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Effectiveness of Flipped Classroom Model (FCM) on Students' Learning Achievement in Physical Science: A Meta-Analysis

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ABSTRACT

Flipped Classroom Model (FCM) is a pedagogical approach in which the activities that students typically do at home are worked on in class, and the direct teaching that students often receive in class is supplied as homework in the form of video lectures, reading assignments, or another technique that delivers direct instruction. This pedagogical approach has been implemented across the world with schools utilizing blended-learning strategy. There have been incongruencies with the result of FCM studies conducted over the years, previous studies suggest that FCM is an effective tool in improving students learning achievement in physical science while there are studies that yield result otherwise. It is necessary to review research on its use in teaching and learning to determine how beneficial it is at various grade levels and scientific fields. This meta-analysis study prompts to investigate the effectiveness of FCM on the learning achievement in different educational level and physical science disciplines. According to the findings, the overall effect size (ES = 1.238) is statistically large and has a positive effect. The result denotes that the use of FCM can generally enhance the learning achievement of students in physical science. Moreover, the moderator analysis revealed that when individual studies are grouped according to educational level and physical science disciplines, there is also a large effect size. These findings suggest that teachers can utilized FCM effectively in improving the learning achievement of students in physical science.

Keywords: Flipped classroom, Learning achievement, Physical Science, Meta-analysis and PRISMA

1. Introduction

The global pandemic, which began in late 2019, had a profound impact on the education sector worldwide (Daniel, 2020; Onyema et al., 2020; Bhasin et al., 2021). As the virus spread rapidly across the globe, governments and health authorities implemented various measures to contain its spread, including social distancing and lockdowns. In response to these measures, schools and educational institutions were forced to adapt to new circumstances, and one of the most significant changes was the transition from in-person classes to online classes (Lemay et al., 2021; Zheng et al., 2021). This shift was necessitated by the need to minimize the risk of transmission and ensure the safety of students, teachers, and staff. As a result, educational institutions worldwide were compelled to adopt online learning platforms, virtual classrooms, and digital resources to continue providing education to students despite the physical constraints (Barrot et al., 2021; Li, 2022). This shift in learning pedagogy necessitated the development of differentiated teaching strategies and instructions to ensure that learning persists in the blended learning environment (Lapitan et al., 2021). One popular teaching strategy that can be employed during the blended learning approach is the use of the flipped learning model (Tucker, 2012; Rotellar & Cain, 2016).

The Flipped Classroom Model (FCM), also known as the "inverted classroom," is a pedagogical approach in which the activities (e.g., problem-solving) that students typically do at home are worked on in class, and the direct teaching that students often receive in class is supplied as homework in the form of video lectures, reading assignments, or another technique that delivers direct instruction (Szparagowski, 2014). However, there are misconceptions regarding the use of FCM. Szparagowski (2014) identified a common misconception that needs to be debunked - the idea that students work without direction, that videos take the place of the teacher, that students work alone, or that a flipped classroom is an online course. In reality, the flipped classroom model is a blended learning approach that combines in-class activities and out-of-class learning experiences, with the goal of creating a more engaging and personalized learning environment for students. The teacher still plays a crucial role in guiding and facilitating the learning process, and students are encouraged to collaborate and engage with the material in meaningful ways.

Numerous studies have been conducted to investigate the effectiveness of the flipped classroom approach in teaching and learning physics and chemistry. The results consistently show that integrating the flipped classroom model is effective in enhancing learning achievement, retention, learning motivation, and critical thinking skills in these subjects. For instance, studies by Al-Abdullatif (2020) , Basriyah et al. (2020), Bawaneh & Moumene (2020), and Jufriansah et al. (2022) all found positive outcomes from using the flipped classroom approach. Specifically, students who have been exposed to the flipped classroom model in physics have been shown to have higher retention rates compared to those without such exposure (Sirakaya & Özdemir, 2017). This suggests that students are more likely to remember physics concepts for a long time if the flipped classroom approach is embedded in the teaching-learning process.

