Cypriot Journal of Educational Sciences

Volume 17, Issue 9, (2022) 3170-3183

www.cjes.eu

Effectiveness of virtual flipped classroom on science achievement and higher thinking skills development

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Suggested Citation:

Rayahneh, M. S. Q. & Al Bataiha, S. S. E. (2022). Effectiveness of virtual flipped classroom on science achievement and higher thinking skills development. *Cypriot Journal of Educational Science. 17*(9), 3170-3183. https://doi.org/10.18844/cjes.v17i9.6996

Received from April 12, 2022; revised from August 15, 2022; accepted from September 15, 2022.

Abstract

The study aimed to gauge the effectiveness of virtual flipped classrooms on the science achievement of seventh graders and the development of higher-order thinking skills. The researcher followed the quasi-experimental research design. The participants were randomly selected and consisted of 60 students divided into a control group (n = 31) and an experimental group (n = 29). The former was taught traditionally and the latter was taught by the virtual flipped classroom method. The researcher applied pre-post diagnostic tests to the two groups, in addition to descriptive statistics and a-test for independent samples. The results revealed that there are significant differences between the means of the two groups in favour of the experimental. Furthermore, the study confirmed the effectiveness of the virtual flipped class in students' achievement and development of higher-order thinking skills. The study recommends activating virtual flipped classrooms in different school subjects and levels.

Keywords: Virtual flipped classroom, students' achievement, higher-order thinking skills.

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1. Introduction

Currently, people all over the world have been affected by coronavirus disease and social distancing was adopted in many, creating unprecedented havoc in all political, economic, and social systems. Like any vital top sector, education has been severely affected, numerous countries around the world decided to close schools nationwide to prevent or contain the spread of the virus, resulting in a sudden, global shift to online learning platforms to keep academic activities going. Disrupted formal schooling resulted in a loss of knowledge, skills and reversals in academic progress, most commonly due to extended gaps or discontinuities in students' education, which was referred to as learning loss. Because in-person learning is still prohibited with no end in sight and the abrupt shift to distance education, the issue of learning loss received great global attention during the COVID-19 pandemic. Experts believe that distance learning will never be an adequate substitute for in-person learning; there are many vital and effective attributes that distance learning simply cannot accommodate.

The way students experience teaching and learning processes has differed drastically over the last 50 years. The experiences of this net generation require changes to be made to the teaching methods. All teachers have faced these issues over time, and have been looking for possible solutions and improvements within their teaching practice. Some innovative teachers started trying it out and the flipped classroom method was formulated and spread in an attempt to provide students with educational competencies, help them in catching up on the learning loss and develop their higher-order thinking skills.

Unlike traditional learning; flipped classroom model has been framed as a panacea for all of the learning challenges faced by students, it applies a student-centred approach to the learning process. Learners get the initial learning material at home and class time is used for cooperative learning, they take part in the learning process with full concentration, learn more cooperatively, and think critically. In the flipped classroom, students watch the instructional video designed by the teacher at home before going to the classroom, then record notes and questions to discuss during class time, which is redirected to in-depth discussions of the content, asking questions, implementing projects, solving assignments and providing more opportunities for fruitful interaction between students and their teacher. In light of COVID-19 and the shift to distance education, flipped classroom as an educational strategy can be used to increase achievement by depending on technology in education (Goodmanet al.,2018; Gopalanet al., 2021). When used effectively, technology can ensure that students arrive to class more prepared for meaningful interaction with teachers while restructuring classes into more active learning environments(Bowen, 2012, p.39).

With the help of technology and a radical reimagining of time and space, teachers no longer have to adhere to the ‘one-size-fits-all’ approach that characterises the traditional system. However, students stand to benefit a lot from the instructional videos in a way that matches their capabilities with greater control over their own learning. The implications for teachers are also exciting; they become freer to take on different roles, including mentor, coach and designer of projects that highlight the real-world relevance of subject material. This creates the potential for them to have a deeper, more fulfilling engagement with students, and a more creative part to play in the design and delivery of curricula (Hampson et al., 2018).

The massive closures of schools have negatively affected education and resulted in a significant learning loss for students, focusing on cognitive levels and moving away from others. Distance learning can satisfy a wide range of needs for many students in diverse circumstances, but it is not for everyone since students are distinguished in abilities, learning styles and intelligence. Therefore, there is an urgent need to investigate the effectiveness of the virtual flipped classroom in developing achievement and higher-order thinking skills.

