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Research Article

The Effectiveness of Fermi Problem solving with Flipped Learning Techniques in Teaching physics on Improving Critical Thinking Skills among Emirati Secondary Students

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Abstract

The urgent need of developing novel teaching methods in education to improve the critical thinking skills has been widely discussed by educational experts. The present study aims to investigate the effectiveness of Fermi problem solving with flipped learning techniques in teaching physics on the improvement of critical thinking skills among Emirati tenth graders. The sample of the study consists of 40 male and female secondary students from two secondary schools belonging to Abu Dhabi Department of Education and Knowledge in United Arab Emirates divided into two groups; the control group consists of 20 students (10 male and 10 female) taught the physics unit by traditional methods, the experimental group consists of 20 students (10 males and 10 females) taught the physics unit by Fermi problem solving with flipped learning techniques. The quasi-experimental design was used, where the modified critical thinking skills test was prepared and administered on the two groups as a pre-test before the students start the treatment and as a post-test once they are finished. The MANCOVA and Two-Way ANCOVA tests were employed to analyze the data. The findings showed that there were statistically significant differences at (a = 0.05) in student's critical thinking skills test (in favor of experimental group), indicating that the performance of students in treatment group was better than the control group in the post-test. This means that the Fermi problem solving with flipped learning techniques has significant effectiveness on improvement of critical thinking skills among the United Arab Emirates secondary students. Also there were no statistically significant differences between male and female students.

Keywords
Critical Thinking skills; Fermi problem solving, Flipped Learning Techniques.

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Introduction

Life in the 21st century became more complicated, citizenship requires levels of information and technological literacy that go beyond the basic knowledge that was sufficient in the past (Malik, 2018; NEA, 2012). In addition, much success lies in being able to use information to solve complex problems (Center, 2010; Laar et al., 2020).Therefore, Schools must transform in ways that will enable students to acquire critical thinking, flexible problem solving and innovative skills that they need in order to be successful in work and life (Alismail & McGuire, 2015; Laar et al., 2020). However, teachers should apply different strategies and methods for teaching these skills because there is no specific strategy to achieve this goal (Alismail & McGuire, 2015). In addition, author of (Anagün, 2018) mentioned that we need to encourage teachers and other educational stakeholders to focus on real-world problems and processes. This is aligned with the modern attempt to provide an effective teaching environment that result in new teaching methods focusing on the utilization of 21st century skills such as critical thinking in all educational infrastructures (Ärlebäck & Albarracín, 2019; Bani-Hamad & Abdullah, 2019b; Laar et al., 2020). This helps in improving students' critical thinking, creativity, and inference skills, also the best practices for implementing critical thinking skills including problem–based learning, real-world problems and technological skills to best preparation of our students for future work that does not yet exist, careers that have not yet been created (Bani-Hamad & Abdullah, 2019a; Bellanca & Brandt, 2010; Laar et al., 2020; Noel & Liub, 2017). The National Standards for curricula and evaluation in the United Arab Emirates (UAE) emphasizes on the need for using modern teaching strategies, as well as taking care of higher order thinking skills including synthesis, analysis, and evaluation, in addition to the investment of technology through smart learning programs inclusion in education through effective integration of technology in all study curricula and in all educational stages (Ministry of Education, 2017). The present study aimed at investigating the effectiveness of Fermi problem solving with flipped learning techniques on improving the United Arab Emirates secondary students' critical thinking skills which is considered as one of the most important 21st century skills.