The flipped classroom approach has been identified to have several positive effects. Firstly, it saves time because students can view lectures on video at home, reducing the amount of time spent listening to lectures in the classroom (Khayat et al., 2021). Secondly, students are more responsible for their own learning, and the teacher acts more as a facilitator to guide learning rather than teaching (Nouri, 2016). This results in more effective instruction and activities during class time. Additionally, the classroom activity becomes more effective and active, allowing teachers to easily observe students' interests and use technology tools as appropriate learning media in the twenty-first century. Furthermore, teachers can identify students' difficulties with homework in class, enabling targeted support and intervention. Overall, the flipped classroom approach has been shown to be a valuable tool in enhancing the learning experience in physics and chemistry.

However, some studies show that flipped classroom may not increase the conceptual understanding and academic performance of students in science (Manoharan & Birundha, 2020). Moreover, the result of the study conducted by Zainuddin & Halili (2016) shows the downside of integrating flipped classroom as a pedagogical approach in blended learning. Teachers that begin implementing the model of instruction frequently encounter difficulties. Most of the time, teachers are very enthusiastic about switching from traditional to flipped learning, but students are not prepared for this change (Collins, 2011 as cited by Zainuddin & Halili, 2016). Some students may not want to watch the video outside of class when the teacher is overly enthusiastic about implementing the flipped classroom (Raths, 2014 as cited by Zainuddin & Halili, 2016).

There are inconsistencies with regard to the result of the studies that implemented the flipped classroom model. It is necessary to review research on its use in teaching and learning to determine how beneficial it is at various grade levels and scientific fields. This meta-analysis study prompts to investigate the effectiveness of FCM on the learning achievement of junior high, senior high, and college students in physics and chemistry. Specifically, this study sought to answer the following:

1. What is the effectiveness of using FCM in students' learning achievement in physical science disciplines?
2. Is there a significant difference in the effect sizes of junior high, senior high, and college in relation to their physical science learning achievement?
3. Is there a statistically significant difference between the effect sizes of in students' learning achievement and physical science disciplines?

2. Methods

2.1 Research Design

The research design utilized on this study is meta-analysis, a statistical method that involves the synthesis of results from a series of studies to investigate the effectiveness of the flipped classroom model (FCM) on enhancing learning achievement of junior high, senior high, and college students in physical science. Meta-analysis refers to the statistical synthesis of results from a series of studies, which allows for the estimation of the overall effect size of the intervention and the identification of potential moderators that may influence the effect size (Borenstein et al., 2019). This approach is particularly useful in this study as it enables the aggregation of data from multiple studies, thereby increasing the statistical power and precision of the results. By using meta-analysis, this study aims to provide a comprehensive overview of the effectiveness of FCM in enhancing learning achievement in physical science across different grade levels, thereby informing educators and policymakers on the potential benefits and limitations of this instructional approach.

2.2 Study Search Procedure

To conduct this meta-analysis study, the researcher established a set of inclusion and exclusion criteria to sift through the necessary journal articles. To facilitate this process, Publish or Perish (Harzing, 2007), a software program, was utilized to obtain a variety of raw citations. The meta-search engines employed for this search were Google Scholar, ERIC (Educational Resources Information Center), and Open Alex. The scope of the search was intentionally restricted to the period from 2018 until the third quarter of 2022 to ensure that the results were relevant and up-to-date. In the meta-search engines, the following descriptions were entered: "flipped classroom", "flipped classroom approach", "flipped classroom model", "learning achievement", and "physics and chemistry". These keywords were chosen to capture studies that specifically investigated the effectiveness of the flipped classroom model on learning achievement in physics and chemistry. The inclusion criteria for the studies were as follows: the study must have been published in a peer-reviewed journal, the study must have investigated the flipped classroom model as an instructional approach, the study must have measured learning achievement as an outcome variable, and the study must have focused on physics and chemistry as the subject areas.

2.3 Inclusion and Exclusion Criteria

In selecting relevant studies , the eligibility criteria were set as follows: (1) must be a peer-reviewed journal article published from 2018 until 2022, (2) must be experimental or quasi-experimental design on use of "Flipped Classroom", (3) must measure the learning achievement, (4) must focus in a science discipline which includes Chemistry and Physics, (5) must use junior high, senior high, and college students as respondents (6) must contain adequate statistical or quantitative data to obtain the effect size (e.g., sample size, mean, standard deviation, and Hedge's g), and (7) must be written in

English language. The collected journal studies were filtered out after identifying the inclusion criteria. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) strategy was utilized for a transparent and quality process of screening relevant journal articles

