Flipped Classrooms With Peer Instruction: The Impact on Students' Conceptual Understanding

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Abstract **– The aim of the research is to explore how flipped classrooms utilizing peer instruction impact students' grasp of the periodic table of elements. In this quasi-experimental design, a total of 64 tenth-grade students participated. The study took place at a public high school situated in Bekasi, a city located in the central region of Indonesia. Experimental group students were instructed in flipped classrooms together with peer instruction (FCPI) and control group students were taught in flipped classrooms without peer instruction (FCX). For quantitative data analysis, *t*-tests and Cohen's *d* were computed. The findings indicated a significant mean disparity between the two groups of students concerning conceptual understanding after the instructions were given. Also, students in FCPI showed a higher increase in conceptual understanding than students in FCX with high effect sizes. It indicates that the integration of flipped classrooms with peer instruction proved more efficacious in enhancing students' conceptual understanding compared to FCX.**

Keywords **– Flipped classroom, peer instruction, conceptual understanding.**

DOI: 10.18421/TEM132-42
https://doi.org/10.18421/TEM132-42

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Received: 10 January 2024.
Revised: 25 March 2024.
Accepted: 22 April 2024.
Published: 28 May 2024.

1. Introduction

In the past few years, the COVID-19 pandemic, which has been spreading since early March 2020, has had a significant impact on education systems worldwide. Educators across the country are moving from in-person learning to computer-assisted learning. In Indonesia, the MoEC [1] issued a policy regarding education implementation, specifically endorsing the adoption of distance learning. The implementation of distance learning causes both students and educators to adapt to be able to integrate technology into the learning process. Without a doubt, technology has become an important part of teaching and learning in modern classrooms of the twenty-first century. In the literature, teaching and learning in the twenty-first century is learning that emphasizes student-centered learning processes [2]. The objective of a student-centered learning process is to empower students to take on an interactive, active and independent role in constructing knowledge and attaining proficiency with information sources obtained through active learning, facilitated by a range of technological devices [3].

Chemistry holds significant importance in the realm of science because it is closely interconnected with various other branches of scientific inquiry. In addition, chemistry also has extensive and influential relationships in everyday life [4]. At school, chemistry is a subject that has characteristics in the form of interrelated concepts. Students' understanding of one chemical concept will affect their understanding of other concepts. This causes every concept to be mastered correctly. Concepts are structured fundamental units stored in long-term memory, capable of being articulated in words that may not precisely match the perceived idea, yet convey the same meaning as the received expression [5]. In short, understanding includes students' ability to construct meaning from learning messages whether spoken, written, or graphic [6].

In the field of chemistry, in general, the periodic table of elements is often regarded as a challenging topic for students. A study conducted by Satilmiş [7] stated that students still had difficulties in understanding the periodicity concept, where only 6% of students answered correctly the question regarding atomic radius as a periodic property of elements. Similarly, Necor [8] reported that 21% of students experienced misconceptions when answering questions about atomic radii in one period and group. In another study, Jack [9] showed that students still had difficulty understanding the concept of the metallic properties of elements in the periodic table of elements. Similarly, Sunyono and Sudjarwo [10] showed that 70% of students still experienced conceptual errors when determining the Bohr electron configuration of elements. Students' limited conceptual understanding of the periodic table of elements often stems from the perception that this topic is inherently difficult and inadequately explained during the chemistry learning process, and there is no adequate exercise in chemistry textbooks [7]. In addition, teachers usually assume that all students can understand the concept simultaneously; thus, many students experience learning difficulties [11]. Therefore, appropriate learning strategies are needed to study chemistry or complete assignments more effectively and efficiently [12].

In implementing a chemistry curriculum based on active teaching principles to achieve effective learning, flipped classrooms have been widely used. The flipped classroom is an inversion of conventional learning in general; thus, learning is designed with a more personal, interactive, and flexible learning environment through the integration of technology [13]. Numerous prior studies have demonstrated that flipped classrooms exert a great impact on student learning outcomes in chemistry [14], [15]. However, there is still not much research that examines the use of flipped classrooms to strengthen students' conceptual understanding. In fact, the activities offered in the flipped classroom have the potential to develop students' conceptual understanding [14], [15].