Problem statement

Despite the efforts made by educational institutions, and the quantitative and qualitative changes and improvements that have occurred to them; their programs, activities, and teaching methods are still deficient in the area of developing proper thinking methods, including critical thinking, and whose programs and methods are still focused on teaching facts and information to students (ADEK, 2017; Beard, Schweiger, & Surendran, 2008). Also, the low academic achievement and low students' skills at university level are attributed to the apparent lack of dealing with critical thinking levels in the secondary stages of school education because they often depend on explanation, recitation, and memorization (Ministry of Education, 2017; Vuong, 2018). It was also noted in report ADEK (2017), through the evaluation of schools, that there were some difficulties that students faced when issuing judgments, evaluating arguments and explanations about the tasks and problems they dealt with. This indicates that there is a decrease in the levels of thinking in general and the level of critical thinking in particular, besides a lack of employing information technology adequately. The United Arab Emirates Ministry of Education (2017) emphasizes that the modern world is advanced in terms of technology and science, and consequently this needs the presence of Emirati citizens who are capable of using critical and creative thinking skills to figure out reasonable responses about the scientific investigations they conduct. Thus, those educated persons who own the knowledge to achieve such results will be able to compete worldwide. Accordingly, there is an urgent necessity, in light of the information revolution and the complexities of daily life, to prepare our students to face main communities' challenges such as global warming and pandemic diseases and then to work on solving them in the future (ADEK, 2017; Anagün, 2018; Bernhardt, 2015; Laar et al., 2020). The problem-based learning allows teachers to develop, and students to concentrate on complex real-life problems and then to be the center of the teaching-learning process (Bani-Hamad & Abdullah, 2019a; Guerrero, 2017). One such approach is Fermi problem. It is an estimating problem, designed to teach approximations and specifying assumptions in a clear manner (Barahmeh & Barahmeh, 2017; Barahmeh, Hamad, & Barahmeh, 2017). Love (Love et al., 2015) emphasized that flipped learning techniques can be implemented or integrated with Fermi problem solving as they are able to reorganize the learning process inside and outside the classroom and to focus on high order thinking instead of lower order thinking. Hence, this research aims at investigating the effectiveness of Fermi problem solving with flipped learning techniques in teaching physics on improving Emirati secondary students' Critical Thinking Skills.

Research Questions and Hypotheses

This research attempts to answer the following two questions:

- How effective is Fermi Problem solving with flipped learning techniques in teaching physics on improving Critical Thinking Skills among Emirati secondary students?
- Is there any statistically significant difference in students' mean scores in critical thinking skills test attributed to the gender variable?

Null Hypotheses

H01: There is no statistically significant effectiveness of Fermi problem solving with flipped learning techniques in teaching physics on critical thinking skills among Emirati secondary students.
H02: Gender has no statistically significant influence in the effectiveness of Fermi problem solving with flipped learning techniques in teaching physics on critical thinking skills among Emirati students.

Study Objective

This study seeks to develop a strategy for educators and specialists that shows the effectiveness of Fermi problem solving with flipped learning techniques in teaching physics on improving Emirati secondary students' critical thinking skills, and then to provide some ideas that help teachers incorporate the new strategy into their own teaching practice.

Definition of Terms

Flipped Learning (FL)

Flipped learning is defined as an educational strategy that is student-centered in which students watch short video lectures, power point presentations at home or before coming to classroom. Then the class time is exploited by teachers through creating active and effective educational environment and directing students towards discussing and applying what they learned (FLN, 2014; Ryu, 2016; Schmidt & Ralph, 2016). Also, author of (Miedany, 2019) defined the flipped learning instruction as a relatively new teaching approach attempting to improve student engagement and performance by moving the lecture outside the classroom via technology and moving homework and exercises with concepts inside the classroom via learning activities.

Fermi Problems

Fermi problems are open, non-routine problems, made with very specific information. They are encouraging students to make processes like asking multiple questions, making reasonable assumptions about the problem situation and numerical estimations, guessing relevant quantities before engaging in, identifying variables and formulas that are related to solving the problem, conducting calculations to attain the answer, and eventually making conclusions (Ärlebäck & Albarracín, 2017; Ärlebäck, 2009; Barahmeh et al., 2017).

Critical thinking skill

This skill is defined as the ability to analyze, interpret, evaluate, summarize, explain, self-regulate, infer, reason, reflect, synthesize information, and decide what to believe or do (Facione, 1998; Paul, 1992; Trilling & Fade, 2009; Willingham, 2007). In this study, we adopted the definition of

Watson and Glaser (1980) where critical thinking consists of making inference, recognizing assumptions, making deductions, making interpretations, and evaluating arguments.

Limitations

The current study is carried out with a few constraints. Firstly, the research is conducted during the academic year 2018/2019 in two schools from Abu Dhabi Department of Education and Knowledge (ADEK) in the United Arab Emirates (UAE), and this could be considered as small sample. Secondly, the educational level of students could have affected the results of the study as the investigation was conducted only on tenth grade students. Lastly, the educational content was limited to one unit of physics.