Educational literature has found that it is necessary to take advantage of the flipped classroom strategy to improve learning processes in various academic courses in general and science courses in

particular. A plethora of research (e.g., Marlowe, 2012; Nagwa& Soliman, 2016; Tuneet al., 2013; Thompson &Mombourquette, 2014) indicated the effectiveness of using the virtual flipped classroom in teaching science at different stages, overcoming learning disability and developing higher-order thinking skills in the scientific content presented to students. Based on the foregoing, the current study aims to investigate the effectiveness of virtual flipped classrooms in developing students' achievement and higher-order thinking skills.

1.1. Literature review

A rock-solid piece of evidence has targeted the effectiveness of virtual flipped classrooms. Sakti and Sukardi (2021) investigated the effectiveness of applying flipped classroom-based e-learning during the COVID-19 period. This study used a deductive approach using a choice of quantitative methods. The study gathered data from 30 students from the vocational secondary schools in Padang in Nigeria (SMKN 5 Padang) for 4 weeks in the academic year 2019–2020. A test was used as an instrument to assess the cognitive domain and the grade scale for the effective psychological assessment. The results revealed that flipped classroom-based e-learning trial effectively improves students' cognitive, affective and psychomotor abilities during the COVID-19 pandemic and it could be effectively used as a media for distance learning.

Gopalon et al. (2021) investigated the effectiveness of virtual flipped classrooms during the pandemic in a graduate-level physiology course, besides assessing the knowledge gained. Student surveys were used to measure their perception and adjustment, confidence in completing the course successfully and the usefulness of assessments and assignments in the new format. The study sample consisted of 9 males and 24 females who reported that they adjusted well to the remote flipped classroom method and their confidence in completing the course in this teaching mode successfully improved from the beginning to the end of the semester. Students expressed a positive response to the synchronous computerised exams, the formative group and individual assessments. Both collaborative activities and in-class discussions were found to be effective. Thus, the study presents a promising new instructional method in the teaching of future physiology courses.

Othman (2016) examined the effect of using the flipped learning strategy on the achievement of seventh-grade female students in science subjects and their attitudes towards it. The study sample (n=56)were selected from two different schools and divided into experimental and control groups. To achieve the study objectives, the researcher used the quasi-experimental approach in addition to an achievement test and a questionnaire in which validity and reliability were verified. The results showed that there were statistically significant differences at (α = 0.05) in students' achievement in science attributed to the teaching method, it also showed that students' positive attitude towards science was at a medium level.

Kim et al.(2014) explored the effects of smart-based flipped learning activities on learners' study achievement, self-directed learning, collaborative learning and information usability. To achieve the study purpose, 112 6th-grade students in the elementary school in South Korea were selected and examined for 11 weeks. The results revealed that flipped learning was found to have improved self-directed learning ability, collaborative learning ability and information usability with statistical significance in the smart-based flipped learning group than the other groups.

Ferrer and Martines (2021) investigated the effects of flipped classroom on students' learning and motivation during the corona pandemic. The sample consisted of 179 student teachers from the faculty of education at the University of Murcia in the academic year 2020–2021, in which the flipped classroom strategy was implemented. Surveys were administered and examined through both descriptive statistics and non-parametric tests. Results showed statistically significant differences between pre-tests and post-tests with experienced students scoring higher on average in the post test. Most students had a positive perception about the flipped classroom, noting the benefit of practical in-class activities, as well as increased self-autonomy in learning.

Smith and Boscak (2021)reported that COVID-19 pandemic resulted in the cancelation of traditional on-site clinical trainings for medical students across the country. Radiology educators had to rapidly adapt to a new, virtual educational landscape and restructuring a trauma and emergency radiology elective to an online format. The course lasted for 4weeks. Changes to the traditional training included assigning an increased number of self-study educational resources, independent review of unknown cases using a virtual workstation and online interactive conferences. After the course, students were asked to complete feedback surveys. Thirteen students enrolled in this online course; they strongly agreed that the course was clinically relevant, with accessible, engaging material and 91.7% of them were very likely to recommend this technique to others.

