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Flipped Classroom Approach in Teaching-Learning Selected Topics of Physics for Engineers

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Effectiveness of Flipped Classroom Approach (FCA) and Students' Mental Effort in Teaching-Learning Selected Topics of Physics for Engineers

Abstract

Instructional models, strategies, and approaches play a vital role in the teaching-learning process. The study explored the effectiveness of the Flipped Classroom Approach (FCA) in teaching-learning selected topics of physics for engineers. Along with the effectiveness, the mental effort expended by the students in learning was also investigated. This study used a quantitative method, specifically a quasi-experimental design, to find out how well the FCA worked compared to the traditional 7E instructional model. The subjects of the study were first-year engineering students from a private university in Mindanao, two intact groups were selected to be the experimental and the control groups of the study. The implementation of the intervention lasted for three weeks, and before the implementation, a pretest was conducted on both groups. Before and after the implementation period, the posttest was given to both groups again to see how well the FCA worked compared to the 7E model when used in class.

The FCA group achieved higher posttest scores (mean: 19.125) than the control group (mean: 16.206), with effect sizes (Cohen's d) of 5.168 and 4.263, respectively, both indicating very large effects. Statistical tests confirmed no significant difference in pretest scores (MWU: showing comparable initial knowledge). However, the posttest analysis (Mann-Whitney U: $p<0.001$) demonstrated a significant performance advantage for the FCA group. Ranked biserial correlation ($r_{rb}=-0.788$) further highlighted a moderate-to-large effect size favoring the FCA.

Mental effort assessments showed the control group reported higher effort both pre- (mean: 6.935) and posttest (mean: 7.161) compared to the FCA group (pretest: 5.739, posttest: 6.565). These findings suggest that while the FCA required less perceived effort, it yielded better learning outcomes, potentially due to its active and self-paced nature. Homogeneity of variances was confirmed (Levene's test: pretest-posttest with $p=0.103$), supporting the robustness of the statistical comparisons.

It was found out that FCA is effective in improving the performance of students in selected topics in Physics for engineers compared to the 7E model; thus, it is recommended to use the FCA in teaching highly technical subjects because it allows students to learn at their own pace and have the necessary learning materials. On the other hand, the mental effort of the students before and after the instructional delivery for both groups are statistically significant, which meant that decreases in students' mental effort correlated with higher performance in the posttest. In conclusion, the FCA is effective in teaching-learning selected topics in Physics for Engineers, and the mental effort of students varies when different strategies are being used in the classroom. We recommend further validating the results of this study by applying it to other disciplines and contextualizing the lessons.

Keywords: Flipped Classroom Approach, Physics for Engineers, Effectiveness, Teaching-Learning, quasi-experimental design

Introduction

Physics as an area of science education plays a pivotal role in 21st-century education and global industry. In 21^{st}-century education, technological skills and competencies are highly in demand, and these skills and competencies are mostly found and taught in the science education discipline. And one of these disciplines is physics education, which deals with the fundamentals of the interaction of energy and matter, as well as engineering and technology. The teaching and learning mechanisms in physics for engineering students involve innovative approaches aimed at enhancing conceptual understanding and promoting deep learning. Research emphasizes the shift from traditional teaching methods to more interactive and inquiry-based strategies to engage students effectively [1]. Interactive simulations play a crucial role in teaching physics, particularly electrostatics, as they significantly improve learners' understanding and outcomes compared to conventional teaching methods alone [2]. These simulations allow students to visualize abstract concepts effectively and actively participate in the learning process, fostering a deeper understanding of physics concepts.

In the study of Ince conducted in 2018, a student's success in solving physics problems depends not only on the student's conceptual understanding of physics but also on establishing a relationship between all of the information and concepts in the problems. It has been observed that problem solvers take more time to understand the problem and concept connections, especially in complex physics calculations [3].

Considering that new education standards emphasize in higher and skills including reasoning, creativity and open problem solving . The learners experience difficulty understanding the basic knowledge and skills in understanding physics. Lecture classes, problem-solving sessions, and laboratory activities deliver these fundamental physics topics to learners. The lack of organization creates many difficulties in the comprehension of basic concepts and in solving complex problems. This leads to the common complaint that students' knowledge of physics is reduced to formulas and labels of the concepts, which are unable to significantly contribute to meaningful reasoning processes [4].

