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Comparative study of flipped classroom vs. traditional classroom in problem solving and critical thinking skills of vocational students

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ABSTRACT

The classroom models are transforming along with the changing demands for skills and the evolution of educational technology globally. This study focuses on analyzing the role of flipped classroom methods against traditional classroom methods for developing critical thinking ability and problem-solving skills among the children of 11th grade in Mainland Chinese vocational high schools. Adopting a quantitative, quasi-experimental design, the study enlisted the participation of 100 students: 50 from a flipped classroom in a private urban school and 50 from a traditional classroom in a public rural school. Each student completed a standardized test of CT and PS skills, benchmarked against 21st-century soft skills. The results of t-tests identified statistically significant differences between the two groups, with flipped classroom students outperforming their traditional classroom peers in both skill sets. Effect size calculations additionally reported very large effects for both CT (Cohen's d = 2.13) and PS (Cohen's d = 2.34). Regression analyses also confirmed instructional method as a significant predictor of both outcomes, explaining 53.6% of the variance in CT scores and 58.3% of the variance in problem-solving scores. These results suggest that flipped classrooms are more conducive to cultivating essential higher-order thinking skills among vocational students. The study offers practical implications for vocational teachers and curriculum developers seeking to align pedagogy with the needs of the future workforce.

Contribution/Originality: This study isolates the effects of instructional methods on vocational CT and PS using a purpose-built, reliability-checked instrument. It reports very large effects and quantifies the explained variance through regression analysis. Additionally, the study contrasts private-urban versus public-rural contexts, providing actionable evidence for scaling flipped learning in Chinese vocational education.

1. INTRODUCTION

Education in the 21st century has been placing a lot of emphasis on developing higher and stronger thinking skills, such as CT and PS skills, in students. Traditional teacher-centered classrooms, which entail lectures and passive student roles, tend to emphasize recall of facts and rote learning rather than active learning (World Economic Forum, 2020). In contrast, the flipped classroom (FC) is a student-centered model that reverses the typical order of learning: initial content acquisition (e.g., watching lectures or reading materials) is completed by students before class, and class time is dedicated to interactive activities such as discussions and problem-solving facilitated by the teacher (Bergmann & Sams, 2012). The model utilizes educational technology (e.g., video lectures) to conserve class time for collaborative, hands-on learning. Through minimizing teacher-centric classes and increasing student participation, the FC models aim to improve students' engagement, which helps in CT skills. Vocational education prepares students for the workforce as demanded by marketing trends, and it helps them learn actively. Students need vocational training from a technical perspective to understand and solve real-world issues. According to the report of the World Economic Forum (2020), CT skills and PT skills are two of the top 10 most needed skills for the future workforce. Hence, this study focuses on exploring these two skills learned by students with two different educational models.

This study examines the effectiveness of FC and traditional classrooms in the development of students' soft skills. The first objective is to illustrate the effectiveness of flipped versus conventional models on the development of students' problem-solving skills. The second objective is to explore the ability of facilities to develop CT skills through flipped versus conventional teaching methods.

2. LITERATURE REVIEW

2.1. Flipped vs. Traditional Classrooms: Conceptual Framework

The traditional classroom model is generally characterized by a teacher-centered instructional style, whereby instructors present course content through direct lectures as students learn passively. The approach often limits student interaction, with students doing most of the listening and note-taking in class. Homework is usually given in the form of repetitive practice drills or memorization-based assignments (Kaymakamoglu, 2018). Critics argue that the model promotes the recall of facts at the expense of building higher-order thinking skills. Research in educational psychology suggests that passive learning environments such as these can dissuade student motivation and are generally linked to higher disengagement and poorer academic performance compared to more interactive, learner-centered instructional methods.

However, on the other hand, the flipped classroom is based on the foundations of active and student-centered learning processes. In a flipped classroom model, students first acquire new knowledge and content on their own through pre-recorded videos, readings, or online modules as pre-class activities. After that, during class time, they discuss it in detail and submit their homework through interactive discussions, group work, practices, and problem-solving activities guided by the teachers (Tomas, Evans, Doyle, & Skamp, 2019). Hence, it can be stated that the flipped model includes various activities that are enabled by technology and based on the constructivist learning theory that contribute to students' knowledge construction in a more effective way when they apply the concepts regularly and receive feedback for further improvements (Jantakoon & Piriyasurawong, 2018; Jiang, Shen, Zhang, & Wang, 2023). The teacher's role in a flipped classroom shifts from an information deliverer to a coach or facilitator, guiding students as they apply concepts and engage in higher-level thinking during class sessions (Eppard & Rochdi, 2017). The overall goal of this model is to maximize the quality of face-to-face instructional time by reserving it for more in-depth learning activities that build students' understanding and skills.