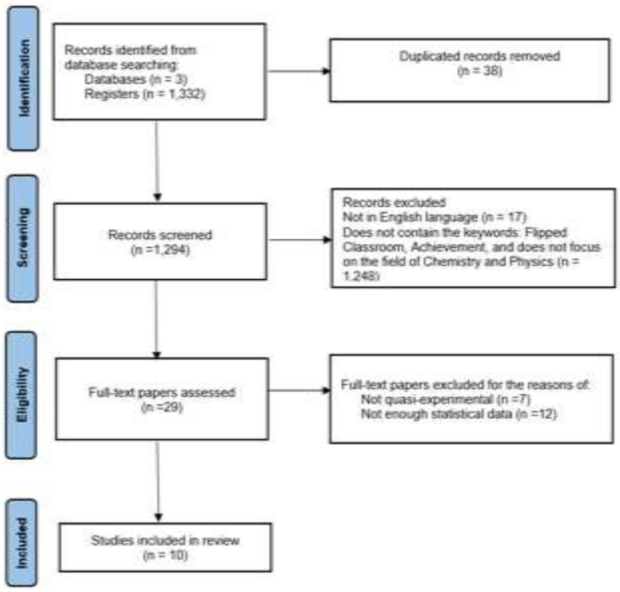


Fig. 1 – PRISMA Flow Diagram

2.4 Selection Process

This meta-analysis included a total of 1,332 studies that employed the Flipped Classroom Model (FCM). However, after a thorough evaluation of these studies, only 10 studies met the inclusion criteria. Initially, 34 full-text studies were assessed, but unfortunately, many of these studies lacked sufficient statistical data, including means, standard deviations, and sample sizes. This lack of statistical data made it unfeasible to include these studies in the meta-analysis, as these data are essential for calculating the effect size (Hedge's g).

2.5 Coding Procedure

To ensure the accuracy and consistency of the data gathered from the relevant journal articles, a systematic coding scheme was employed to classify the data. The following coding schemes were used to categorize the data:

1. Researchers' Last Name and Year of Publication: Each study was coded with the researcher's last name and the year of publication, allowing for the identification of the specific study and the researcher responsible for conducting it.
2. Students' Educational Level: The educational level of the students involved in each study was coded, including junior high, senior high, and college students.
3. Scientific Discipline Identified: The scientific discipline that was the focus of each study was coded, including chemistry and physics.
4. Control/Comparison Condition: The control or comparison condition used in each study was coded, allowing for the comparison of the flipped classroom model with other instructional approaches.
5. Research Design Utilized: The research design used in each study was coded, including experimental, quasi-experimental, and non-experimental designs.
6. Statistical Data: The statistical data collected from each study was coded, including means, standard deviations, and sample sizes.

2.6 Effect Size Calculation

The effect size (Hedge's g) was employed to efficiently measure the effectiveness of FCM in learning achievement of students in chemistry and physics. When sample size studies are small enough to avoid bias, Hedge's g is more valid to use than Cohen's d (Wasserman et al., 1988). The value of effect size was interpreted following the values: above 0.80 is considered large effect, 0.50 to 0.79 is considered medium effect, 0.20-0.49 is considered small effect, and less than 0.20 is considered no effect (Cohen, 1988 as cited by Lakens, 2013). In statistically assessing the data, the CMA (Comprehensive Meta-Analysis) Version 4.0 software developed by Biostat, Inc. was utilized. The statistical data of this meta-analysis study were grouped and compared using moderator analysis, which was also used to determine other crucial statistics including effect sizes, heterogeneity, and forest plot.

3. Results

This meta-analysis study conducted a comprehensive review of 10 empirical studies that employed the Flipped Classroom Model (FCM) in teaching and learning physics and chemistry. The total sample size of these studies consisted of 946 students, representing junior high, senior high, and college students. The occurrence of qualified studies with educational level and scientific disciplines is presented in Table 1, providing a detailed breakdown of the studies included in the meta-analysis.