To address students' learning difficulties in physics, the subject needs to be made enjoyable and the learning content needs to be carefully examined based on relevance, necessity, and the learner's interest [5]. Moreover, many of the teaching strategies used and explored make physics easy and interactive to grow the motivation and understanding skills of each learner. Flipped classroom, or reverse classroom, is an element of blended learning, integrating both face-to-face learning in the class through group discussion and distance learning outside class by watching asynchronous video lessons and online collaboration [6].

Flipped classroom is also known as a student-centered approach to learning where the students are more active that the instructor in the classroom activity. In this case the instructor acts as a facilitator to motivate, guide, and give feedback on students' performance [7]. Hence, by applying the flipped classroom approach to the concepts of physics in teaching and learning activities, the instructor can move from traditional lecture's talk to video, and the students can listen to the lecture anywhere at their preferred time and need and can study at their own pace. This approach can contribute to better understanding of technology use in teaching and learning activities while students can independently do the learning activities using media as teaching practices [8].

The flipped classroom approach has been shown to be an effective teaching method in various educational settings. Several studies have investigated the effectiveness of the flipped classroom compared to traditional lecture-based learning. A meta-analysis done by Zheng et al. in 2023 found a small positive effect of the flipped classroom on assessed student learning outcomes in STEM subjects [9]. Supported by another study with the same method, it was revealed that the flipped classroom approach can enhance student self-efficacy, potentially increasing student engagement in learning [10]. Compared a task-driven flipped classroom approach to lecture-based learning and found that students receiving flipped learning teaching scored higher on the final test.

The 7E model

The 7E model refers to the approach that seeks to improve student learning by emphasizing active engagement with the material first developed and published by Eisenkraft in 2003. In order, these Es are elicit, engage, explore, explain, elaborate, evaluate and extend. This was an expansion of the 5E learning cycle originally from Bybee and colleagues at BSCS (Biological Sciences Curriculum Study). The objective of the 7E model is to facilitate an organized approach to science teaching. The table that follows

Table 1. A summary of the 7E process

Step	Name	Rationale/Explanation
1	Elicit	Students assess prior knowledge and misconceptions of the topic
2	Engage	Instructors seek to capture students' interest of the topic
3	Explore	Provide a hands-on experience
4	Explain	Formal explanations given to explain phenomena
5	Elaborate	Providing students opportunities to deepen understanding through application
6	Evaluate	Assessment of the learning process
7	Extend	Connection of students' learning to new contexts

This framework was used a basis for designing the flipped classroom approach reported in the study.

Statement of the Problem

This study evaluated the effectiveness of the flipped classroom approach in teaching Newton's Selected Topics in Physics for Engineers class. Specifically, it answered the following:

1) What are the pretest and posttest scores of the students (in both experimental and control groups) on selected topics in Physics for engineers?
2) Is there a significant difference between the pretest scores of the students in the control and experimental groups?
3) Is there a significant difference in the posttest scores of the control and experimental groups?

Methods

Participant Profiles

This study utilized a quantitative research method, specifically a quasi-experimental research design. The study employed this design to compare the performance of the experimental and control groups. Both groups were made up of students at a higher education institution (HEI) in Mindanao who were taking Engineering Physics 1 for the second semester, academic year 2023-2024. This design is a good fit for the study because it evaluated the effectiveness of the flipped classroom approach (FCA) in teaching-learning of selected topics in engineering physics.

The students pursued majors in civil engineering, electronics communication, and electrical engineering. All of them completed the Science, Technology, Mathematics and Engineering (STEM) senior high school track prior to university. Sixty-three (63) students were part of this study; they were divided into two different groups: the experimental group with 35 students and the control group with 28 students. Students came from comparatively similar socio-economic and demographic backgrounds, as determined by the course instructor, who was a co-author of this work.