Several frameworks account for why FC can enhance learning; one common explanation relies on Bloom's Taxonomy of cognitive domains. In the traditional model, class time is often devoted to lower-order cognitive tasks (remembering and understanding content), and students are left to fend for themselves with higher-order tasks (application, analysis, evaluation, creation) as homework. The flipped model "flips" this alignment to Bloom's Taxonomy: students do initial knowledge acquisition (lower-order tasks) on their own, releasing class time to devote to the higher levels of the taxonomy through applied activities and critical questioning (Guo, 2021; Wu, Chi, Wu, & Kang, 2018). By reallocating classroom time to activities like analysis, evaluation, and synthesis, the flipped method offers an environment for practicing higher-order thinking under the teacher's guidance. The flipped classroom employs principles of active learning that have been shown to deepen student engagement and understanding. Active learning methods (including group problem-solving, discussion, case studies, and peer teaching) engage students to think critically, ask questions, and learn from each other. These methods are fundamentally different from passive listening, and they have been shown to promote soft skills like teamwork, communication, and problem-solving.

2.2. Relevance of Soft Skills in Vocational Education

In the last several years, international organizations and industry leaders have emphasized the necessity of obtaining soft skills, especially in vocational and technical education. The World Economic Forum (2020) has ranked critical thinking skills and problem-solving skills as among the top 10 skills that will be needed by the future workforce. These skills are important for white-collar as well as for students' vocational careers, where workers need to make decisions, solve issues, adapt to new technologies, and collaborate with others in evolving settings. Vocational education has traditionally focused on job-specific technical training, but it is now being recognized that soft skills are equally necessary for employability and career advancement (López et al., 2023). Employers across all industries consistently express that they desire candidates who are not only technically competent but also capable of independent thinking, creative problem-solving, and good communication. Education systems that give equal weight to soft skills and technical education are more likely to prepare students with the competencies to handle the challenges of modern work. With this global emphasis, there is an urgent need to examine which pedagogical approaches most effectively support soft skills. The flipped classroom encourages students to be active participants in their learning and to collaborate on problems in class, presenting an attractive alternative (Novitri, Pada, Nurmaliah, Khairil, & Artika, 2022). The traditional classroom, with its emphasis on passive learning, may not provide sufficient opportunities to practice or develop these essential skills.

2.3. Impact of Flipped Classroom on Higher-Order Thinking Skills

As FC utilizes class time for active learning, it is likely to have a positive impact on students' thinking skills, including problem-solving and critical thinking. Problem-solving is the ability to use knowledge and reasoning to solve new problems and situations, and critical thinking is the systematic way of analyzing information, evaluating evidence, and coming to reasoned judgments. Both are seen as fundamental competencies for vocational students who will be faced with complex tasks in the workplace. Traditional lecture-based instruction, with its potential emphasis on content coverage and factual recall, may not be sufficient to develop these skills (Klein et al., 2023). In contrast, the interactive and student-centered learning in flipped classrooms (for example, solving real-world problems in groups, Socratic questioning sessions, and group projects) directly engages students with the analysis, evaluation, and synthesis processes that underlie CT and PT.

Empirical data increasingly support the perception that flipped learning can enhance higher-order cognitive skills. A review of earlier research by Zhou (2023) revealed that flipped learning interventions in vocational education significantly positively affected students' cognitive outcomes, including CT and PS skills. In Zhou's review, vocational students in flipped settings showed improvement in critical thinking, problem-solving, learning strategies, and other skills compared to students in conventional classrooms. This aligns with findings from several single studies. Bhagat, Cheng-Nan, and Chun-Yen (2016) have conducted a quasi-experimental study with vocational students learning mathematics and reported that the flipped classroom group showed significantly higher academic performance than the control group taught using traditional lectures. Although the concern of Bhagat et al. (2016). was achievement in mathematics, the higher performance likely reflects increased problem-solving capacity developed by the flipped method (which, in their study, included pre-class videos and in-class problem exercises).

Higher-order thinking advantages of flipped classrooms have also been discovered in non-Western learning contexts. A recent study by Wang, Abdullah, and Puah (2025) compared the impacts of flipped and traditional teaching on 1,000 first-year vocational college students in China. Using a quasi-experimental design with 50 classes, the researchers measured not only academic performance but also aspects of analytical, creative, and practical thinking (approximately corresponding to CT and PS skills). The results showed that the flipped classroom method significantly outperformed the traditional approach: students in flipped classrooms had higher learning achievement and significantly higher analytical and creative thinking scores, as well as more positive learning attitudes. These findings suggest that flipping the classroom can enhance students' abilities to analyze information and devise creative solutions, core components of CT and PS, even on a large scale in Chinese vocational education. Similarly, an earlier study in a Chinese vocational high school by Jouryabi (2019) discovered that employing a flipped model led to learning improvement, although it noted that the level of student proficiency affected the extent of improvement. Together, such studies provide evidence that the flipped method can be effective in Eastern pedagogical contexts and with vocational students, who benefit from the active, practice-based learning environment.