One suitable learning strategy combined with a flipped classroom is peer instruction [16]. Peer instruction is a form of learning that can develop student activity and share ideas with colleagues. Peer instruction is carried out by involving students to become tutors for each other. Peer instruction begins with conceptual questions (called ConceptTest) which involve various concepts relevant to the topic being taught [17]. In their study, Schell and Mazur [18] consistently observed a rise in the percentage of correct answers on ConceptTests. Peer instruction, overall, has been validated as an effective and widely favored teaching approach for students [20].

Given the characteristics of peer instruction, this form of learning is suitable to be combined with a flipped classroom in an effort to increase students' conceptual understanding [19].

Based on the issues described previously, this research needs to be done. The issue arises from students' limited grasp of the concept of the periodic table of elements [7], [9], [10], hence there is potential in employing flipped classroom learning with peer instruction to enhance students' understanding [18]. The novelty of this research is that we implement flipped classrooms with peer instruction as an effort to make school learning activities more effective in order to overcome students' difficulties in understanding chemistry concepts by utilizing ConceptTest. Hence, the present study was carried out to elucidate the impact of combining flipped classrooms with peer instruction on enhancing students' conceptual understanding of the periodic table of elements, as opposed to FCX.

2. Method

In this section, we outline the research methodology as follows.

2.1. Design

The aim of the study was to investigate the impacts of independent variables, such as the flipped classroom with peer instruction (FCPI) and flipped classroom only (FCX), on dependent variables, such as tenth-grade students' conceptual understanding. To accomplish this objective, a quasi-experimental study employing a pretest-posttest control group design [21] was utilized. This approach enabled researchers to establish connections between instructional conditions and students' conceptual understanding [22]. The research was employed during the first term of the 2022-2023 academic year.

2.2. Participants

The study involved 64 tenth-grade students from a public senior high school located in Bekasi City, Indonesia. There were 32 students in the control group, comprising 16 boys and 16 girls, and 32 students in the intervention group, consisting of 15 boys and 17 girls. The ages of the students ranged from 15 to 16 years old. It should be noted that all students had never studied the topic of the periodic system of elements. All students, taught by the same female teacher, had sufficient access to gadgets and the Internet to partake in the study. They were duly informed about the research's purpose and had the option to withdraw at any point.

Their participation was on a voluntary basis, so it will not affect their grades. All data and the identities of the participants were kept anonymous.

2.3. Data Collection Tool

In this study, a conceptual test containing 23 items was designed and used as an instrument. The test was administered both as a pretest and a posttest to evaluate students' conceptual understanding. The conceptual test included seven cognitive processes [6] including interpreting (5 items), exemplifying (2 items), classifying (4 items), summarizing (1 item), inferring (4 items), comparing (2 items), and explaining (5 items). Students were asked to make their answer choices for each item. The test underwent review and validation by two chemistry lecturers and three chemistry teachers. It encompassed three primary concepts, namely electron configuration, the positioning of elements in the periodic table, and the characteristics of the periods and groups within the periodic table.

The difficulty index for each item fell within the range of 32.75%–44.12%, indicating that all items had acceptable difficulty levels [23]. The discrimination index (r) for each item ranged from 0.25 to 0.44. Within this range, there were 2 items with an r value falling between 0.20–0.29 (considered acceptable), 18 items with an r value between 0.30–0.39 (considered good), and 3 items with an *r* value exceeding 0.40 (considered excellent discrimination). This indicates that all items have good discriminatory values [23]. Furthermore, the reliability of the entire test, according to the Kuder–Richardson 20 formula, was determined to be 0.75. It can be concluded that the instrument is reliable according to Pallant [24]. The administration of the test took about 45 minutes. We gave a score of 1 for the correct answer and 0 for the wrong answer. Hence, the maximum point a student could get was 23. High scores on the test indicate high conceptual understanding.

2.4. Procedure

Before the treatment, all students completed the pretest. During the treatment, students studied chemistry using a different approach. The intervention was carried out in three meetings. It should be noted that teaching materials and data collection tools were presented in Indonesian. After treatment, all students completed the posttest.

At the beginning of the instruction, all students in both FCPI and FCX were directed to join Google Classroom, an online platform aimed at facilitating "before class" activities for students. Then the teacher gave directions regarding activities that students would carry out in Google Classroom before face-to-face classes.