Table 1 - Occurrences of Educational Level and Scientific Discipline

Educational Level	**Frequency**	**Percentage**
Junior High School	4	40%
Senior High School	4	40%
College	2	20%
Scientific Discipline	**Frequency**	**Percentage**
Chemistry	3	30%
Physics	7	70%

As displayed on Table 1, there were studies conducted from 2018-2022 that employed junior high school level (n = 4), senior high school level (n = 4) and the lowest number of research articles was conducted in college level (n = 2). Many studies involved physics (n = 7) and there were few studies that use Chemistry (3) in investigating the effectiveness of FCM in learning achievement of students.

In measuring the result of overall effect size, the combined effect sizes of qualified studies were shown in Table 2. It shows the values of number of studies *k*, overall effect size *ES*, standard error *SE*, variance, confidence interval *CI*, and heterogeneity.

Table 2 - Result of Overall Effect Size

					95% CI				**Heterogeneity**			
	k	**ES**	**SE**	**Variance**	**Lower Limit**	**Upper Limit**	**Z**	***p***	**Q**	**df (Q)**	**P**	**I-squared**
Fixed	10	1.154	0.073	0.005	1.011	1.297	15.82	0.000	137.960	9	0.000	93.476
Random	10	1.238	0.289	0.084	0.671	1.805	4.28	0.000				

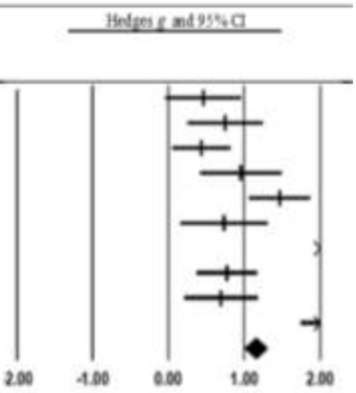
Based on the result of the overall effect size, its value is found to be 1.238, which indicates that there is a statistically large effect (Cohen, 1988 as cited by Lakens, 2013) on the learning achievement of the students after using the Flipped Classroom Model (FCM) in physics and chemistry. This large effect size suggests that the FCM has a significant impact on student learning outcomes, and it is likely to be a valuable instructional strategy for improving student performance in these subjects.

In addition, the result of heterogeneity reveals that the p-value is less than the criterion alpha for testing the heterogeneity, which is 0.05 ($p < 0.05$). This suggests that the FCM has more significant effects in some studies than others. Hence, this result suggests that the distribution of the effect sizes is statistically heterogenous, and this implies that the random-effects method should be deployed in this meta-analysis (Borenstein et al., 2011; Hedges & Vevea, 1998; Langan, 2021).

In 95% of all populations, the overall effect size falls between 0.671 to 1.805. This confidence interval provides a range of values within which the true effect size is likely to lie. The I-squared statistic is 93%, indicating that roughly 93% of the observed effect variation is due to overall size effect variance rather than sampling error. This high value of I-squared suggests that there is significant heterogeneity in the effect sizes across the studies, and this highlights the importance of using a random-effects model to account for this heterogeneity.

Table 3 - Forest Plot of Individual Studies

Study Name	Hedges g	Standard Error	Variance	Lower Limit	Upper Limit	Z-value	p-value
	Statistics for each study						
Al-Abdullatif et al. (2020)	0.459	0.253	0.064	-0.037	0.956	1.813	0.070
Astra et al. (2018)	0.748	0.251	0.063	0.256	1.239	2.981	0.003
Atwa et al. (2018)	0.435	0.194	0.038	0.055	0.815	2.245	0.025
Basriyah et al. (2020)	0.954	0.272	0.074	0.420	1.488	3.501	0.000
Bawaneh et al. (2020)	1.464	0.203	0.041	1.065	1.862	7.200	0.000
Jufriansa et al. (2022)	0.733	0.292	0.085	0.160	1.305	2.508	0.012
Macale et al. (2021)	4.222	0.356	0.127	3.524	4.921	11.855	0.000
Rohyami et al. (2020)	0.771	0.201	0.041	0.376	1.165	3.827	0.000
Manoharan et al. (2020)	0.694	0.246	0.061	0.211	1.176	2.819	0.005
Ugwuanyi et al. (2020)	2.096	0.179	0.032	1.746	2.447	11.727	0.000
	1.154	0.073	0.005	1.011	1.297	15.821	0.000