The influence of flipped classrooms on the development of CT skills has also been explored in subject-specific domains. For example, in a secondary school context, Lee and Lai (2017) study has found that applying a flipped learning approach to an information technology class enhanced students' higher-order thinking significantly. This was expressed through improved performance in project and test tasks geared towards higher levels of Bloom's taxonomy. Their study showed that flipped instruction can successfully promote students' critical thinking abilities. Similar findings have been documented across other levels of education. In fields such as medical and health sciences, where analytical reasoning is critical, flipped classroom methods have been linked to improved performance in exams emphasizing applied knowledge and clinical judgment, outperforming students who were taught with traditional lectures (Chen et al., 2018). A meta-analysis by Chen et al. (2018) compared flipped versus lecture-based instruction across 46 studies and reported that flipped classrooms were associated with better academic performance on higher-level cognitive outcomes, an advantage that was more pronounced in more recent studies. These higher-level outcomes included problem-solving and analytical test items, indicating that flipped classes provide students with an advantage on tasks involving understanding and applying knowledge compared to recall.

Various existing studies find large differences, and the effectiveness of FC may depend on the quality of implementation. Some research suggests that the advantage of flipped instruction comes largely from the incorporation of active learning, which, in theory, could also be infused into non-flipped classroom models. For example, Jensen, Kummer, and Godoy (2015) conducted a controlled study in a college biology course to isolate the effect of the "flip." They were careful to have both flipped and non-flipped sections experience active learning exercises, with the only difference being whether initial content delivery was in the form of in-class lectures or pre-class videos. Their findings showed no difference in exam scores between the flipped section and the non-flipped (active learning) section when both were taught the same material using the same in-class activities. This suggests that simply moving lectures outside of class (the structural flip) may not in itself improve learning unless the in-class component actively engages students.

3. METHODOLOGY

3.1. Research Design

This study adopts a quasi-experimental research design by considering a nonequivalent control group to compare the flipped classroom and traditional classroom models. Quantitative methods were used to measure student outcomes in problem-solving and critical thinking. The instructional method (flipped vs. traditional) was the independent variable, and students' scores on a problem-solving and critical thinking test administered at the end of the intervention were the dependent variables. Since the participants could not be randomly assigned to instructional methods (intact classes were used), the quasi-experimental design was selected. Instructional content was held constant: the two groups studied the same curriculum units in a core vocational subject, covering the same learning goals and assessments, but with variation in instructional methodology. The design allowed for a controlled comparison of learning outcomes resulting from the flipped versus traditional pedagogical models.

3.2. Participants

The participants were 100 Mainland Chinese vocational high school students, divided into two groups of 50. The experimental group (Flipped Classroom) consisted of 50 students from a private vocational high school in an urban setting. These students experienced a flipped learning approach for the target course. The control group (Traditional

Classroom) comprised 50 students from a public vocational high school in a rural setting, where a traditional mode of teaching was employed for the same course. The two schools were selected through purposive sampling to ensure different school environments (one private/urban, one public/rural), but with the same grade level and curriculum. All participants were in Grade 11, approximately 16–17 years old, and enrolled in one vocational subject (Information Technology). Demographic information and academic background were collected prior to the intervention.

The research was conducted within Mainland China, focusing on the urban-rural gap in education. The two selected schools are from Beijing and Tianjin. The first 50 students were from a private vocational high school based in Beijing, an urban hub recognized for its well-developed school facilities and high numbers of private schools (Flipped Classroom). The remaining 50 students were from a public vocational high school based in Tianjin, a neighboring city with both urban and rural school environments. Beijing and Tianjin were chosen based on their geographic proximity (within 1 to 1.5 hours by high-speed train), which facilitated logistical coordination while still providing a contrast between a metropolitan urban environment and a more rural-focused public vocational education system. This selection aligns with the study's purpose to compare flipped and conventional classrooms across different socio-educational contexts and logistical considerations. The groups were roughly equal in prior academic performance, as indicated by their previous term grades. Participation was voluntary, with informed consent obtained from students and their parents, as the participants were minors, and approval from school administrators was secured. Attendance throughout the semester was high for both groups, and nearly all students completed the final post-test, resulting in a final sample size of N=50 per condition.