The teacher gave students teaching materials one week before each meeting. Students were asked to read learning resources and watch videos that had been provided by the teacher on Google Classroom. Resources were sections of the textbook explaining topics to be studied. It was intended that students could adequately prepare and learn the concepts. The deadline for completing the test ended the day before in-class learning. Students in both groups were then instructed to take a short quiz through the Kahoot platform to check their own level of understanding, and also answer the question: "*In your opinion, which part is the most important for us to discuss together in class related to the topics studied today?*". Before each class, the teacher reviewed the percentage of correct answers for each question on the test. In this way, the teacher could identify concepts that students had already grasped outside of class and pinpoint those that were more challenging to understand. Consequently, in-class activities were tailored to concentrate on these more difficult and challenging concepts. At the next meeting, the teacher motivated students and then gave a short interactive lecture to help students recall the content that had been learned in the before-class activities.

The difference between the two groups was that only students in FCPI were involved in peer instruction activities. In this setting, the teacher gave the experimental group students a ConceptTest for each concept that needed to be mastered. The teacher then collected students' ConceptTest answers using ABCD flashcards and reviewed student answers. Throughout class activities, the peer instruction strategy was employed to facilitate learning and foster discussions among students. The teacher also used the online quiz platform to manage questions in class. The teacher asked the students the most difficult questions. Following this, students were prompted to engage in small group discussions regarding the question for a few minutes and answered using their own devices. The teacher presented the correct answer and discussed the question with the students. Finally, students and teachers together reflected on the results obtained after studying the periodic system of elements using the FCPI and then the students worked on the posttest. Students were then directed to carry out after-class activities.

2.5. Data Analysis

To evaluate the impact of the treatment, quantitative data analysis was conducted, involving descriptive and inferential statistics using SPSS 25. First, descriptive statistics were reported in terms of mean scores and standard deviations. Inferential statistics were then conducted using *t*-tests.

Before the statistical analysis, the normality of the data was checked using the Kolmogorov-Smirnov test, and the homogeneity of variance was verified using the Levene test. The results of the assumption tests showed that they were fulfilled ($p > 0.05$). To address the first and second research questions, we employed a paired *t*-test to check whether students' conceptual understanding improved significantly in both groups. Additionally, an independent *t*-test was utilized to compare the scores between the intervention and comparison groups. Effect sizes were then computed using Cohen's *d* to quantify the intervention's effect size [21]. According to Cohen [21], effect sizes are classified as small (0.20 - 0.50), moderate (0.50 - 0.80), and large (>0.80). All statistical analyses were conducted at the 0.05 significance level.

3. Findings

The goal of the current study was to investigate the impact of FCPI on the conceptual understanding of the periodic table of elements among tenth-grade students. To investigate whether the experimental (EG) and control group (CG) students' conceptual understanding differed prior to and subsequent treatment, an independent *t*-test was performed. As depicted in Table 1, there was no statistically significant gap found between the overall subscale scores of the two groups (EG: M = 13.88, SD = 2.34; CG: M = 13.88, SD = 2.34; $t = -0.87$, $p > 0.05$). Hence, it can be highlighted that no significant gap appeared in terms of conceptual understanding between students in the EG and CG before the treatment. Since the results of the students regarding the pretest did not show a significant difference, it can be assumed that students have similar backgrounds and experiences.

Table 1. The independent t-test results for the pretest

Sub-scale		M	SD	*t*	*p*
Interpreting	CG	3.88	1.01	0.51	0.61
	EG	3.75	0.95		
Exemplifying	CG	1.09	0.73	-0.53	0.60
	EG	1.19	0.69		
Classifying	CG	1.59	0.95	-0.71	0.48
	EG	1.75	0.80		
Summarizing	CG	0.34	0.48	-1.26	0.21
	EG	0.50	0.51		
Inferring	CG	2.69	0.86	0.13	0.90
	EG	2.66	1.04		
Comparing	CG	0.66	0.48	-0.81	0.42
	EG	0.75	0.44		
Explaining	CG	3.13	1.31	-0.53	0.60
	EG	3.28	1.02		
All subscales	CG	13.38	2.30	-0.86	0.39
	EG	13.88	2.34		

As depicted in Table 2, the independent *t*-test results indicated a statistically significant gap between the groups of students regarding conceptual understanding following the instruction, $t(62) = -6.01$, $p < 0.05$.

This suggests a significant disparity in the understanding of students in the EG and CG after the treatment. Specifically, the mean scores of the EG (M = 20.47, SD = 2.05) were notably higher than those of the CG (M = 17.41, SD = 2.03).