Research Instruments (Diagnostic Tests and Mental Effort)

This study utilized mechanics diagnostic tests by Korsunsky in 2005 [11] , learning plans, and a learning management system (LMS). The mechanics diagnostic test is a standardized test adopted by the researchers that would serve as a pretest and posttest questionnaire. The content of the MDT is aligned with the selected topics in engineering physics, which are engineering mechanics, Newton's Laws of Motion, and Work and Energy. After that, the researchers used the learning plans and learning management systems to put the FCA into practice in the experimental group and the old-fashioned method in the control group.

The 9-point Likert scale first proposed by Paas was used to determine the degree of mental effort students perceived during the activity [19]. In this investigation, mental effort was defined according to the cognitive load theory, which was championed by Sweller, Ayres and Paas as the cognitive capacity allocated to accommodate the demands of a task. Although these authors further subdivided the students' cognitive load as intrinsic (related to task complexity and interactivity), extrinsic (caused by inefficiency of instructional design) and germane (useful effort dedicated to schema construction and learning), the authors did not distinguish which cognitive load was indicated in the scale, but rather operating on the assumption that extraneous load was the primary contributor to mental effort. Therefore, the hypothesis was that if the method was well designed, then the mental effort caused by extraneous load would be reported to be lower. Further studies could explore this aspect further.

Data gathering Procedure

In conducting this study, the researchers first secured the necessary permission letter from the university where the research will be implemented. After securing the permission, the preparation of necessary instructional materials and the mechanism of implementation were planned out, and the questionnaires to be used in the study. After the preparations, the pretest was administered by the researchers to both groups; then the data were analyzed, and it was found that the two groups were comparable and almost had the same academic performance.

During the conduct of instruction for the implementation, the experimental group had the FCA as the main instructional strategy in teaching selected topics in engineering physics. On the other hand, the control group was instructed using the 7E instructional model, and most of the activities are being done inside the classroom in a traditional approach. As the implementation commenced, the researchers identified the mental effort of the students towards learning the subject through the mental effort scale. The implementation of the FCA lasted for 3 weeks, and then after that, the posttest was administered to both groups.

In the posttest, the items were rearranged so that familiarity and other testing biases were minimized. Along with the posttest, the mental effort rating scale was then given again to the students for them to rate their mental effort after the implementation of the FCA and 7E to the groups being studied. Then, the researchers gathered all the necessary data and proceeded to the data analysis.

Application of the 7E model to the study

Overall, since the objective of the study was to determine if there were any differences between traditional lecture-based instruction as control and the flipped classroom approach (FCA) as the intervention, the authors emphasized that the learning outcomes be very similar between treatment groups using the same 7E framework.

The tables that follow shows the pre=class, in-class and post-class activities for the flipped classroom approach using the 7E model. This was the general flow for both topics studied: Newton's Laws and Work, Energy and Power,

Table 2. 7E implementation in the Flipped Classroom Approach (FCA)

7E Phase	Pre-class activities	In-class activities	Post-class activities
Elicit	Pretest	Discussion of responses from pretest	None
Engage	Assigned interactive online videos on topic	Guided groupwork on analysis on how	Reflection paper on how topic could be applied in

		Newton's laws were applied to the situations in the video clips	different situations
Explore	Instructions for the in-class experiment that would happen	Hands-on activity involving a DIY engineering challenge	None
Explain	Gude questions assigned for students before in-class activity	Students answer questions and problems related to guide questions	None
Elaborate	Asssign problem whose solution requires application of learned principles	Finalization and collection of solutions to assigned problems	Reflection of design submitted as feasible or infeasible
Evaluate	Posttest	Discussion of answers from posttest; comparison with correct answers	Case study on a real-world scenario
Extend	Assign students to contribute to an online discussion board on other applications	Give students hypotheticals and case studies where students predict what happens	Encourage students to conduct exploratory research on more complex systems

Data Analysis

To find the best way to compare means (parametric or non-parametric statistics), a test for normality and Levene's test for homogeneity of variances were run to see how well FCA helps future engineers learn physics.

We used non-parametric statistics, specifically the Mann-Whitney U test, to compare the groups' pre-test scores, post-test scores, and gain scores. This was done after checking the assumptions for inferential statistics and finding that the data are not normally distributed. We evaluated the effectiveness of FCA compared to the traditional teaching approach based on the results of these tests.