3.3. Instrumentation

To assess problem-solving and critical thinking skills among students, this study used a single standardized multiple-choice questionnaire designed for this study. The instrument was constructed based on current frameworks of CT and PS in education. Specifically, the critical thinking items were mapped on Facione's (1990) Delphi consensus views of critical thinking skills. The problem-solving items were modeled after scenario-based tasks involving the use of knowledge in real-world situations, reflecting steps such as problem definition, strategy generation, and solution evaluation. In all, the test consisted of 40 multiple-choice items: 20 on analytical and critical reasoning (e.g., interpreting information, identifying logical fallacies, making inferences) and 20 on applied problem-solving (e.g., selecting the most appropriate approach to carry out a specified vocational task or troubleshooting a technical problem scenario). Each item had four options with one correct answer, and one point was awarded for each correct response, making 40 points the highest possible score.

Three experts in vocational education (two teachers) reviewed the test items to see if they were at the students' level of education and applicable to the course content. Their feedback led to minor revisions for clarity and applicability. Pilot-tested the questionnaire with another class of 30 vocational students (not included in the study sample), and achieved a Cronbach's alpha of 0.82, indicating good internal consistency reliability. The test was thus a valid and reliable measure of the intended higher-order skills. Students were instructed to complete the exam individually in a supervised classroom within a 50-minute time limit.

3.4. Data Analysis

Following data collection, the responses were analyzed with IBM SPSS. For each student, the total test score based on the number of correct answers out of a possible 40 was noted in the dataset. The initial step in the analysis was to compute descriptive statistics, such as the mean and standard deviation, to characterize the performance of the two instructional groups. To determine the appropriateness of parametric testing, the data were tested for normality with the Shapiro-Wilk test and equality of variances with Levene's test. These tests confirmed whether or not key statistical assumptions were met. In addition to the comparison of group means, a regression analysis was performed to identify the extent to which the teaching method (flipped versus traditional) could predict students' overall performance on the assessment.

4. RESULTS

For the analysis and tables, the group labeled Group Code = 1 refers to students who participated in the flipped classroom, while Group Code = 2 refers to students in the traditional classroom. These numeric codes were used for statistical analysis in SPSS and are consistently applied throughout the tables in this section.

4.1. Comparison of Critical Thinking Performance

The first part of the assessment measured students' critical thinking skills. The flipped classroom group had a mean score of 16.56 (SD = 1.728), while the traditional classroom group recorded a lower mean of 13.04 (SD = 1.577). The data suggest a considerable difference in favor of the flipped classroom students.

Table 1. Descriptive statistics for critical-thinking scores by instructional group.

	Group_code	N	Mean	Std. deviation	Std. error mean
Critical_Thinking_Score	1.00	50	16.56	1.728	0.244
	2.00	50	13.04	1.577	0.223

Table 1 presents group means and dispersions for critical-thinking scores, showing higher performance in the flipped group. Before interpreting the results of the t-test, the Levene test for the equality of variances was conducted to assess the assumption of homogeneity of variance. The result (F = 0.850, p = .359) indicates that the variances were not significantly different, supporting the use of the equal variances assumption in the t-test.

The independent samples t-test showed a highly significant difference between the groups, t(98) = 10.638, p < .001. The mean difference of 3.52 points (95% CI: [2.86, 4.18]) between groups confirms that students taught using the flipped model demonstrated higher critical thinking skills.

Table 2. Independent-samples t-test for critical-thinking scores.

		Levene's test for equality of variances		t-test for Equality of Means						
									95% confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Critical_Thinking_Score	Equal variances assumed	0.850	0.359	10.638	98	0.000	3.520	0.331	2.863	4.177
	Equal variances not assumed			10.638	97.196	0.000	3.520	0.331	2.863	4.177

Table 2 reports the independent-samples t-test for critical thinking, indicating a statistically significant difference in favor of the flipped classroom. Effect size calculations provided further insights. The Cohen's d value of 2.13 indicates a very large effect size. Complementary statistics, including Hedges' g = 2.11 and Glass's Δ = 2.23, also suggested that the difference was not only statistically significant but practically meaningful.

Table 3. Effect sizes (Cohen's d, Hedges' g, Glass's Δ) for critical-thinking scores.

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
Critical_Thinking_Score	Cohen's d	1.654	2.128	1.632	2.616
	Hedges' correction	1.667	2.111	1.619	2.596
	Glass's delta	1.577	2.232	1.637	2.816

Note: a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

Table 3 displays very large effect sizes for critical-thinking outcomes. These findings align with the literature that attributes better higher-order thinking performance to active learning environments. The flipped classroom, by shifting passive content delivery outside class and dedicating classroom time to problem-solving, likely provided students with more opportunities to practice analysis, evaluation, and logical reasoning. This instructional dynamic appears to have supported the development of deeper cognitive skills in the flipped group.

4.2. Comparison of Problem-Solving Performance

The second part of the assessment evaluated students' ability to solve problems in context. The flipped classroom group scored an average of 17.04 (SD = 2.020), while the traditional classroom group had a mean score of 12.32 (SD = 2.015).