Review Of Literature

Fermi Problem-Based Learning

Problem-based learning (PBL) is a teaching approach to science education that focuses on helping students develops self-directed learning skills (Bani-Hamad & Abdullah, 2019a; Boud & Feletti, 1997). It was originally used in a medical school in 1969 at McMaster University, but has spread to other subjects (Neville & Norman, 2007). It is derived from the idea that education, knowledge and learning is a process in which the learner actively constructs new knowledge on the basis of current knowledge (Bada & Olusegun, 2015).
Fermi problem-based learning (FPBL), which presented to the students in this study, is a form of problem-based learning that is related to Enrico Fermi who used this problem in a slightly different way in lessons with his physics students at the University of Chicago many times over the years (Ärlebäck & Albarracín, 2017; Ärlebäck & Albarracín, 2019; Barahmeh & Barahmeh, 2017). Ärlebäck and Albarracín (2017) defined Fermi problem as an open, non-routine problems that could be solved by quick calculations and reasonable answers based on a few sensible assumptions and estimates. In recent years, a number of studies in mathematics education have focused on the use of Fermi problems in teaching and learning mathematical modeling. Much research on the use of Fermi problem solving in teaching mathematics and science have proven its positive impact on students' understanding and interaction (Ärlebäck & Albarracín, 2017; Barahmeh & Barahmeh, 2017; Barahmeh et al., 2017). Peter-Koop (2004) used Fermi problems to investigate third and fourth graders' problem-solving strategies. At the secondary level, Ärlebäck (2009) has investigated the potential of using Fermi problems, results showed the complexity of the modeling process involved when students at high school level engaged in solving Fermi problems. Unfortunately, a systematic science education research focusing on Fermi problem is sparse or marginalized (Ärlebäck & Albarracín, 2017; Barahmeh & Barahmeh, 2017). Therefore, it is necessary to use an effective model for solving Fermi problems which helps in developing problem-solving skills among students and helps in improving critical thinking skills. Accordingly, the current study adopted the six steps for each Fermi question that were recommended by Riverbend Community Math Centre (Riverbend, 2021) to form a model to be used for solving Fermi problems. More details can be found in Methodology section.
Sriraman and Lesh (2006) have argued that Fermi problems are considered as interdisciplinary tasks which can bridge and connect mathematics and other school subjects such as physics and science. Similarly, Ärlebäck and Albarracín (2017) showed that Fermi problems have been used in physics and engineering college courses in the United States (US). In the same vein, Barahmeh and Barahmeh (2017) revealed that the Fermi problems have been utilized in physics to improve ninth graders' creative thinking skills in Jordan. However, for decades, this type of problems has been part of everyday science teaching in various levels and various forms, but only in recent time it has been subject for more systematic investigation. Hence, the use of Fermi problems in schools and through research is necessary (Ärlebäck & Albarracín, 2017). Fermi problems noticeably help in developing problem-solving skills among students, as well as in developing and improving their estimating skills. Furthermore, making success and getting results, students feel confident, regardless of whether their answer is correct or not. In addition, what is good about Fermi problems is the methodology followed in attaining the answer for these problems, i.e. the solution steps are more important than the answer (Ärlebäck, 2009; Ärlebäck &

Albarracín, 2019; Barahmeh & Barahmeh, 2017; Barahmeh et al., 2017; Kanopka, 2015). The authors of (Albarracín & Gorgorió, 2015) revealed that Fermi problem has positive effect on the students' critical thinking skills. In addition, (Ärlebäck & Albarracín, 2019) found that Fermi problem in the STEM disciplines supported 21st century competencies.

Flipped Learning

Flipped learning is one of modern solutions in developing students' thinking skills as well as in providing a unique mix of two learning theories, were considered incompatible, which are traditional and active learning theories (Bishop & Verleger, 2013; Miedany, 2019). Thus, it is a teaching strategy that includes taking advantage from using technology in the educational process; whereby teachers can spend more time in interacting, dialoguing and discussing with students in the classroom, and where students can see short videos of the lesson at home, and consequently saving a large part of time for content discussions in the class under the teacher's supervision (Barahmeh & Barahmeh, 2017; Roberts, 2004).

Flipped learning can be defined as an educational program aimed at using modern technology and internet in a way that allows teachers to prepare lessons through videos, voice files, or any other media to be seen by students at home or any other place using their computers or smart phones before attending the lesson, while allocating the class time for discussions, projects, problem-solving, and exercises. Videos are an important element in this teaching approach, where the teacher prepares a video of about 5-10 minutes and then shares it with students on a website or social communication sites (Miedany, 2019; Schmidt & Ralph, 2016).