Another variable being studied in this study was the mental effort of the students towards learning the subject This test was given before and after the instruction to both groups was administered. To determine the mental effort of the students, descriptive statistics were used, such as mean and standard deviation, and values were interpreted. After identifying the mental effort of the students before and after the implementation of the interventions, a test for comparing means was utilized, specifically a t-test.

Results and Discussion

In Table 1, you can see the descriptive statistics for test scores and mental effort scores. These show the mean and standard deviations for the control and experimental groups before and after the tests.

Table 2. Descriptive statistics for test scores and mental effort scores

Variable	Lecture (Control)		FCA (Experimental)	
	M	SD	M	SD
Pretest score	6.353	1.555	5.667	1.204
Posttest score	16.206	1.409	19.125	2.050
Mental effort scale (pretest)	6.935	1.878	5.739	2.435
Mental effort scale (posttest)	7.161	1.969	6.565	1.973

The information given describes two ways of teaching: traditional lectures (control) and the Flipped Classroom Approach (FCA) (experimental). It is based on scores from a pre- and post-test and a mental effort scale. The pretest scores show that both groups started with similar levels of knowledge, with the control group scoring slightly higher on average (6.353) than the FCA group (5.667). However, the posttest scores reveal a significant improvement in both groups, with the FCA group achieving a notably higher mean score (19.125) compared to the control group (16.206). This suggests that the FCA might be more effective in enhancing student learning outcomes.

In terms of mental effort, the control group reported higher perceived effort both before and after the intervention. The pretest mental effort scores were 6.935 for the control group and 5.739 for the FCA group, while the posttest scores were 7.161 and 6.565, respectively. This indicates that students in the lecture-based setting found the material more mentally taxing throughout the study. The FCA group said they had to work less mentally, and their post-test scores were higher. This suggests that the Flipped Classroom Approach may be a better way to learn, possibly because it includes active and self-paced learning, which apparently reduces perception of cognitive difficulty. The exact mechanism was not explored in the study.

Effectiveness of Flipped Classroom Approach

1.1. Pretest-pretest comparison

Since the Shapiro-Wilk test revealed that the data was non-parametric (control:), the pretest scores of the lecture (control) and FCA (experimental) groups were compared using the Mann-Whitney U test for independent samples.This resulted in p-value of 0.037. Table 3 displays the outcome of the MWU analysis. Levene's Test performed on the pretest scores indicated equal variances for both groups (p=0.377). Results for Levene's test is presented in Table 5. Table 4 displays the Shapiro-Wilk (SW) test results. The mean pretest scores between the groups did not differ significantly (p=0.097) according to the MWU result. This suggests that both groups' ability levels were comparable before any intervention.

Table 3. Pretest-pretest Shapiro-Wilk test on pretest scores results

		W	**p**
Pretest scores	Lecture (Control)	0.917	0.013
	FCA (Experimental)	0.911	0.037

The first test conducted was the test for normality which is the Shapiro-Wilk's test. The test for normality is very important before performing further statistical analysis because it will determine whether the data in this case pretest data is normal or not. When the data is found to be normal the then parametric statistic will be used otherwise non-parametric statistics will be used. The table below shows that the p-value of the pretest scores is equal to 0.917 and 0.911 ($p>0.05$), thus, the data is not normally distributed meaning we reject the null hypothesis assuming that data is normally distributed hence it confirms the assumption of the alternative hypothesis that data deviates from the normality which means that the further test will be under non-parametric statistics.

Studies have highlighted the importance of testing for normality before conducting statistical analyses. In the study of Ghasemi and Zahediasl done in 2012, it was emphasized that many statistical procedures assume normality, and violations of this assumption can lead to inaccurate conclusions [12]. Similarly, according to Field in 2013, failing to test for normality can invalidate the results of parametric tests, thus making the initial assessment of data distribution a critical step in the analysis process [13].