The individual analysis of the studies is presented in Table 3, providing a detailed breakdown of the results for each study. The analysis reveals that the overall effect size consistently favored the experimental group, which utilized the Flipped Classroom Model (FCM), compared to the control group, which employed non-FCM instructional approaches. This finding suggests that the implementation of the FCM has a significant positive impact on student learning achievement in physics and chemistry, outperforming traditional teaching methods. The individual study results contribute to the overall large effect size of 1.238 found in the meta-analysis, indicating that the FCM is a highly effective instructional strategy for enhancing student learning outcomes in these scientific disciplines. The consistent superiority of the FCM group across the studies underscores the potential of this pedagogical approach to transform teaching and learning in physics and chemistry, and highlights the importance of further investigating the specific mechanisms and factors that contribute to its effectiveness.

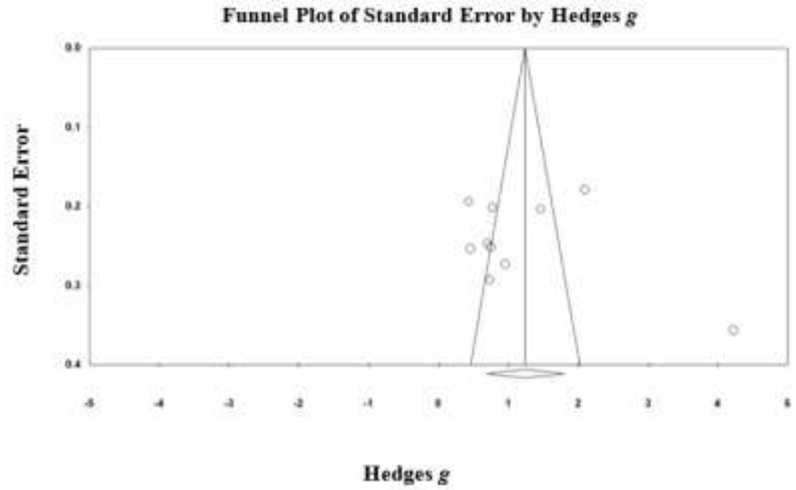


Fig. 2 – Funnel Plot of Publication Bias of Qualified Status

As presented on Table 2, by visually assessing the funnel plot, it can be drawn that there are outliers among the qualified studies that have been included in this meta-analysis. In addition, the funnel plot shows visually that there is an asymmetric distribution among these studies, which may indicate the presence of publication bias. However, based on the result of Begg-Mazumdar's rank correlation test, the result reveals a p-value of 0.593, which suggests that there is no publication bias ($p > 0.05$). The Begg-Mazumdar's test prompts that there is a symmetric distribution of the studies statistically. The study is resistant to publication bias if the distribution of effect size is symmetrical (Borenstein et al., 2011).

Moreover, based on the result of Classic Fail-Safe N analysis, the p-value resulted with a value of 0.05 ($p \leqslant 0.05$), which supports that the qualified studies in this meta-analysis are resistant to publication bias. This means that the results are not influenced by the selective reporting of studies with significant findings. Additionally, the Classic Fail-Safe N analysis suggests that there should be additional 221 studies to refute this meta-analysis, indicating that the results are robust and not susceptible to publication bias.

In identifying the significant difference of effect sizes between educational level and physical science groups, the utilization of moderator analysis is needed. This analysis allows for the examination of the relationship between the effect size and the moderator variables, such as educational level and physical science, to determine if there are any significant differences in the effect sizes between these groups. Table 3 provides the information for moderator analysis between groups, including the effect size, standard error, and p-value for each group.

Table 4 - Moderator Analysis between Groups (Educational Level and Physical Science)

Moderator Variables	k	ES	SE	Variance	95% CI		Z	*p*	Heterogeneity		
					Lower Limit	Upper Limit			Q	df (Q)	P
Educational Level	10	1.139	0.253	0.064	0.642	1.635	4.497	0.000	0.304	2	0.859
JHS	4	1.524	0.760	0.577	0.035	3.014	2.006	0.045			
SHS	4	1.051	0.425	0.180	0.219	1.883	2.475	0.013			
College	2	1.117	0.347	0.120	0.437	1.796	3.221	0.001			
Physical Science	10	1.058	0.254	0.065	0.560	1.557	4.163	0.000	0.796	1	0.372
Chemistry	3	1.874	0.949	0.9001	0.015	3.734	1.975	0.048			
Physics	7	0.995	0.264	0.070	0.478	1.513	3.772	0.000			

As the result of moderator analysis reveals on Table 3, there is a statistically significant difference on the effect sizes of the individual studies according to education level and physical science discipline ($p < 0.05$). In referring to the educational level of the students, the analysis shows that the FCM had the greatest triumph in the junior high school level (ES = 1.524) followed by in college level (ES =1.051). FCM had the least effect size on the senior high school level (ES = 1.051). Furthermore, the analysis suggests that FCM had a larger effect on chemistry (ES = 1.874) than on physics (0.995) in relation to their learning achievement.