Table 2. The independent t-test results for the posttest

Sub-scale		M	SD	*t*	*p*
Interpreting	CG	4.59	0.88	-3.72	0.00
	EG	5.41	0.88		
Exemplifying	CG	1.44	0.62	-2.33	0.02
	EG	1.75	0.44		
Classifying	CG	2.28	0.73	-2.13	0.04
	EG	2.26	0.55		
Summarizing	CG	0.69	0.47	-2.66	0.01
	EG	0.94	0.25		
Inferring	CG	3.13	0.91	-2.49	0.02
	EG	3.59	0.56		
Comparing	CG	0.88	0.34	-2.10	0.04
	EG	1.00	0.00		
Explaining	CG	4.38	0.98	-3.08	0.00
	EG	5.16	1.05		
All subscales	CG	17.41	2.03	-6.01	0.00
	EG	20.47	2.05		

To investigate whether students in the two groups improved their conceptual understanding after treatment, a paired-sample *t*-test was utilized. The results of the *t*-test indicated a statistically significant mean gap in conceptual understanding prior to and following the intervention for the two groups (Table 3). Nevertheless, the EG exhibited a higher improvement in their posttest scores compared to the CG. This reaffirmed that the mean scores for the posttest were significantly greater than those for the pretest after the intervention. The results demonstrated that the treatment given can enhance students' conceptual understanding. Also, the effect sizes for the experimental ($d = 3.00$) and control ($d = 1.81$) groups were all higher than 0.80, indicating that the magnitude of the intervention effects in both groups was very large.

Table 3. The paired t-test results for both groups

Sub-scale		Paired Differences		*t*	*d*
		M	SD		
Interpreting	CG	-3.13	6.07	-2.91*	0.76
	EG	-7.20	5.01	-8.13*	1.81
Exemplifying	CG	-1.50	3.24	-2.61*	0.51
	EG	-2.45	3.30	-4.19*	0.97
Classifying	CG	-2.99	5.11	-3.31*	0.81
	EG	-3.80	4.09	-5.26*	1.27
Summarizing	CG	-1.50	3.05	-2.78*	0.76
	EG	-1.90	2.19	-4.91*	1.10
Inferring	CG	-1.90	4.80	-2.24*	0.50
	EG	-4.07	5.62	-4.01*	1.13
Comparing	CG	-0.54	2.14	-2.24*	0.53
	EG	-1.09	1.91	-3.22*	0.80
Explaining	CG	-5.84	7.04	-4.70*	1.08
	EG	-8.15	5.71	-8.08*	1.81
All subscales	CG	-18.75	9.59	-10.27*	1.81
	EG	-30.44	10.31	-14.08*	3.00

$p < 0.05$ (significant)

4. Discussion

This study successfully examined the impact of FCPI on students' understanding of the periodic table of elements. The statistical results suggested that no statistically significant gap existed among the students' pretest scores. It can be concluded that all students in both groups have a similar conceptual understanding of the periodic system of elements before the treatment. This may be the result of giving the same teaching program to students in the previous intervention [1]. Prior to treatment, students in both groups showed similar conceptual understanding and were still low. This suggests that the traditional learning methods employed thus far have not effectively enhanced students' conceptual understanding. The study conducted by Kilic and Topsakal [25] also concluded that teacher-centered conventional learning has not been able to improve students' conceptual understanding. This may be because teacher-centered learning tends to make the student the object of learning and the teacher the subject; thus, students become passive learners [26].

Conversely, comparisons of the *t*-test results revealed that following the treatment, there were significant gaps in favor of the posttest in the EG. It can be said that the FCPI was more effective in enhancing students' understanding of the periodic table of elements compared to the FCX, following the intervention. This finding aligns with previous studies. For example, research conducted by Gok [27] showed that peer instruction has a promising impact on conceptual learning. In a recent research study, Macale *et al.* [16] reported that peer instruction and flipped classrooms together had a positive influence on chemistry learning. It may be the result of peer instruction that positively influences students' conceptual understanding during their learning [27], [28]. As stated by Ruiz de Miras *et al*. [29], the implementation of FCPI has proven effective in enhancing the quality of students' independent work and fostering their engagement in the learning process, so that their acquisition of knowledge increases.