Table 4. Descriptive statistics for problem-solving scores by instructional group.

	Group_code	N	Mean	Std. deviation	Std. error mean
Problem_Solving_Score	1.00	50	17.04	2.020	0.286
	2.00	50	12.32	2.015	0.285

Table 4 presents descriptive statistics for problem-solving, again indicating higher scores under the flipped method. Levene's test for equality of variances indicated no significant difference in variances ($F = 0.020$, $p = .887$), again validating the assumption of equal variances in the t-test.

The independent samples t-test produced a statistically significant result: $t(98) = 11.699$, $p < .001$, with a mean difference of 4.72 points (95% CI: [3.92, 5.52]). This demonstrates that the flipped classroom group performed better on problem-solving tasks.

Table 5. Independent-samples t-test for problem-solving scores.

		Levene's test for equality of variances		t-test for equality of means						
									95% confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Problem_Solving_Score	Equal variances assumed	0.020	0.887	11.699	98	0.000	4.720	0.403	3.919	5.521
	Equal variances not assumed			11.699	97.999	0.000	4.720	0.403	3.919	5.521

Table 5 reports the t-test for problem-solving, confirming a significant flipped-classroom advantage. Effect sizes further highlight the strength of this difference. The Cohen's d of **2.34**, Hedges' g of **2.32**, and Glass's Δ of **2.34** each indicate a very large effect.

Table 6. Effect sizes (Cohen's d, Hedges' g, Glass's Δ) for problem-solving scores.

				95% confidence interval	
		Standardizer[a]	Point Estimate	Lower	Upper
Problem_Solving_Score	Cohen's d	2.017	2.340	1.826	2.847
	Hedges' correction	2.033	2.322	1.812	2.825
	Glass's delta	2.015	2.343	1.731	2.944

Note: a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

Table 6 displays very large effect sizes for problem-solving outcomes. The nature of the flipped model likely contributed to this result. In flipped classrooms, students had time to reflect on content before class and then apply it actively in a social learning context. The problem-solving section of the test required scenario-based reasoning and real-world decision-making skills, frequently reinforced through interactive classroom engagement. Traditional instruction, in contrast, focused more on content absorption with limited practical application, which may have hindered student performance on this task.

4.3. Combined Performance Across Both Skills

Table 7 presents descriptive statistics for total CT+PS scores, showing an overall advantage for flipped instruction. The total score out of 40 points was also analyzed to explore the combined effect of both instructional methods across the two soft skills. Students in the flipped classroom achieved a mean total score of 33.60 (SD = 3.016), while those in the traditional group had a mean of 25.36 (SD = 2.772).

Table 7. Descriptive statistics for total test scores (CT+PS) by instructional group.

	Group_code	N	Mean	Std. deviation	Std. error mean
Total_Score	1.00	50	33.60	2.799	0.396
	2.00	50	25.36	2.625	0.371

Before interpreting the results of the t-test, Levene's Test for Equality of Variances was performed to check the assumption of homogeneity. The result was not significant (F = 0.081, p = .777), which indicates that the variances in total scores across the two groups are statistically equal. Therefore, it was appropriate to interpret the t-test results using the row labeled "Equal variances assumed."

The analysis revealed a highly significant difference in total score performance between the two groups (t98) = 15.184, p < .001). The mean difference was 8.24 points, with a standard error of 0.543, and a 95% confidence interval ranging from 7.16 to 9.32. This indicates that, on average, students in the flipped classroom scored over eight points higher on the overall assessment than those in the traditional classroom. Given that the total possible score was 40, this difference is not only statistically significant but also educationally meaningful.

These findings suggest that the flipped classroom method had a consistently positive impact on both measured competencies and, when combined, significantly elevated students' overall performance. The confidence interval further reinforces the reliability of the result, with no overlap in likely score outcomes between the two instructional models.

This result consolidates the findings from the individual sections. The flipped model was effective not only in one domain but consistently across both. With a Cohen's d of 2.71, the effect was not only significant but educationally substantial. Hedges' g and Glass's delta were similarly strong, at 2.62 and 2.73, respectively, for the total score between the groups.

Table 8. Independent-samples t-test for total test scores (CT+PS).

		Levene's test for equality of variances		t-test for equality of means						
									95% confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. error difference	Lower	Upper
Total_Score	Equal variances assumed	0.081	0.777	15.184	98	0.000	8.240	0.543	7.163	9.317
	Equal variances not assumed			15.184	97.595	0.000	8.240	0.543	7.163	9.317

Table 8 reports the t-test on total scores, evidencing a substantial overall difference between methods. These combined results reinforce that the flipped classroom format supports the development of essential soft skills by offering meaningful engagement, structured collaboration, and opportunities for applied thinking. The pedagogical shift enables learners to extend beyond rote memorization into functional, adaptive knowledge use.