1.2. Problem of the study

Educational literature indicates that there is learning loss among students due to school closure and distance education during the COVID-19 pandemic. Students made little or no progress while learning from home and learning loss was most pronounced among students from disadvantaged homes (Loeb, 2020).The study of Storey and Zhang (2021) indicated that students lose 15% of learning in comparison with other school years. Engzell et al. (2021)reported a learning loss of about 3% or 0.08 SD. In addition, Canovan and Fallon(2020) indicated that school closures have exacerbated the science learning loss in basic subjects. In the same context, other educational studies (e.g., Kim et al., 2014; Othman, 2016; Sakti &Sukardi, 2021) indicated the effectiveness of the flipped classroom strategy in developing achievement. Based on the foregoing, the study examined the effectiveness of the virtual flipped classroom in the development of students' achievement and higher-order thinking skills. Therefore, the current study seeks to answer the following overarching question: What is the effectiveness of virtual flipped classrooms on science achievement of seventh-grade students and the development of higher-order thinking skills? Two supplementary questions drove the collection of the subsequent data:

1- Are there any statistically significant differences at α = 0.05 between the mean scores of the experimental and control groups in the post-diagnostic test in science for the seventh-grade students on the total degree of achievement?

2- Are there any statistically significant differences at α = 0.05 between the mean scores of the experimental and control groups in the post-diagnostic test in science for the seventh-grade students at higher cognitive levels (knowledge, application and inference)?

1.3. Study objectives

The current study seeks to achieve the following research objectives:

1- Investigating the effectiveness of virtual flipped classrooms in developing achievement in the 'Force/Motion and Simple Machines' unit for the seventh-grade students.

2- Revealing the effectiveness of virtual flipped classrooms in developing the higher-order thinking skills in the 'Force/MotionandSimple Machines' unit for the seventh-grade students.

3- Exposing the challenges that may arise during the application of virtual flipped learning and providing educational insights to deal with these challenges.

1.4. Significance of the study

The findings of the study are expected to provide potentially significant information in the following aspects:

1- Redesigning the 'Force/Motion and Simple Machines' unit according to the virtual flipped learning, examining its effectiveness in mastering the academic competencies in science for the seventh grade, providing a fertile field to improve school achievement and delivering practical guidelines for those involved in the educational process to deal with the learning loss.

2- Providing visions to overcome challenges that may result from the application of the virtual flipped classroom strategy.

3- Investigating the effectiveness of the virtual flipped classroom in developing the higher-order thinking skills.

1.5. Terms of Definition

Virtual Flipped Classroom: In flipped classrooms, students engage in knowledge acquisition of course material prior to a class session, typically through assigned readings or lecture videos, leaving class time for the integration of knowledge through the application, analysis or synthesis-based activities. By introducing students to course material in advance of a class session, class time is available to explore challenging concepts, address student questions, engage in active learning and connect to real-life situations(Stone,2014). While the virtual flipped classroom is a computer-based environment in which active learning can be applied, almost everything that can be done in a real classroom can also be done in a virtual one. Students watch and listen to lectures at home and then perform their interactive activities and apply their knowledge in a virtual synchronised classroom in a way similar to the real classroom environment

Achievement: It is the measurement of students' overall academic learning over a particular period in the unit of 'Force/Motion and Simple Machines' included in the science textbook for seventh-grade students in the Kingdom of Bahrain. In this study, it is the score that the student obtains on the achievement test prepared according to the unit of 'Force/Motion and Simple Machines)'in the science textbook for the seventh-grade students.

Traditional teaching unit: It is addressing the learning loss through re-teaching the educational competencies in the unit of 'Force/Motion and Simple Machines in science textbook for the academic year 2021–2022 using MS Teams. On the contrary, teaching in virtual flipped classrooms takes place outside the official class time and then students discuss what they have learned through MS Teams, which contributes to investing class time for discussions and deepening understanding.

Higher-order thinking skills: They are the cognitive skills that the learner is supposed to possess. The diagnostic test targeted three levels of thinking: knowledge, application and inference. Knowledge refers to the remembering of previously learned material from facts to complete theories; knowledge represents the lowest level of learning outcomes in the cognitive domain. Application refers to the ability to use learned material in new and concrete situations. This may include the application of rules, methods, concepts, principles, laws and theories. When providing answers, students should use illustrations and schematic models. Inference means making predictions or generalisations. It is concerned with more complex scientific tasks, such as providing scientific justifications to solve problems, reaching conclusions, making decisions and expanding scientific knowledge on new cases (Al-Hussan, 2015).

