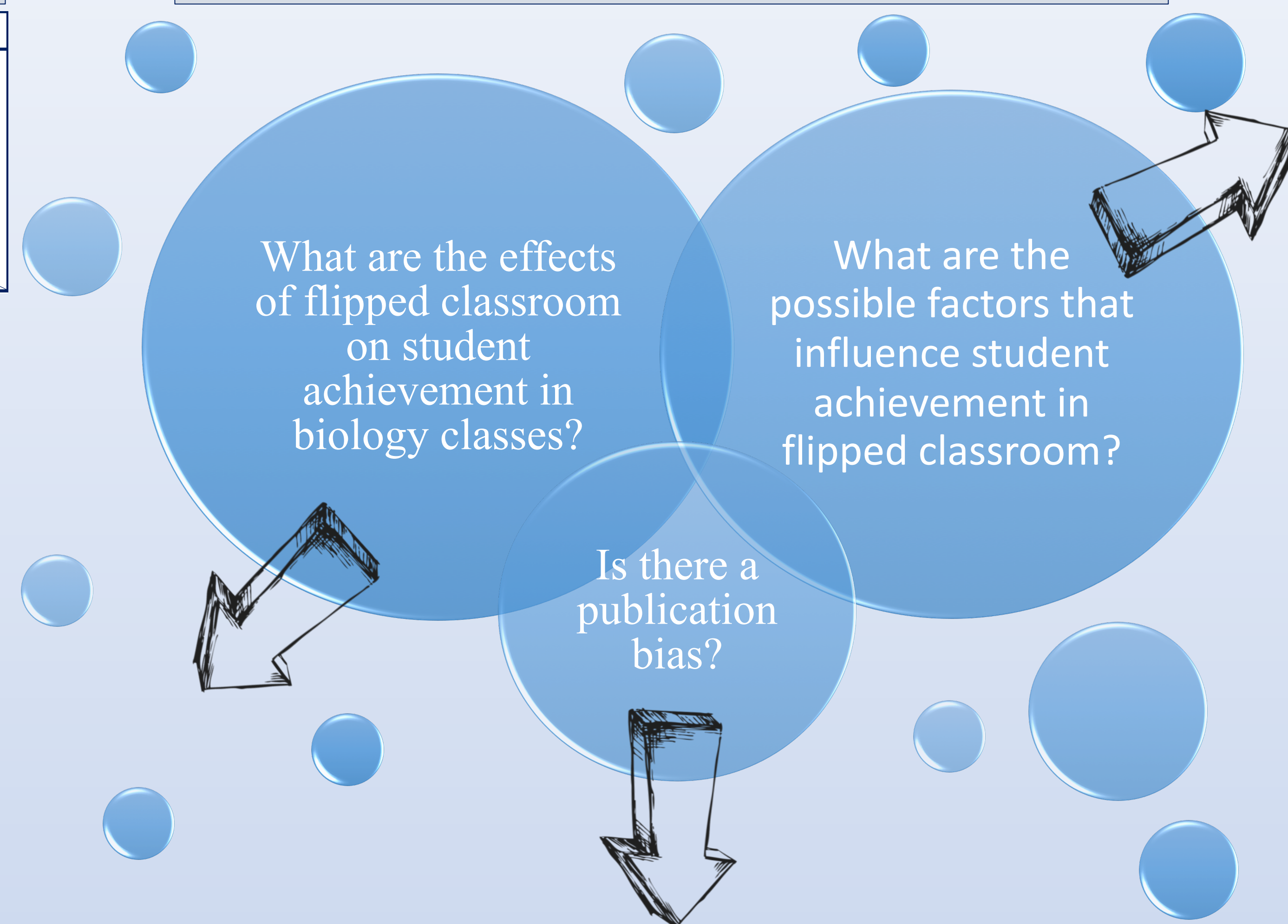
The *Comprehensive Meta-Analysis* version 3.0 was used. The studies that did not provide mean, standard deviation, sample size, *t*-value or *p*-value, were analyzed further to see if the data can be extracted in any way. The studies that reported more than one outcome, we took an average of outcomes to produce one single point estimate.