4.4. Regression Analysis

To explore the predictive influence of instructional method (flipped versus traditional) on vocational students' soft skills, two simple linear regressions were conducted. The independent variable in both models was the instructional method, captured using the Group_Code variable, where 1 represented the flipped classroom and 2 represented the traditional classroom. The dependent variables were students' scores on the CT and PS sections of the standardized test. These regressions aimed to quantify how instructional methods influenced each skill separately and to assess whether the flipped classroom approach contributed significantly to students' cognitive development.

The analysis of critical thinking performance began with a review of descriptive and correlational statistics. Students had an overall mean score of 14.80 (SD = 2.416) on the critical thinking test. The Pearson correlation between instructional method and critical thinking was –0.732 ($p < .001$), indicating a strong, statistically significant inverse relationship. Given the coding of the Group_Code variable, the negative sign reflects higher performance among students in the flipped classroom group. The second regression model examined students' problem-solving scores as the dependent variable. Descriptive statistics showed an average score of 14.68 (SD = 3.107) across all participants. The correlation between instructional method and problem-solving was –0.763 ($p < .001$), once again reflecting a strong and statistically significant inverse relationship, with flipped classroom students outperforming their traditional classroom peers.

The regression model demonstrated a substantial ability to predict critical thinking scores. The model summary indicated that $R^2 = 0.536$, meaning that 53.6% of the variance in students' critical thinking performance could be explained by the instructional method. The adjusted R^2 was 0.531, showing minimal shrinkage and confirming the stability of the model. The standard error of the estimate was 1.654, indicating a reasonably close fit between observed and predicted values. The model summary also reported an R^2 value of 0.583, indicating that the instructional method accounted for 58.3% of the variance in problem-solving performance. The adjusted R^2 was 0.578, with a standard error of the estimate of 2.017. These results show a slightly stronger model fit than the critical thinking regression, which is consistent with the slightly higher correlation coefficient found for problem-solving.

Table 9. Regression model summaries predicting CT and PS from instructional method.

Model summary[b]						
Model	**R**	**R square**	**Adjusted R-squared**	**Std. error of the estimate**	**b (Unstd.)**	**β (Std.)**
1	0.732[a]	0.536	0.531	1.654	-3.520	-0.732

Note: a. Predictors: (Constant), Group_Code.
b. Dependent Variable: Critical_Thinking_Score.

Model summary[b]						
Model	**R**	**R square**	**Adjusted R-squared**	**Std. error of the estimate**	**b (Unstd.)**	**β (Std.)**
1	0.763[a]	0.583	0.578	2.017	-4.720	-0.763

Note: a. Predictors: (Constant), Group_Code
b. Dependent Variable: Problem_Solving_Score

Table 9 summarizes regression models demonstrating that instructional method significantly predicts CT and PS performance with strong explained variance. The ANOVA test for the model produced a significant result, $F(1, 98) = 113.169$, $p < .001$, validating that the instructional method contributes significantly to variations in critical thinking scores. The regression coefficient for Group_Code was −3.520 ($p < .001$), indicating that students in the flipped classroom scored, on average, 3.52 points higher than those in the traditional classroom, controlling for group membership. The standardized coefficient (Beta) was −0.732, reflecting the strength and direction of the bivariate correlation. The 95% confidence interval for the unstandardized B ranged from −4.177 to −2.863, reinforcing the precision of the estimated effect. In the ANOVA table, the regression model was again statistically significant, with $F(1, 98) = 136.866$, $p < .001$, suggesting that instructional method is a highly significant predictor of students' problem-solving skills. The unstandardized coefficient (B) for Group_Code was −4.720, indicating that students in the flipped classroom scored, on average, 4.72 points higher than those in the traditional group. The standardized Beta coefficient was −0.763, showing an even stronger predictive relationship than in the critical thinking model. The 95% confidence interval for B ranged from −5.521 to −3.919, confirming a consistently strong and reliable effect size.