1.6. Limitation of the study

The generalisability of the findings may be limited by the following considerations:

1- The study is restricted to the seventh-grade students from two schools affiliated with the fourth educational district and the extent to which the study sample represents their counterparts.

2- The educational material is from the unit of 'Force/Motion and Simple Machines' included in the science textbook for seventh-grade students in the Kingdom of Bahrain. In the first semester of the academic year 2021–2022.

3- The results are only generalised to teaching according to the virtual flipped classroom.

2. Method

2.1. Study approach

The study used the quasi-experimental approach to investigate the effectiveness of the virtual flipped classroom in developing students' achievement and their higher-order thinking skills in the unit of 'Force/Motion and Simple Machines' in the science textbook for seventh-grade students.

2.2. Study population

The study population consisted of all seventh-grade students in Tariq Bin Ziada school located in the Muharraq Governorate in the academic year (2021–2021), wherein data are collected from an economically and socially homogeneous group.

2.3. Study sample

The study sample consisted of 60 students randomly selected and divided into 2groups, control and experimental. Table 1 shows the distribution of the study sample according to their school and group.

Table 1

The Distribution of the Study Sample According to Their School and Group

School	Group	NO
Tariq Bin Ziada	Experimental	29
	Control	31
	Total	**60**

2.4. Study instrument

The study aimed to investigate the effectiveness of the virtual flipped classroom in developing students' achievement and their higher-order thinking skills. To answer the questions of the study, the researcher prepared a diagnostic test and re-designed the educational material in a form of an instructional video according to the virtual flipped classroom strategy.

1- **Diagnostic test**: The test aimed to determine the learning competencies (knowledge, application and inference) in the unit of 'Force/Motion and Simple Machines' in the science subject for the seventh-grade students. According to the Trends in International Mathematics and Science Study criteria, the topics will be on a test broken down and each section has a percentage of weight on the final test grade (Mullis et al., 2009,p. 52).

   The unit of Force/Motion and Simple Machines was chosen because it contains basic concepts and rules for what the students will study later.

2- **Unit analysis:** The content of the 'Force/Motion &Simple Machines' unit was analysed and the table of specification was constructed, as shown in Table 2.

Table 2

Table of Specification for the Seventh-Grade Diagnostic Test in the Force/Motion and Simple Machines Unit

Lesson	**Competencies**	**Cognitive levels**			**%**
		knowledge %33.3	**Application %33.3**	**Inference %33.3**	
Motion	Shows instantaneous velocity, average velocity, and acceleration	1	20	3	**%43**
	Solves numerical problems at average velocity	12	2	11	
	Calculates velocity and acceleration	10	13	19	

	through graphs				
Force and simple machines	Explains what is meant by the following concepts: work, simple machine, compound machine, mechanical advantage, lever	18	16	21	**%57**
	Solves numerical problems about work	17	15	6	
	Solves arithmetic problems using the law of lever	8	5	14	
	Calculates the Mechanical for machines	9	7	4	

3- Writing a set of paragraphs that take into account the cognitive levels (knowledge, application and inference) in a multiple-choice test of 21 questions.

4- Converting the diagnostic test into an electronic format through Google Form.

2.5. Validity and reliability of the study instruments

2.5.1. The diagnostic test

To examine the validity of the diagnostic test, a panel of educational experts reviewed the instrument. They critiqued the test items based on their harmony with the study objectives, integrity and clarity of the linguistic formulation, affiliation of the paragraphs under which they were classified and their matching to the unit content. The experts made sure that the test provides a clear snapshot of students' learning and whether the question type assesses the specific cognitive level depending on how well the designer crafts them.

In addition, the test was applied to a pilot study of 31 students at Al-Basateen School to calculate the item difficulty, ensure language clarity and suitability and determine the expected duration of a test. After correcting students' answers, item difficulty and discrimination for the diagnostic test questions were calculated, as shown in Table 3.