Table 4. Test of Equality of Variances (Levene's) for pretest scores

	F	**df_1**	**df_2**	**p**
Pretest scores	0.792	1	56	0.377

Since the pretest data was found to be departing from normality, as long as the data did not violate the homogeneity of variances Mann-Whitney U can be used. In Table 3, the significance value of the test for equality of variances is shown, since the $p= 0.377, (p>0.05)$ we fail to reject the assumption of the null hypothesis that the two groups have equal aptitude in their engineering physics subject. Hence, we can assume that the two groups are suitable to become the subjects of the study.

Table 4b. Pretest-pretest independent samples t-test results

	W	p
Pretest	**511.000**	**0.097**

1.2. Posttest-posttest comparison

A similar analysis was conducted on the posttest scores of both groups. SW indicated that posttest scores for the control group were non-parametric (p=0.001), with the FCA group being parametric (p=0.274). Levene's test indicates equal variances (p=0.103). Mann-Whitney U test was used for comparison, which showed a significant result (p<0.001). Due to the significant difference, the effect size was calculated using ranked biserial correlation (r_rb=-0.788) which revealed a moderate to large effect size when the experimental (FCA) group is compared to the control. This finding provides evidence that students in the experimental FCA group performed better than the control group. The results of these analyses are shown in Tables 5, 6 and 7, respectively.

Table 5. Test of Normality (Shapiro-Wilk) for posttest scores

		W	p
Posttest Score	Lecture (Control)	0.881	0.001
	FCA (Experimental)	0.950	0.274

Table 6. Test of Equality of Variances (Levene's) for posttest scores

	F	df_1	df_2	p
Score	2.745	1	56	0.103

Table 7. Independent Samples T-Test for with effect size for posttest scores

	95% CI for Rank-Biserial Correlation

	W	p	Rank-Biserial Correlation	SE Rank-Biserial Correlation	Lower	Upper
Post test scores	86.500	< .001	-0.788	0.154	-0.879	-0.642

Note. For the Mann-Whitney test, effect size is given by the rank biserial correlation.

In Table 7, the p-value for the comparison of the posttest scores between the experimental and control groups is presented. Since the p-value is less than 0.05 ($p <.001$), it indicates that the null hypothesis should be rejected, and we can conclude that there is a significant difference between the control and experimental groups. This suggests that the use of the flipped classroom approach in teaching selected topics in Physics for Engineers is effective and can result in better student performance compared to the traditional 7E instructional model.

The effectiveness of the flipped classroom approach is supported by numerous studies in the field of education. For example, a meta-analysis by Bishop and Verleger in 2013 reviewed 24 studies on flipped classrooms and found consistent improvements in student performance and engagement. Similarly, O'Flaherty and Phillips in 2015 noted that flipped classrooms often result in higher levels of student achievement and satisfaction due to increased interaction and engagement during class time.

Moreover, research by He, Holton, Farkas, and Warschauer in 2016 demonstrated that students in a flipped classroom performed significantly better on assessments compared to their peers in traditional lecture-based classes. Their findings suggest that the active learning and student-centered environment of the flipped classroom promotes deeper understanding and retention of material. Further support comes from a study by Love, Hodge, Grandgenett, and Swift (2014), which showed that the flipped classroom model led to significant improvements in both exam scores and overall course grades in an engineering context. This aligns with the findings in Table 8, reinforcing the conclusion that flipped classrooms are particularly effective for teaching complex subjects like Physics for Engineers.

Table 8. Paired samples t-test with Cohen's d for control (lecture) and FCA (experimental groups)

							95% CI for Cohen's d	
Groups	Pretest score	Posttest score	df	p-value	Cohen's d	SE Cohen's d	Lower	Upper
Control	6.353	16.206	33	< .001	4.263	0.849	3.182	5.337
FCA	5.667	19.125	23	< .001	5.168	1.213	3.627	6.699

The information given shows a comparison of test scores before and after an intervention with an FCA (Flipped Classroom Approach) group, showing that both groups made big progress.

In the control group, the pretest score mean is 6.353, and the posttest score mean is 16.206. With 33 degrees of freedom, the p-value is less than 0.001, indicating a highly significant increase in scores from pretest to posttest. The effect size, represented by Cohen's d, is 4.263, with a standard error (SE) of 0.849. The 95% confidence interval (CI) for Cohen's d ranges from 3.182 to 5.337, demonstrating a very large effect size according to conventional standards (Cohen, 1988). This substantial effect suggests that the intervention or instructional method applied to the control group had a profound impact on improving student scores.