During the treatment, students in the FCPI and FCX treatments studied the same topics using different teaching approaches. Then the posttest was re-administered. According to the results of the paired *t*-test, it seems that there was a notable increase in scores indicating conceptual comprehension in both groups before and after learning was carried out. This shows that both flipped classrooms with and without peer instruction have a positive influence in increasing students' understanding of the periodic system of elements. However, the experimental group exhibited a greater increase in conceptual understanding compared to their counterparts.

This reflects that flipped classrooms with peer instruction have a greater influence than flipped classrooms only in order to improve students' conceptual understanding. The heightened conceptual understanding observed in both the CG and EG could be attributed to the flipped classroom intervention. In an FCPI setting, students are tasked with grappling with challenging concepts during activities conducted outside the traditional classroom setting. As a result, students have a good initial knowledge of the challenging topics that will be studied before participating in class activities. In other words, students have learned topics from textbooks and videos in pre-class activities, so that in-class activities can be maximized for discussion [19]. This is consistent with the fact that discussion can increase student activity and involvement so that students with teacher guidance are able to deepen learning topics to reach the desired realm of conceptual understanding [30].

Interestingly, participants in the experimental group demonstrated a more significant increase in conceptual understanding compared to the comparison group. This could be attributed to the fact that students in the EG were exposed to the combined approach of flipped classrooms with peer instruction. In this setting, there are pre-class activities carried out by students before attending face-to-face learning. In the before-class activities, students study the periodic system of elements through textbooks and videos so that face-to-face time in groups can be maximized for peer instruction activities. In the before-class activities, students also fill out quizzes and provide comments regarding what concepts they think are the most difficult so that the teacher can determine the most important concepts for students to learn in face-to-face activities [19]. In peer instruction, there are ConceptTests which are conceptual questions tailored to students' needs to understand specific concepts in chemistry [19]. Previous studies claimed that peer instruction can help students learn and improve their conceptual understanding because peer instruction involves students playing an active role in their learning [19], [31], [32].

As an active learning pedagogy, the utilization of peer instruction is believed to be able to promote student performance and conceptual understanding in chemistry education. Peer instruction provides equal support for each student to ultimately achieve a better understanding of concepts. Through peer instruction activities, it was revealed that the increase in student performance was caused by intense interaction between students, peer support, active participation of all students during learning, maximum teacher support, and increased interaction between teachers and students [33].

In small group discussions, students who answer incorrectly can learn from each other's reasoning because individuals can find out the answer by discussing the question with other friends who also do not know the answer [34]. The present findings are in accordance with the research done by Vickrey *et al*. [35], who concluded that students gave good responses to various aspects of peer instruction, especially the direct feedback given, and most importantly students agreed that peer learning helped them to develop their understanding in the learning process. In another empirical research study, Antwi *et al.* [33] similarly discovered that students who were exposed to peer instruction enjoyed their lessons and participated actively in learning. Because peer instruction learning is activity-oriented, students are encouraged to learn collaboratively with their peers and teachers. Peer instruction offers valuable opportunities for students to engage in intensive interaction and discussion with their classmates. With peer instruction, students show good effort in the process of constructing and discovering their own knowledge. Thus, the combination of flipped classrooms with peer instruction is effective in increasing students' understanding of chemistry, especially the topic of the periodic system of elements.

5. Conclusions and Suggestions

In the present study, it was concluded that employing flipped classrooms with peer instruction surpassed using flipped classrooms alone in addressing students' alternative concepts. The findings highlighted that there was a higher positive conceptual change in the treatment group. In other words, the FCPI has a greater influence than a flipped classroom without peer instruction in increasing students' conceptual understanding. This shows that the combination of flipped classrooms with peer instruction is seen as an effective strategy for increasing 10th-grade students' understanding of the periodic system of elements.

The current study expands on previous findings related to the effectiveness of FCPI on students' conceptual understanding. Although this study succeeded in investigating the effect of FCPI on high school students' conceptual understanding of the periodic system of elements, several limitations should be taken into consideration. First, this study only produces quantitative data obtained from conceptual tests. Future research can use a mixed methods design by adding qualitative findings which can provide more detailed and comprehensive information about how students' conceptual understanding develops. Second, the study was performed in only five meetings.

Future studies may extend the use of the flipped classroom throughout the semester. Since the study only recruited two intact classes in a public high school, future studies should consider expanding the group sample size so as to obtain more comprehensive data.

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