Table 3

Item Difficulty and Discrimination for the Diagnostic Test Questions

Question No	item difficulty	item discrimination	Question No	item difficulty	item discrimination
1	0.65	0.48	12	0.50	0.70
2	0.30	0.27	13	0.50	0.69
3	0.50	0.49	14	0.57	0.25
4	0.50	0.29	15	0.73	0.28
5	0.69	0.39	16	0.53	0.60
6	0.65	0.48	17	0.61	0.30
7	0.42	0.42	18	0.69	0.38
8	0.61	0.35	19	.53	0.49
9	0.61	0.31	20	0.53	0.35
10	0.61	30.	21	0.57	0.31
11	0.53	0.21			

Table 3 shows that the values of the difficulty for the test items ranged between 0.30 and 0.73 and the values of the discrimination ranged between 0.21 and 0.69. The test reliability

coefficient was calculated using the internal consistency and reached 0.80;the test time is extended by 40 minutes for students. Some paragraphs were deleted and modified in amending the final version of the study instrument. Thus, test items in the final form consisted of 21 multiple-choice paragraphs with 4 alternatives each; the questions allow only one answer to be chosen, one mark for the correct answer and zero mark for wrong answers; the maximum score is 21; the key answer sheet was prepared for the achievement test.

2.5.2. The redesigned unit in the form of an instructional video:

The educational video meets quality standards that fit the virtual flipped classroom strategy and aims to provide the educational competencies lost in the unit of Force/Motion and Simple Machines. The unit was redesigned according to the following steps:

- Designing a study plan for each learning situation in light of the educational competencies in the unit of Force/Motion and Simple Machines, then preparing a presentation and converting it into an instructional video through Active Presenter programme.
- Video judging: The educational videos were reviewed by a team of educational experts (two experts in science curricula and instruction, one in measurement and evaluation and two science teachers who are teaching the course). The percentage of agreement between the teams' evaluation went up to 0.80 and is considered acceptable to conduct the study.

2.6. Study procedures

The following procedures were carried out in the course of the study:

- Reviewing the related literature to narrow the topic, aggregate the theoretical and empirical research related to the topic and build the study instruments.
- Verifying the equivalence between experimental and control group in pre-diagnostic test before intervention
- Designing learning situations and determining the extent of their applicability.
- Preparing three presentations and converting them into high-quality instructional videos, through the Active Presenter programme, lasting 8–10 minutes each.
- Choosing Tariq Bin Ziyad School and two seventh-grade classes in the fourth educational district randomly.
- Teacher training: the researcher met the science teacher (12 years of experience) who teaches the control and experimental groups, he was informed of the purpose, importance and philosophy of the research, the teaching steps for each lesson and the role of the teacher and student during teaching. He was also provided with the instructional videos that were re-designed according to the flipped classroom; furthermore, the researcher followed up and observed the two groups remotely to make sure that the lessons were going properly. Teaching the two groups started in 3November2021and lasted for 3 weeks.
- Applying the diagnostic test to the control and experimental groups through an electronic link to obtain preliminary information that helps in the statistical operations of the research results and shows the extent of equivalence between groups; besides, students' marks were monitored before teaching them electronically.
- Uploading the instructional videos through several ways such as an educational channel for the researcher or sharing a link via WhatsApp. Students in the experimental group are required to record their own responses on a worksheet (three notes, two questions and two inquiries) and send it to the teacher to verify that students have watched the videos.
- Teaching the control group traditionally and teaching the experimental group at the same time in both schools through the virtual flipped classroom strategy

- Discussing the scientific material included in the video with students through MS Teams by asking questions and inquiries, solving pre-planned educational activities to monitor and evaluate their learning and obtain deeper understanding of the content.
- Measuring the effectiveness of the virtual flipped classroom strategy by applying the post-test to the control and experimental groups, and correcting students' answers electronically.

2.7. Study variables

The study included one dependent variable – the achievement of seventh-grade students in terms of educational competencies and higher-order thinking skills according to the results of the diagnostic test – and two independent variables – teaching method (virtual flipped classroom class applied to the experimental group and the traditional method applied to the control group). Gender removed.

2.8. Statistical treatment

To investigate the effectiveness of the virtual flipped classroom in students' achievement and development of higher-order thinking, means and standard deviations were calculated, in addition to *t*-test for independent samples.