$$Effect\ Size = \frac{\bar{X}_{flipped} - \bar{X}_{traditional}}{SD_{pooled}}$$

Forest Plot



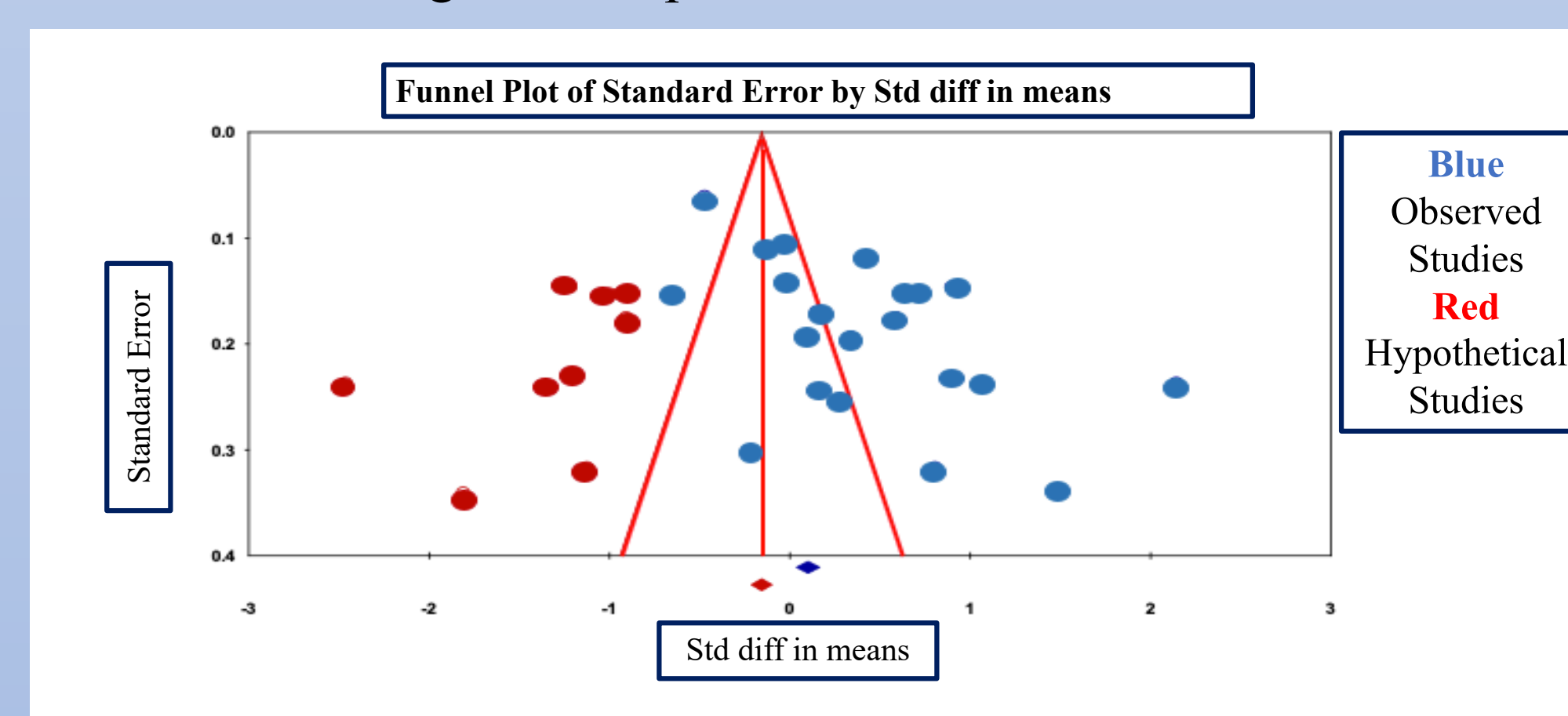
Research Questions



Publication Bias

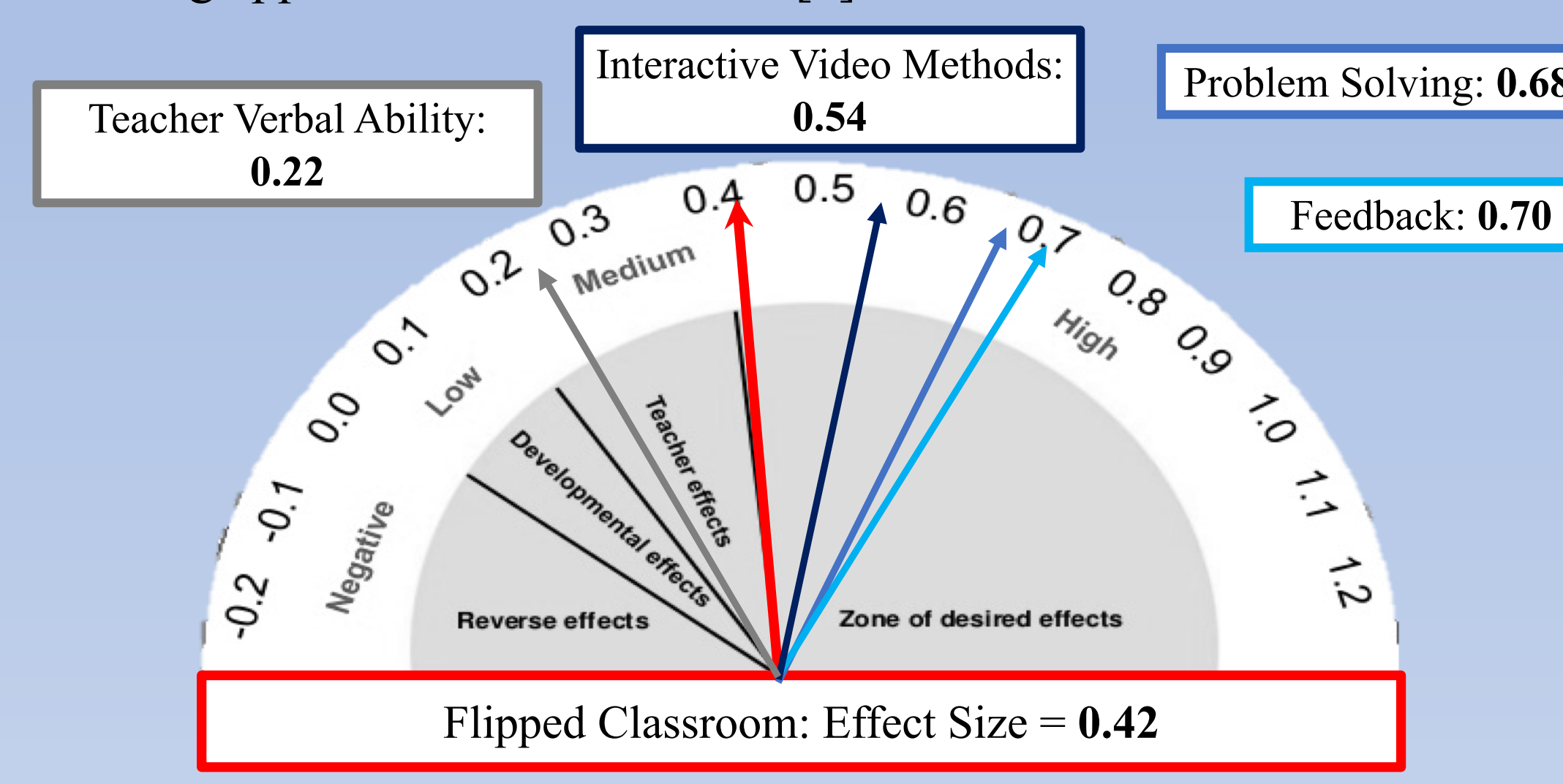
Publication bias occurs when studies that do not show a positive or significant result are not published, creating error [5]. To assess this issue, we generated following tests:

- Classis Fail-Safe *N*: Number of hypothetical articles that needed to remove publication bias → *N* = 332
- Begg and Mazumdar's Rank Correlation: Non-parametric test based on rank correlation between intervention effect estimates and sampling variances → Kendall's tau = 0.26 (*p* = 0.05)
- Egger's Regression test: Regression method that test linear association between the intervention effect and standard error → Intercept = 6.12 (*p* < 0.00)
- Trim and Fill: Adjust a meta-analysis for the impact of missing studies. This method first removes smaller studies, then trimmed funnel plot is used to estimate the true "center" to replace the studies and their missing "counterparts" around the center.



Hattie's Barometer of Influence

Provides a visual representation of different influences on academic achievement using effect sizes. Includes 7 areas that contribute to the achievement: students, home, school, curricula, teacher, teaching and learning approaches and classroom [6].



Heterogeneity

The degree of variation in the true effect that is due to something else other than sampling error (there are more factors that contribute to the results). Can be measured either by Cochran's *Q* test or *I*² statistics. The difference between *Q* test and *I*² is that *Q* test is biased towards the sample size. In contrast, *I*², does not have that bias, and provides the ratio of true heterogeneity (or signal-to-noise ratio).

<i>Q</i> -value	<i>df</i>	<i>p</i> -value	<i>I</i> ²	Tau ²
315.40	20.00	0.00	93.66	0.35

Both *Q* and *I*² value suggest that the results are heterogeneous. To see if the imprecision within studies explains the variance between the studies, tau-squared was measured. Tau is an estimate of the standard deviation of the distribution of true effect sizes, under the assumption that these true effect sizes are normally distributed.

Moderator Analysis

Moderator variables affects the magnitude of the relationship between independent and dependent variables. We explored the effect of the following moderator variables :

- Class Size
 - Course Level
- Moderators were chosen for the sufficient amount of studies for each of the levels.

Class size		Test for Effect of Class Size				
		<i>k</i> (Number of Studies)	Point Estimate	Standard Error	Lower Limit	Upper Limit
Small	Large	10	0.70	0.19	0.33	1.07
	Small	11	0.19	0.17	-0.14	0.51

Small classes benefitted more than large classes from implementation of a flipped classroom. This moderator did not reduce heterogeneity of meta-analysis.

Course Level		Test for Effect of Course Level				
		<i>k</i> (Number of Studies)	Point Estimate	Standard Error	Lower Limit	Upper Limit
K-12	Undergraduate	5	0.93	0.28	0.39	1.47
	Graduate	9	0.27	0.19	-0.11	0.65
	Graduate	7	0.27	0.22	-0.15	0.70

Students in K-12 benefitted more than undergraduate and graduate students from implementation of a flipped classroom. This moderator did not reduce heterogeneity of meta-analysis.

Conclusions

- First meta-analysis in life sciences using more than 4000 students
- Flipped classroom in life sciences has a positive effect on student achievement based on 21 studies
- Evidence of publication bias based on multiple tests
- Small classes and students in K-12 benefited the most from flipped classroom
- Flipped classroom fall in the zone of desired effect on Hattie's barometer of influence

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[1] Roehl, A., Reddy, S. L., & Shannon, G. J. (2013). The flipped classroom: An opportunity to engage millennial students through active learning strategies. *Journal of Family & Consumer Sciences*, 105(2), 44-49.
 [2] Cheng, L., Ritzhaupt, A. D., & Antonenko, P. (2019). Effects of the flipped classroom instructional strategy on students' learning outcomes: A meta-analysis. *Educational Technology Research and Development*, 67(4), 793-824.
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 [5] Rothstein, H. R., Sutton, A. J., & Borenstein, M. (2005). *Publication bias in meta-analysis: Prevention, Assessment and Adjustments*. Wiley.
 [6] Hattie, J. (2012). *Visible learning for teachers: Maximizing impact on learning*. Routledge.

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