The Flipped Learning Network FLN (2014) defined it as an educational approach that allows shifting from group education to individualistic learning, resulting in increased dynamic and interactivity of educational environment; whereby teachers guide students during the application of the material concepts and encouraging their creative participation. It is also a form of inclusive learning that uses technology outside the classroom by which teacher can spend more time interacting with students instead of lecturing.

Flipped learning relies on the Bloom's Taxonomy where students utilize remembering and understanding at home by video lectures and then employ applying, analyzing, evaluating, and creating in the classroom while they encounter a problem or make a project (Zainuddin & Halili, 2016). Flipped learning technique also reinforces learning by technology outside the study time to achieve maximum student participation and learning during study time in the classroom that is replacing direct teaching through ways of discovering and reviewing teaching materials outside the classroom through videos, readings, or screen shots, etc (Mazur, Brown, & Jacobsen, 2015). Many teachers around the world tried the flipped learning technique in different ways and using different tools in order to teach different subjects for different grades. Applying the flipped classroom teaching methods needs a lot of preparation and technological tools (Baki Mohammed Diab, 2016). Also, several researchers have revealed that Flipped learning promotes effective students' critical thinking skills such as DeRuisseau (2016) and Lee (2018).

Critical Thinking and Real-Problem Solving

Students draw on critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources by identifying and defining authentic problems and significant questions for investigation, planning and managing activities to develop a solution, collecting and analyzing data to identify solutions and make informed decisions, and using multiple processes and diverse perspectives to explore alternative solutions (Albarracín & Gorgorió, 2015; Collins & Halverson, 2009; Songkram et al., 2021).

Facione (1998) acknowledged that critical thinking is linked to problem solving, decision-making, and recognizing assumptions that not enough research has been done to examine. According to Constructivism theory, the meaning is formed when students engage in real world problems (Cobern, 1991). Problem solving is firmly rooted in constructivism (Noel & Liub, 2017). Thus, the International Society for Technology in Education (ISTE) put standards for students, educators, and administrators to rethink education and create innovative learning environments. This framework of standards is helping educators and education leaders reengineer schools and classrooms for digital-age learning (Spires, Paul, & Kerkhoff, 2019). Furthermore, P21 explicitly targets its efforts on the capability of students to reason or justify certain outcomes or thoughts, utilize systematic thinking, and make decisions and judgments in solving problems (Bernhardt, 2015; Choo, 2018; Larson & Miller, 2012) .

Methodology

Participants

The Sample was selected from a population of two Emirati secondary schools which are Remah School for boys and Al Talee'ah School for girls in Abu Dhabi Department of Education and Knowledge under Ministry of Education, United Arab Emirates, and both schools are in the same region and are environmentally similar. In addition, all participants' overall ability and homogeneity were taken into consideration where they all had scores above 70% in academic achievement in physics. The schools contain more than one section of tenth grade, allowing the study the freedom to choose a sample of 40 participants (20 male students and 20 female students), who were intentionally selected. The sample was divided evenly into two groups; the control group were selected randomly consisted of 10 males' students from Remah Secondary School and 10 females' students from AlTalee'ah Secondary School and they were taught the physics unit by an ordinary (traditional) method, and the experimental group consisted of 10 males' students from Remah Secondary School and 10 females' students from AlTalee'ah Secondary School and they were taught the physics unit by Fermi problem solving with flipped learning techniques. Table 1 illustrates the distribution of the sample.

Instrumentation

This study sought to answer the research questions which were related to probable effectiveness of Fermi problem solving with Flipped learning techniques on the developing of critical thinking skills among Emirati secondary students. Hence, this study has prepared a critical thinking skills test based on Appraisal Watson Glaser Critical Thinking Test (Watson & Glaser, 1980) and it was modified to be applicable and appropriate for Emirati students. The modified critical thinking skills test consisted of 50 items (10 items for every sub-skill), which aimed to elicit the critical thinking sub-skills (inference, recognizing assumptions, deduction, interpretation, and evaluating arguments). The reliability of critical thinking test was examined by administering the test to 15 Emirati Secondary Students as a pilot study out of the study sample, which hit a high significant point of 0.89. In addition, the validity of the test was checked by educational science and psychological experts from Abu Dhabi University, United Arab Emirates. The modified critical thinking skills tests were administrated as pre and post-tests. About 50 minutes were allocated for answering the pre-test before intervention, and about 50 minutes for post-test in the class after the participants had finished the intervention.