Similarly, the FCA group shows a pretest score mean of 5.667 and a posttest score mean of 19.125. With 23 degrees of freedom, the p-value is again less than 0.001, indicating a significant increase in scores. The Cohen's d for this group is 5.168, with an SE of 1.213. The 95% CI for Cohen's d ranges from 3.627 to 6.699, which also indicates a very large effect size. The higher Cohen's d value for the FCA group compared to the control group suggests that the flipped classroom approach may be more effective in enhancing student performance.

These findings are supported by existing literature, which indicates that flipped classroom approaches can lead to significant improvements in student learning outcomes compared to traditional lecture-based methods. Studies by Bishop and Verleger in 2013 and Lage, Platt, and Treglia in 2000 show that flipped classrooms are good for active learning and getting students more involved. This is in line with the bigger effect size seen in the FCA group [14, 15].

Mental Effort

2.1 Pretest-pretest comparison
No significant difference in mental effort for the pretest in both groups: non-parametric control group (p=0.002) and parametric FCA group (p=0.078). Equal variances (p=0.106) were observed.

Table 9 Independent Samples T-Test for Mental Effort (Pretest-pretest)

	W	**df**	**p**
Scale	462.500		0.060

The table above shows the comparison results of the means of the mental effort of students before the implementation of the intervention in both the experimental and control groups. Given that the p-value is greater than 0.05, it indicates that the mental effort scores of the two groups are statistically comparable, as there is no significant difference between their values. This finding is crucial as it establishes a baseline equivalence between the groups before the intervention.

Such equivalence is essential for ensuring the validity of the subsequent comparisons of post-intervention outcomes. Salkind wrote in 2010 that making sure that groups are similar at the start of an experiment removes any possible confounding factors and boosts the study's internal validity [16]. Further supporting this, research by Tabachnick and Fidell in 2013 emphasizes the importance of baseline comparisons in experimental designs. They say that if initial equivalence isn't shown, it's hard to tell if any differences seen after the intervention were caused by the intervention itself or differences between the groups that were there before [17].

Additionally, Stevens in 2012 points out that pretest measures help in assessing the effect of the intervention by comparing pre- and posttest scores within and between groups. By considering differences at the start, this method gives a strong framework for judging how well educational interventions work [18].

Table 10. Independent Samples T-Test for Mental Effort (Posttest-posttest)

	W	df	p
Mental Effort	429.500		0.197

Table 10 shows the results of the Mann-Whitney U test comparing the means of the mental effort of students after three weeks of implementing the intervention. The p-value indicates that there is no significant difference between the mental effort of the control and experimental groups, despite the different instructional strategies used in the classes.

This finding aligns with existing literature, which suggests that the type of instructional strategy may not always have a significant impact on students' perceived mental effort. In 2003, Paas et al. did research that showed mental effort, which is a key indicator of cognitive load, can be changed by many things besides just the way you teach [19]. These things include the difficulty of the task and what you already know about it. Similarly, Kirschner, Sweller, and Clark in 2006 highlighted that while instructional strategies such as the flipped classroom approach can improve learning outcomes, they do not necessarily reduce perceived mental effort, especially in the short term [20].

Moreover, Leppink et al. (2013) found that changes in instructional design often lead to variations in learning efficiency and effectiveness rather than in mental effort. This supports the observation that different instructional strategies may produce similar levels of mental effort as students adapt to new ways of learning [21].

Conclusions

The Flipped Classroom Approach was able to promote students' learning, positive attitude, and mental effort, resulting in increased achievement. As inspired by the relevant studies, FCA was found to be effective in teaching selected topics on Physics for Engineers, specifically on the motion, forces, and energy concepts in a private higher education institution in Mindanao. Additionally, the use of FCA increases the students' mental effort towards learning the subject. As a result, teaching engineering physics with real-world problems and letting them find answers to their own questions improves both their performance in class and their attitude toward physics. Despite the proven effectiveness, the researchers acknowledge the fact that the participants and instructional strategy implementer may influence each other and cause bias in any way.