3. Findings and discussion

The first research question sought if there were any statistically significant differences at $\alpha = 0.05$ between the mean scores of the experimental and control groups in the post-diagnostic test in science subject for the seventh-grade students on the total degree of achievement. Before answering this question, means and standard deviations of the control and experimental groups on the pre-scale items were calculated to ensure that the two groups are equivalent before starting the experiment, as shown in Table 4.

Table 4

Means and Standard Deviations of the Study Members in the Two Groups on the Pre-Scale Items

	Group	No	Mean	SD
Pre-test	Control	21	0.49	0.09
	Experimental	21	0.52	0.11

Table 4 shows that the means core of the experimental group on the pre-scale items (0.52) is higher than the means core of the control group(0.49). To find out whether these differences were statistically significant at $\alpha = 0.05$,the independent sample *t*-test was used, as shown Table 5.

Table 5

t-Test Value Calculated and Tabulated on the Pre-Scale Items of the Two Sample Groups

	t	df	Sig. (2-tailed)
Pre scale	−1.018	40	0.315

Table 5 shows that that the tabulated *t*-value exceeds the calculated *t*-value. This means that null hypothesis is accepted; there are no statistically significant differences at α = 0.05 in the scores of students attributed to the group variable, which indicates that they are equal at the academic level.

For answering the question, means and standard deviations of the study members in the two groups (control and experimental) were calculated on the post-scale items as shown in Table 6.

Table 6

Means and Standard Deviations of the Study Members in the Two Groups on the Post-Scale Items

	Group	No	Mean	SD
Post-test	Control	21	0.67	0.08
	Experimental	21	0.82	0.07

Table 6 shows that the mean score of the experimental on the post-scale items (0.82) is higher than the mean score of the control group (0.67). To find out whether these differences were statistically significant at α = 0.05, the independent sample *t*-test was used, as shown Table 7.

Table 7

T-Test Value Calculated and Tabulated on the Post-Scale Items of the Two Sample Groups

	t	df	Sig. (2-tailed)
Post-scale	−6.179	40	0.00

Table 7shows that the calculated *T*-value exceeds the tabulated *T*-value. This means that the null hypothesis is rejected; there are statistically significant differences at α = 0.05 in the scores of students attributed to group variable, in favour of the experimental group.

This result can be explained by the fact that the flipped classroom strategy creates rich learning opportunities and make students the centre of the teaching–learning process. Furthermore, flipped classroom model has clearly shifted the learning paradigm, enabled students the autonomy of their self-directed learning pace and has become acquainted with the currency of video lectures that promoted efficacious learning. Flipped models allow the teacher and students to make the most use of their time and effort during class. Essentially, this model gives teachers more time to support their students in acquiring multiple skills by reallocating time spent teaching and learning. According to OECD, there is a relationship between learning time in individual study and his academic performance; students who have more instruction time learn more. Similarly, the results of PISA confirmed that students who spend longer time in learning language, mathematics and science achieve higher scores (OECD, 2019). It also can be interpreted that students participate in their learning assessment in a meaningful way (Al-kuhaili, 2015).

According to Johnson and Renner (2012), today's students have grown under the availability of the Internet, YouTube and Facebook. These digital sources are almost everywhere; they help students to broaden their knowledge by accessing information worldwide and lead to greater academic success. Students see these digital sources as a favourable environment for studies and a source of relevant and realistic information for research because they provide readily information at

all times, faster access to information, help students to be responsible for their on learning and work according to their self-understanding and absorption.

The result goes in line with a plethora of research (e.g., Sakti &Sukardi, 2021;Gopalan et al., 2021; Othman, 2016; Kim et al., 2014) which indicated the effectiveness of the flipped classroom in achievement in the science subject and in developing self and cooperative learning skills among students who adapted well to the virtual flipped classroom.

The second research question sought if there are any statistically significant differences at α = 0.05 between the mean scores of the experimental and control groups in the post-diagnostic test in the science subject for the seventh-grade students at the higher cognitive levels (knowledge, application and inference).

To answer this question, means and standard deviations of the two groups (control and experimental) were calculated on the items of each cognitive level (knowledge, application and inference) for the post-scale, as shown in Table 8.