Procedure

A pre-test was administrated to the participants before the intervention start in order to evaluate their critical thinking skills. The content was modified in the physics unit according to the Fermi problem with flipped learning techniques. After that, the students in the experimental group received the physics lessons through video lectures and PowerPoint presentations via their WhatsApp application and their emails at home, while the control group still used the conventional method. In the classroom the experimental group students started using the suggested Fermi problem solving model as shown in figure 1. In order to solve Fermi problem, this Model starts with asking questions, then making wild guesses, making educated guesses, making variables and formulas to solve Fermi problem, and then gathering extra information, and finally drawing the conclusion. Also, the intervention continued for six weeks. When the intervention was completed, the same modified critical thinking skills test used previously as the pre-test was administered to both groups of students (experimental and control groups) but functioning here as the post-test with 50 minutes to investigate whether their critical thinking skills essentially changed after the intervention or not. Finally, the data was analyzed by SPSS software and more specifically MANCOVA and Two-Way ANCOVA tests to elicit the results.

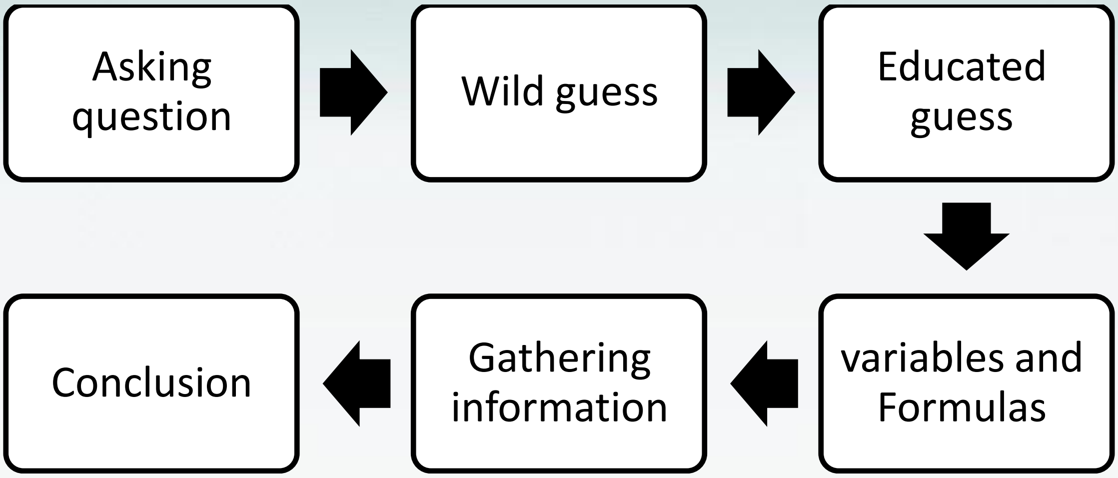

Figure 1. The suggested Fermi problem solving model.

Study design

This study concentrates on investigating the possible effectiveness of Fermi problem solving with flipped learning techniques on improving critical thinking skills for a sample of Emirati secondary students before and after the intervention. Therefore, the viewed design of the study was a quasi-experimental design.

Result and Discussions

Based upon the study questions, which were mentioned previously i.e. How effective is the Fermi Problem solving with flipped learning techniques in teaching physics on improving Emirati' secondary students' Critical Thinking Skills? Is there a statistically significant difference in students' mean scores in critical thinking skills test attributed to the gender variable? In order to answer these questions, the means and standard deviations of the students' scores were computed from the pre and post-tests of critical thinking test for the experimental and control groups as well as the differences in the post test according to the group (experimental, control) and the gender (male, female), see Table 2.
As shown in table 2, there are apparent differences between the means of the experimental and control groups in the pre and post-tests of the critical thinking skills test. To demonstrate the significance of the statistical differences between the means, the Multivariate analysis of covariance test (MANCOVA) was used to determine if there are significant differences in mean scores before and after treatment as illustrated in table 3.
As shown in the table above:

1. There is a statistically significant difference at the level of statistical significance (a = 0.05) in the means at the post inference skill due to the teaching method, where the value of (P) reached (90.655). Through the modified mean shown in Table 2 The sub-skill of the post inference of the experimental group was (4.09) versus (3.21) for the control group, meaning that the experimental group enjoys a better conclusion than the control group, and this shows the effect of using Fermi problem solving with flipped learning techniques in developing critical thinking skills. It is clear from Table (3) that the value of the partial ETA square for the inference skill is (0.496), it is the size of the effect of Fermi problem solving with flipped learning techniques in developing students' critical thinking skills. (49.6%) of the explained variance is explained after the inference, and the rest (unexplained) is attributable to other variables.
2. There is statistically significant difference at the level of statistical significance (a = 0.05) in the means after recognizing assumptions due to the group (teaching method), where the value of (p) reached (75.959). Through the modified means shown in Table 2, The sub-skill of recognizing assumptions of the experimental group was (4.00) compared to (3.20) for the control group, meaning that the experimental group has recognized the assumptions better than the control group, and this shows the effect of using the Fermi problem solving with flipped learning techniques in developing critical thinking skills. It is clear from Table 3 that the

value of the partial ETA square to recognize the assumptions is (0.452), which is the size of the effect of the learning strategy of students, and it explains (45.2%) of the explained variance in the recognition of assumptions sub-skill, and the rest (unexplained) is attributable to other variables.

3. There is statistically significant difference at (a = 0.05) in the means on the deduction sub-skill due to the group, where the value of (P) was (125.757). Through the modified means shown in Table 2, The post deduction sub-skill for the experimental group is (3.85) versus (2.89) for the control group, meaning that the experimental group enjoys a better result than the control group, which shows the effect of the strategy of Fermi problem solving using flipped learning techniques in developing critical thinking skills. It is clear from Table 3 that the value of the partial ETA square for deduction is (0.578), which is the size of the effect of the learning strategy, explains (57.8%) of the explained variance in the deduction sub-skill, and the rest (unexplained) is attributable to other variables.
4. There are statistically significant differences at the (a = 0.05) in the means on the interpretation sub-skill due to the group, where the value of (P) was (143.463). Through the modified means shown in Table 2, The interpretation of the experimental group was (3.65) versus (2.62) for the control group, meaning that the experimental group has a better interpretation skill than the control group, which shows the effect of Fermi problem solving using flipped learning techniques in developing critical thinking skills. It is clear from Table 3 that the value of the partial ETA square for interpretation is (0.609), which is the size of the effect of students' learning strategy, it explains (60.9%) of the explained variance in the interpretation sub-skill, and the rest (unexplained) is attributable to other variables.
5. There is statistically significant differences at the (a = 0.05) in the means of evaluation of arguments post due to the group, where the value of (P) was (159.258). Through the modified means shown in Table 2, The post evaluation of the arguments for the experimental group was (3.46) compared to (2.33) for the control group, meaning that the experimental group enjoys a higher score of evaluating arguments than the control group, and this shows the effect of the strategy of Fermi problems solving using flipped learning techniques in developing critical thinking skills. It is clear from Table 3 that the value of the partial ETA square to evaluate the arguments is (0.634), which is the size of the effect of the students' learning strategy. (63.4%) of the variance explained evaluating the arguments post, and the rest (unexplained) is attributable to other variables.

Two-Way ANCOVA was used for the differences between the scores of the sample individuals on the post critical thinking test as a total, according to the difference in the teaching method and gender variables. The results are demonstrated as shown in Table 4.

As shown in table 4, there are statistically significant differences at (a = 0.05) in the means on the post critical thinking test as total attributed to the group, where the value of (P) was (566.311). Through the modified means shown in Table 2, The post critical thinking test for the experimental group was (19.05) versus (14.23) for the control group, meaning that the experimental group enjoys a better level of critical thinking total compared to the control group, and this shows the effect of using Fermi problem solving with flipped learning techniques in developing critical thinking as a total. It is clear from Table 4 that the value of the partial ETA square for the post critical thinking test as total is (0.855), which is the size of the effect of students' learning strategy and explains (85.5%) of the explained variance in the post critical thinking test as total, and the rest (unexplained) is attributable to other variables.