Recommendations

For further research, this study suggests that more research be done on how FCA can be used in other subjects and in different places to make sure that the results are valid from a different point of view and to make the lessons more relevant when using FCA as a strategy in the classroom.

REFERENCES

[1] L. Bao, "Teaching and learning physics: A model-based approach," *Am. J. Phys.*, vol. 87, no. 7, pp. 575–585, 2019.

[2] A. Ogegbo, "Impact of interactive simulations on students' understanding of electrostatics," *Int. J. Sci. Educ.*, vol. 44, no. 5, pp. 634–649, 2022.

[3] E. Ince, "An overview of problem-solving studies in physics education," *J. Educ. Train. Stud.*, vol. 6, no. 4, pp. 41–56, 2018.

[4] K. Koenig, *Assessing student learning: A practical guide for college faculty*. Jossey-Bass, 2019.

[5] S. Wangchuk, "Effective teaching strategies to reduce student anxiety and increase motivation for learning physics," *J. Educ. Res.*, vol. 20, no. 4, pp. 321–336, 2017.

[6] S. H. Halili and S. Zainussin, "Flipping the classroom: What we know and what we don't," *Online J. Distance Educ. E-Learn.*, vol. 3, no. 1, pp. 15–22, 2015.

[7] A. Sams and J. Bergmann, *Flip your classroom: Reach every student in every class every day*. International Society for Technology in Education, 2012.

[8] Z. Zainuddin and M. Attaran, "The impact of flipped classroom on student learning: A review of literature," *J. Educ. Technol. Soc.*, vol. 18, no. 1, pp. 48–60, 2015.

[9] L. Zheng, K. K. Bhagat, Y. Zhen, and X. Zhang, "The effectiveness of the flipped classroom approach on student learning in STEM disciplines: A meta-analysis," *Educ. Technol. Res. Dev.*, vol. 71, no. 2, pp. 45–62, 2023.

[10] K. F. Hew and C. K. Lo, "Flipped classroom improves student learning in health professions education: A meta-analysis," *BMC Med. Educ.*, vol. 18, no. 1, p. 38, 2018.

[11] B. M. Korsunsky, "Exploring the cognitive components of solving non-trivial physics problems," Harvard University, 2003.

[12] A. Ghasemi and S. Zahediasl, "Normality tests for statistical analysis: A guide for non-statisticians," *Int. J. Endocrinol. Metab.*, vol. 10, no. 2, pp. 486–489, 2012.

[13] A. Field, *Discovering statistics using IBM SPSS statistics*, 4th ed. SAGE Publications, 2013.

[14] J. L. Bishop and M. A. Verleger, "The flipped classroom: A survey of the research," in *ASEE National Conference Proceedings*, Atlanta, GA, 2013.

[15] M. J. Lage, G. J. Platt, and M. Treglia, "Inverting the classroom: A gateway to creating an inclusive learning environment," *J. Econ. Educ.*, vol. 31, no. 1, pp. 30–43, 2000.

[16] N. J. Salkind, *Encyclopedia of research design*. SAGE Publications, 2010.

[17] B. G. Tabachnick and L. S. Fidell, *Using multivariate statistics*, 6th ed. Pearson, 2013.

[18] J. P. Stevens, *Applied multivariate statistics for the social sciences*, 5th ed. Routledge, 2012.

[19] F. Paas, A. Renkl, and J. Sweller, "Cognitive load theory and instructional design: Recent developments," *Educ. Psychol.*, vol. 38, no. 1, pp. 1–4, 2003.

[20] P. A. Kirschner, J. Sweller, and R. E. Clark, “Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching,” *Educ. Psychol.*, vol. 41, no. 2, pp. 75–86, 2006.
[21] J. Leppink, F. Paas, T. Gog, C. P. M. Vleuten, and J. J. G. Merriënboer, “Effects of pairs of problems and examples on task performance and different types of cognitive load,” *Learn. Instr.*, vol. 23, pp. 56–64, 2013.