4. Discussions

The implementation of flipped classroom model (FCM) has been widely used as a pedagogical approach across the world during blended learning. The result of this meta-analysis revealed that the FCM has been an effective tool in enhancing the learning achievement of the students in junior high, senior high, and college level across physical science disciplines. The studies that were qualified for this meta-analysis were 10 empirical students that implemented FCM from 2018-2022.

The result revealed that the overall effect obtained is 1.238 which is interpreted as a statistically large and positive effect. This result denotes that the use of FCM can generally enhance the learning achievement of junior high, senior high, and college students in physical science disciplines. Individually, the studies that obtained large effects were Macale et al., 2021 (ES = 4.222), Ugwuanyi, et al., 2020 (ES = 2.096), and Bawaneh, et al., 2020 (ES=1.464). Moreover, the studies that result medium effect were Basriyah et al., 2020 (ES = 0.954), Astra et al., 2018 (ES=0.748), Rohyami et al., 2020 (ES = 0.771), Jufriansa et al., 2022 (ES = 0.733), Manoharan et al., 2020 and (ES = 0.694). The results of Al-Abullatif et al. (2020) and Atwa et al. (2018) only had a small effect of 0.459 and 0.435, respectively. The analysis of this meta-analysis concluded that FCM enhances the learning achievement of students compared to convention and other pedagogical strategies ($p > 0.000$).

In addition, the moderator analysis shows that the educational level and physical disciplines had positive effects on the learning achievement of junior high, senior high, and college students. The results revealed that there is a statistically significant large effect on Junior High Level (ES = 1.524), College Level (ES = 1.117) and Senior High Level (ES = 1.051). It can be concluded that the FCM is a success in enhancing the learning achievement of students at different levels. Not only that FCM had a positive effect on educational level, in fact the findings of this meta-analysis show that both physical science disciplines had a statistically significant large effect, Chemistry (ES = 1.874) and Physics (ES = 1.058), respectively. These numbers are manifestation that the use of FCM is efficient in physical science discipline in improving students learning achievement.

5. Limitations of the Study

The studies involved in this meta-analysis study are constraint to the inclusion and exclusion criteria set by the researcher. It can be gleaned from the study that the studies that were included are small. For the reason that the researcher set an exclusion and infusion criteria, there are studies that did not qualify as a consequence that some studies are:

1. did not use an experimental or quasi-experimental design on use of “Flipped Classroom”,
2. did not measure students’ learning achievement,
3. did not focus on physical science disciplines such as physics and chemistry,
4. did not use junior high, senior high, or college students,

5. did not contain enough statistical data.

6. Conclusions and Recommendations

The result of this meta-analysis study led to the following conclusions:

1. The implementation of FCM in blended learning is found to improve the learning achievement of Junior Highschool, Senior Highschool, and College students in various physical science disciplines (Chemistry and Physics). The findings show that there is a statistically large significant effect in integrating FCM. This blended-learning pedagogical approach, flipped classroom, is effective in enhancing students learning achievement in physics and chemistry.
2. The effect sizes obtained when the individual studies are grouped whether educational level (Junior Highschool, Senior Highschool or College) and physical science disciplines (Chemistry and Physics), the result obtained a large effect suggesting that the FCM is effective when implemented regardless of the educational level and physical science disciplines in improving students learning achievement.

Most schools across the world are still implementing blended learning approaches because of the constraint brought by COVID-19 pandemic. The result of this meta-analysis provided that the implementation of FCM as a pedagogical approach in blended learning is very effective in enhancing the learning achievement of students in physical science. This is a great approach that can be embedded in class for teachers supervising classes with blended-learning approach.

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