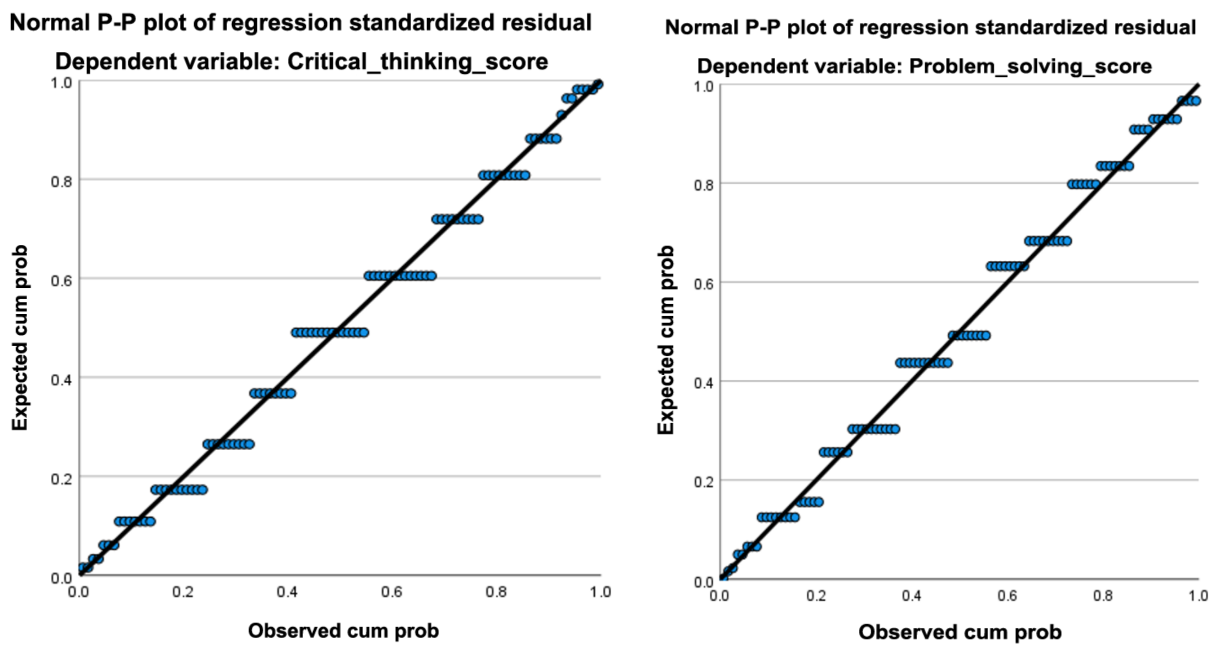

Figure 1. Normal PP plot of regression standardized residual.

Figure 1 illustrates normal P–P plots of standardized residuals for both regressions, indicating residuals closely follow the diagonal and supporting the normality assumption. Collinearity diagnostics revealed no concern, with a tolerance value of 1.000 and a variance inflation factor (VIF) of 1.000, indicating that the model does not suffer from multicollinearity. The residuals were normally distributed, as shown by a residual mean of 0.000, a standard deviation of 1.646, and values ranging from −3.560 to +3.960 for critical thinking. Similarly, for problem-solving, residual statistics also supported the model's validity. Residual values ranged from −6.04 to +3.68, with a mean of 0.000 and a standard deviation of 2.007. Furthermore, the P–P plot for standardized residuals showed that the data points closely followed the diagonal line, confirming that the assumption of normality of residuals was met for both variables. Overall, the regression model for critical thinking was statistically sound and suggested that flipped instruction had a significant positive impact on students' ability to engage in analytical reasoning, evaluation, and inference.

4.5. Additional Observations from Score Distributions

Further examination of the score distributions within each group provides additional depth to the analysis. In the flipped classroom group, the majority of students scored above 15 in critical thinking and above 16 in problem-solving, with several achieving scores near the maximum of 20 in both sections. In contrast, students in the traditional classroom showed more clustered performance, with most scores falling between 11–14 in critical thinking and 10–13 in problem-solving. These patterns suggest not only that the flipped model improved overall averages but also that it had an uplifting effect across the full spectrum of students, including both high and middle performers. No extreme outliers were identified in either group, and both datasets met the assumptions of normality required for valid parametric testing.

Moreover, the variance within each group was relatively similar, indicating that the flipped method did not disproportionately benefit only the highest achievers; it enhanced average performance broadly. The robustness of the results was confirmed by repeating the analysis using non-parametric equivalents (Mann–Whitney U tests), which also revealed statistically significant differences in all three score categories ($p < .001$ in each case). These secondary results provide further confidence in the validity of the findings, even if assumptions for parametric tests were marginally violated.

5. DISCUSSION

The results from the two groups strongly suggest that the flipped classroom model leads to higher scores in problem-solving and critical-thinking skills compared to the traditional classroom model. The standardized test results indicated that the flipped classroom group achieved a mean of 16.56 in critical thinking skills and 17.04 in problem-solving skills. In contrast, students in traditional classrooms achieved only a mean of 13.03 and 12.32, respectively. Therefore, these findings strongly suggest that the flipped classroom methods provide a better learning environment for the development of soft skills among students, aligning with the demands of contemporary and future workplaces.