The study found that students improved their critical thinking skills through Fermi problem solving with flipped learning techniques in teaching physics. The result of this study is aligned with constructivism theory which stressed that the meaning is formed when students engaged in real world problems. In addition, the findings of this study concur with (Albarracín & Gorgorió, 2015), (Barahmeh & Barahmeh, 2017), and (Ärlebäck & Albarracín, 2019) in the positive effect of Fermi problem solving on critical thinking skills and creative thinking. Moreover, this study is aligned with (DeRuisseau (2016)) in the impact of Flipped learning techniques on critical thinking skills.

Based on the second study question: Is there a statistically significant difference in students' mean scores in critical thinking skills test attributed to the gender variable?

The findings in the above tables related to that question showed that there are no statistically significant differences at (a = 0.05) in the means on critical thinking skills test as total and on all sub-skills of the critical thinking test between male and female students.

Conclusion

Preparing students with critical thinking skills is important for university study and future jobs. Also, the need of new teaching methods is becoming necessary in order to help the students acquire critical thinking skills, and reform the educational system in general. Therefore, the objective of the current study was to investigate the effectiveness of a new method based on Fermi problem solving with flipped learning techniques in teaching physics on improving critical thinking skills among Emirati secondary students. To sum up, this study found out that using Fermi problem solving with flipped learning techniques is very useful to empower students in increasing their critical thinking skills. Utilizing technological techniques in teaching is enhancing the teachers' efforts to convey the content easily and create an exciting educational environment. Besides, using Fermi problem solving in the classroom helps students acquire the higher order thinking skills and build their ideas effectively. The hypotheses and study objective were supported by the study findings and proven the effectiveness of Fermi problem solving with flipped learning techniques on developing the secondary students' critical thinking skills. In addition, the study gives the educational experts in The Ministry of Education in UAE the importance of this model on developing the critical thinking skills among students as well as recommends including this model in the teachers' training plan. Moreover, the study recommends expanding using this teaching model with all students and with other subjects in schools and universities in order to help them acquire the important skills that they will surely need in their life and work.

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Tables

Table 1
Distribution of the selected sample

Group	gender	School	N	Total
control	male	Remah School	10	20
(traditional)	female	Al Talee'ah School	10	
experimental	male	Remah School	10	20
(FPS-FLT)	female	Al Talee'ah School	10	
Total		40		

Table 2
Compare groups' measures (mean and standard deviation) before and after treatment of critical thinking skills test.

Critical Thinking Skills	variable		Pretest		Post test		Adjusted means	Standard errors
			Mean	SD	Mean	SD		
	Group	Control	2.76	0.56	3.22	0.55	3.21	
Inference		Treatment	2.98	0.62	4.08	0.53	4.09	0.06
(5 marks)	Gender	Male	2.78	0.64	3.64	0.72	3.67	
		Female	2.96	0.62	3.66	0.66	3.63	0.06
Recognition of	Group	Control	2.60	0.57	3.20	0.54	3.20	
Assumptions		Treatment	2.62	0.57	4.00	0.49	4.00	0.06
(5 marks)	Gender	Male	2.60	0.57	3.56	0.64	3.57	
		Female	2.62	0.57	3.64	0.66	3.63	0.06
	Group	Control	2.50	0.51	2.88	0.48	2.89	
Deduction		Treatment	2.40	0.57	3.86	0.41	3.85	0.60
(5 marks)	Gender	Male	2.48	0.54	3.36	0.66	3.37	
		Female	2.42	0.54	3.38	0.67	3.37	0.06
Interpretations	Group	Control	2.30	0.46	2.62	0.49	2.62	
(5 marks)		Treatment	2.24	0.48	3.64	0.49	3.65	0.06
	Gender	Male	2.26	0.49	3.06	2.86	3.09	
		Female	2.28	0.45	3.20	2.92	3.17	0.06
Evaluation of	Group	Control	2.06	0.59	2.36	0.63	2.33	0.061
Arguments		Treatment	1.82	0.48	3.42	0.50	3.46	
	Gender	Male	1.92	0.60	2.86	0.81	2.87	0.059
(5 marks)		Female	1.96	0.49	2.92	0.75	2.91	
	Group	Control	12.26	2.18	14.28	1.91	14.23	
CTS TOTAL		Treatment	12.08	2.29	19.00	1.90	19.05	0.15
	Gender	Male	12.04	2.294	16.48	3.228	16.59	
(25 marks)		Female	12.30	2.18	16.80	2.85	16.68	0.15