Table 8

Means and Standard Deviations of the Control and Experimental on the Items of Each Cognitive Level (Knowledge, Application and Inference) for the Post-Scale

Higher-order thinking level	Groups	No	Means	SD
Application	Control	21	.68	.14
	Experimental	21	.82	.14
Knowledge	Control	21	.70	.14
	Experimental	21	0.76	0.17
Inference	Control	21	0.61	0.23
	Experimental	21	0.92	0.09

Table 8shows that students' scores on the post-scale items at all thinking levels (knowledge, application and inference) increased in the experimental group as compared to the control group. The experimental group scored 0.82, 0.76 and 0.92on the thinking levels (knowledge, application and inference, respectively),while the control group scored 0.68, 0.70 and 0.61, respectively. To find out whether these differences were statistically significant at α = 0.05,the independent sample *t*-test was used, as shown in Table 9.

Table 9

Independent Sample t-Test for the Differences in the Mean Scores of the Study Members According to Group Variable on the Items of Each Higher Cognitive Level Scale (Knowledge, Application and Inference)

Higher-order thinking level	*t*	Df	Sig. (2-tailed)
Application	−3.177	40	0.003
Knowledge	-1.398	40	0.170
Inference	-5.647	40	0.000

Table 9 shows that the calculated *t*-value exceeds the tabulated *t*-value on the items of inference and application levels. This means that null hypothesis is rejected; there are statistically significant differences at α = 0.05 in the scores of students attributed to group variable, in favour of the experimental group, which means that the performance of the experimental group on the items that measure the levels of application and inference was better than the performance of the control group at the same levels.

As for the performance of the two groups on the items that measure the level of knowledge, the tabulated *t*-value exceeds the calculated *t*-value. This means that the null hypothesis is accepted; there are no statistically significant differences at α = 0.05 in the scores of students attributed to group variable.

This result might be attributed to the fact that the virtual flipped strategy provides a high level of motivation, encourages self-learning among students and makes better use of the classroom sessions, which results in better motivation and greater interest in their learning and enable them to tackle complex problems. In addition, the flipped learning model enhances the active and autonomous learning of students and encourages innovation within the learning process.

Besides, flipped learning changes the entire teaching process and engages multiple learning styles in the classroom. Moreover, the selected teaching unit is based on students' skills in collecting and evaluating information from multiple sources to generate solutions to issues addressed in the flipped learning modes, which in turn, contributed to strengthening their research and survey skills and increased their achievement and motivation to reach advanced levels.

It also can be explained that this type of learning environment can increase the learning potential of the students who can learn anytime and anywhere, and the possibility of re-teaching to promote students' learning and motivation to confirm understanding and taking notes.

4. Conclusion

Based on the results and discussion, the following are concluded:

1- There are statistically significant differences at α = 0.05 in the scores of students attributed to group variable in favour of the experimental group.

2- There are statistically significant differences at α = 0.05 in the scores of students attributed to group variable in favour of the experimental group. The performance of the experimental group on the items that measure the levels of application and inference was better than the performance of the control group on the same levels.

3- There are no statistically significant differences at α = 0.05 in the scores of students attributed to group variable on the items of the post scale that measure the level of knowledge which means that there is no difference in the performance of the two groups on the level mentioned.

5. Recommendations

Based on the results of the current study, the researcher recommends the following:

- Adopting the virtual flipped classroom strategy in teaching science course at various levels and subjects.(I think it can be applied globally.)
- Training teachers to use the flipped classroom to improve the teaching and learning processes(can use it in different circumstances especially when student dropout of school).
- Teachers may face some challenging during the application of virtual flipped classrooms such as students' lack of motivation to watch the instructional videos which can be overcome by the following:

- Providing guiding questions to consider while watching. Preparing high-quality videos that do not exceed 10 minutes for primary level students and 15 minutes for secondary level students. Focusing on one interactive topic that includes open-ended questions.
- Asking students to answer the 3-2-1 promptly: three things that they have learned from this video, two questions that they still have, one aspect of the video that they enjoyed. Sharing 3-2-1 responses is also an effective way to prompt a class discussion or to review material from the previous lesson.

This study was limited to investigating the effectiveness of the virtual flipped classroom strategy in developing achievement and higher-order thinking skills in science for the seventh-grade students at Tariq bin Ziyad School. There is a need to conduct further research at the basic and secondary educational levels and in other school subjects such as biology, chemistry, geology, mathematics, physics and humanities.

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