The current findings on the flipped classroom model's maximum contributions to developing students' critical thinking skills and problem-solving skills are supported by the existing literature as well. Alias, Iksan, Abd Karim, Nawawi, and Nawawi (2020) studied the application of a flipped instructional approach to improve students' problem-solving skills and concluded that such approaches significantly improve analytical thinking. This is highly consistent with the current study's findings that show improved performance in analytical skills by students in the flipped setting. Similarly, Wen, Zaid, and Harun (2016) explored the flipped model in an ICT setting and concluded that it improves problem-solving skills, which suggests the approach is versatile and effective in numerous subject matters. Further evidence to support this is given by Pimdee, Sukkamart, Nantha, Kantathanawat, and Leekitchwatana (2024), who applied a blended problem-based learning approach to a flipped classroom for Thai pre-service teachers. They reported improvement in problem-solving performance and academic achievement. Karabulut-Ilgu, Yao, Savolainen, and Jahren (2017) researched students' perceptions of collaborative learning in flipped classrooms and observed positive student engagement, which they attributed to increased interaction and learner-centered instruction. Wider and Wider (2023) study on metacognitive skills for physics problem-solving skills strongly suggests that developing monitoring, evaluation, and regulation skills is necessary for metacognitive skills development. The inclusion of new and innovative teaching plans suggests that the flipped classroom is effective in problem-solving.

Critical thinking outcomes are also accorded equal attention in the literature. Nugraheni, Surjono, and Aji (2022), through a literature review, it was established that the flipped classroom enables the cultivation of critical thinking by supporting deep learning and interactive engagement with course content. Ma (2023) also confirmed that critical thinking was significantly enhanced when students underwent a flipped instructional design. In another study conducted by Listiqowati, Budijanto, Sumarmi, and Ruja (2022), the use of a project-based flipped classroom model was effective in cultivating analytical reasoning among students, consistent with current research findings. Collectively, these studies confirm the effectiveness of flipped teaching designs in supporting essential cognitive competencies across disciplines and levels of education. The success of the flipped classroom can be explained through theoretical models such as constructivism and Bloom's taxonomy. Constructivist theory holds that students build knowledge actively rather than passively receiving it. Flipped learning supports this by having students acquire basic material outside class, with classroom time being utilized for applied learning, peer discussion, and problem-solving. This aligns with Bloom's hierarchical model, where classroom time is spent on higher-order tasks such as application, analysis, and evaluation necessary to build critical thinking and problem-solving skills.

These findings also hold deep implications for teaching professionals and instructional designers, especially in vocational education. As the workplace increasingly requires more flexible, critical, and reflective thinkers in today's workforce, pedagogy must also keep pace (World Economic Forum, 2020). The flipped classroom approach appears to offer a sound way forward for integrating these essential soft skills into pedagogical practice. Teachers in vocational education are especially encouraged to adopt flipped approaches to better prepare students to tackle real-world professional practice issues. Successful implementation, nonetheless, requires careful planning and support. Instructors must invest time in creating pre-class materials and strategizing for in-class activities. Institutions must also offer instructors ample training and resources to enable them to make the shift from traditional to flipped methods as smoothly as possible. Such support systems are required to fully leverage the benefits of this model and ensure that it improves both teaching and learning experiences.

6. CONCLUSION

The findings of this study provide strong evidence that the flipped classroom model is superior to the traditional approach to teaching for skills related to problem-solving and critical thinking among students. This study highlights that not only were the differences between the two classroom models statistically significant, but there were also notable differences in educational aspects, indicating that the flipped model fosters greater engagement and more effective learning. The comparison revealed that the flipped classroom group scored, on average, over three points higher in critical thinking and nearly five points higher in problem-solving compared to the traditional group. Regression analysis further confirmed that the instructional method (flipped vs. traditional) was a significant predictor of student performance in both skills. The results emphasize the instructional value of flipped learning in supporting active learning, collaboration, and applied thinking, key components of 21st-century soft skills. Importantly, the flipped classroom not only improved average performance but also enhanced overall achievement across the entire spectrum of students, suggesting that the benefits are inclusive and not limited to high performers. These findings affirm the flipped classroom as an effective and valuable pedagogical approach for vocational education, especially when the goal is to equip students with cognitive tools necessary for real-world problem-solving and independent thinking.

Future studies should aim at the long-term impact of the FC on skill acquisition and retention. Comparison studies across disciplines, study levels, and cultures would also provide more insight into the model's flexibility and effectiveness. Investigating the integration of technology and digital tools within the flipped classroom could also provide insight into the optimization of this instructional model.

Therefore, focusing on the enhancement of CT and PS skills, the study directly contributes to addressing educational inequality between private and public schools and the lack of equal opportunities to learn vocational skills. This study also contributes to the development of learning environments that foster youth empowerment and reduce the education gap. The FC model not only supports improved academic outcomes but also promotes an inclusive pedagogical approach that actively engages students in meaningful learning. These findings are relevant for educators and policymakers in developing countries, where innovative instructional strategies are essential to support education reform, teacher training, and sustainable development education as emphasized in recent SDG-focused research.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
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