Table 3

The Multivariate analysis of covariance test (MANCOVA), for the performance of the students on the critical thinking skills according to the teaching method and gender

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Inference before	Inference after	1.008	1	1.008	5.949	0.017	0.061
	Recognition of assumptions after	0.513	1	0.513	2.939	0.090	0.031
	Deduction after	0.561	1	0.561	3.616	0.060	0.038
	interpretations after	0.390	1	0.390	2.624	0.109	0.028
	Evaluating of arguments after	0.107	1	0.107	0.646	0.424	0.007
Recognition of Assumptions before	Inference after	0.016	1	0.016	0.093	0.762	0.001
	Recognition of assumptions after	0.174	1	0.174	0.996	0.321	0.011
	Deduction after	0.180	1	0.180	1.158	0.285	0.012
	Interpretations after	0.813	1	0.813	5.469	0.022	0.056
	Evaluating of arguments after	0.238	1	0.238	1.434	0.234	0.015
Deduction before	Inference after	0.544	1	0.544	3.211	0.076	0.034
	Recognition of assumptions after	0.323	1	0.323	1.854	0.177	0.020
	Deduction after	0.003	1	0.003	0.021	0.886	0.000
	Interpretations after	0.004	1	0.004	0.025	0.874	0.000
	Evaluating of arguments after	0.777	1	0.777	4.681	0.033	0.048
Interpretations before	Inference after	0.785	1	0.785	4.635	0.034	0.048
	Recognition of assumptions after	0.562	1	0.562	3.222	0.076	0.034
	Deduction after	0.048	1	0.048	.310	0.579	0.003
	Interpretations after	0.393	1	0.393	2.644	0.107	0.028
	Evaluating of arguments after	0.919	1	0.919	5.533	0.021	0.057
Evaluation of Arguments before	Inference after	0.056	1	0.056	0.333	0.565	0.004
	Recognition of assumptions after	0.015	1	0.015	0.086	0.769	0.001
	Deduction after	0.153	1	0.153	0.983	0.324	0.011
	Interpretations after	0.115	1	0.115	0.771	0.382	0.008
	Evaluating of arguments after	0.545	1	0.545	3.282	0.073	0.034
Group Hotelling= 4.713 f= 82.951 p0.000=	Inference after	15.362	1	15.362	90.655	0.000*	0.496
	Recognition of assumptions after	13.253	1	13.253	75.959	0.000*	0.452
	Deduction after	19.511	1	19.511	125.757	0.000*	0.578
	Interpretations after	21.332	1	21.332	143.463	0.000*	0.609
	Evaluating of arguments after	26.441	1	26.441	159.258	0.000*	0.634
Gender	Inference after	0.007	1	0.007	0.043	0.836	0.000

Hotelling= 0.035 0.618=f 0.686=p	Recognition of assumptions after	0.064	1	0.064	0.367	0.546	0.004
	Deduction after	0.008	1	0.008	0.050	0.824	0.001
	Interpretations after	0.240	1	0.240	1.614	0.207	0.017
	Evaluating of arguments after	0.050	1	0.050	0.300	0.585	0.003
Error	Inference after	15.590	92	0.169			
	Recognition of assumptions after	16.051	92	0.174			
	Deduction after	14.274	92	0.155			
	Interpretations after	13.680	92	0.149			
	Evaluating of arguments after	15.275	92	0.166			
Corrected Total	Inference after	46.750	99				
	Recognition of assumptions after	42.000	99				
	Deduction after	43.310	99				
	Interpretations after	49.310	99				
	Evaluating of arguments after	59.790	99				

* Statistically significant at the level of significance (a = 0.05).

Table 4

The results of the Two-Way ANCOVA test for the performance of the student of the total critical thinking test according to the teaching method (group) and gender

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Critical thinking after	Critical thinking total before	252.033	1	252.033	243.198	0.000	0.717
	Group	586.884	1	586.884	566.311	0.000*	0.855
	Gender	0.444	1	0.444	0.428	0.514	0.004
	Error	99.487	96	1.036			
	Corrected Total	911.040	99				

* Statistically significant at the level of significance (a = 0.05).