THE IMPACT OF BLENDED-FLIPPED LEARNING ON MATHEMATICAL CREATIVE THINKING SKILLS

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ABSTRACT

Due to the outbreak of COVID-19, educational institutions are currently in need of alternative learning methods. The current study discusses the impact of the flipped and blended methods of instruction on students' creative thinking skills in comparison to the traditional instructional method. A quasi-experimental approach was used to assess three capabilities of 10th grade students in mathematics: fluency, flexibility, and originality. The participants, 540 students from private schools, were divided into one control group and two experimental groups. One of the experimental groups followed the blended learning strategy while the other used the flipped learning strategy. Students were given a 30-question test to assess their mathematical creative thinking skills. The scores' mean of the experimental groups was remarkably higher than the control group. Moreover, the performance of the experimental group that followed the flipped learning strategy was better than the group that used the blended strategy. This study informs educational institutions designing and producing educational virtual activities like 3D videos, helps them overcome the traditional classroom limitations, and investigates the role of these methods in enhancing students' mathematical creative thinking skills.

Keywords: *Real World, 3D virtual worlds, creative thinking skills, flipped learning, blended learning*

INTRODUCTION

Digital educational tools are currently playing a pivotal role in providing a better educational environment to study mathematics (Al Sarhan et al., 2013). Thus, a wide range of high-tech teaching strategies are needed to motivate students to learn, attract their attention, and offer them a rich learning experience that inspires their innovative skills. Through applying these strategies, students' abilities to use high-tech tools would improve, which would enhance their learning experience (Piedra Noriega et al., 2019).

Technological advances have affected education in a way that makes it imperative for educational institutions to reconsider which curricula and teaching methods they select in mathematics. Therefore, it is necessary to keep up with the information age and educate students who can deal with computer technologies to cope with rapid changes (Raja & Nagasubramani, 2018).

Elearning is an integrated system that consists of teachers, students, and electronic content. In this system, the student's role does not cease at merely accessing of information. they must also actively contribute, comment, and present their thoughts. The teacher's role is to facilitate such a learning process through providing constant guidance and making sure that the offered material properly meshes with the student's actual level. Thus, teachers have to make sure that the provided content is engaging and stimulates the students to interact with one another, the teachers, and the material itself (Meskhi et al., 2019). In this respect, Murugesan (2019) pinpointed the necessity of designing different approaches that enhance the educational environment. These approaches must deploy up-to-date technologies in curriculum design to enrich the learning experience (Kapur, 2019; Saxena, 2017).

However, the limitations of the elearning environment have been studied by some researchers, like Meskhi et al. (2019), who reported about the shortage of financial support, the different level of technical skills of teachers and students, and the reluctance of using technological tools in the educational process. In addition, many teachers still follow the traditional teaching method, and many students still depend on teachers to learn (Raja & Khan, 2018). Thus, the solution is to design learning strategies that make use of both the traditional teaching method and the interactive elearning method. Hence, blended learning has emerged as a method that utilizes high-tech tools and the traditional classroom methods (Raja & Nagasubramani, 2018).

Although blended learning has several advantages, such as flexibility, reduced material costs, and increased interaction between learners (Dziuban et al., 2018; Singh, 2020), it faces some obstacles in its application. These obstacles include a lack of the components of a blended learning system such as the required technology, an unwillingness to transition from the traditional classroom, a lack of training for teachers in the necessary technical skills, a technological gap between teachers and learners, and a problem with cultural adaptation (Guri-Rosenblit, 2018).

In the past few years, many kinds of blended learning have appeared in spite of the mentioned hindrances. There is the flexible approach (Li et al., 2020), the rotational approach (Wilkes et al., 2020), the improved virtual approach (Fleischmann, 2021), and the selective approach (Uzir et al., 2020). The most widely adopted approach is the rotational one with its four submodels. The flipped learning model is the most important of these submodels, which grew out of constant improvements in blended learning. Despite the fact that flipped learning is an extension of blended learning, its applied procedures make it a distinctive approach (Cabı, 2018).

Flipped learning is a strategy based on the direct interaction between teachers and learners as well as among learners themselves (Akçayır & Akçayır, 2018). In this strategy, teachers design lessons in the form of videos, audio clips, or other multimedia formats, and make them accessible to students anywhere and anytime via the internet (Fielden Burns et al., 2020). To assess the students' understanding of the lesson, teachers allocate time in the class for answering the exercises of the online lessons (Awidi & Paynter, 2019). Teachers categorize the students based on their level of understanding and help those who struggle to get the lesson objectives by making those who do get the objectives actively participate in the learning process (Chang & Hwang, 2018; Zhang & Wang, 2017).

When a person has a high level of attentiveness to insufficiencies, cognitive deficits, errors, and dissimilar facts, then this person is said to have creative thinking skills (Ng & Lee, 2019). This also entails the mental capacity to detect obstacles and to think of the best way to solve them. In order to achieve these best practices, a person hypothesizes a solving technique and tests its effectiveness several times until eventually they reach the best practical solution (Cramond, 2018).

Many studies, like Alzoubi et al., 2016 and Ng & Lee, 2019, have advocated for the impact of creative thinking on learning science and mathematics. Afew studies have discussed using real-life experience and 3D virtual techniques in the mathematics and science learning experience (Palanica et al., 2019).

Chang & Hwang (2018) suggested carrying out more research concerning the use of cutting-edge virtual technologies in teaching mathematics and science. Accordingly, our current study examines the impact of deploying state-of-the-art 3D techniques to stimulate students' creative thinking skills while studying science and mathematics.

The importance of our study is based on changing the status quo of education. Its positive impact on improving creative thinking skills will be of great assistance for teachers of mathematics, as well as supervisors and parents, to have more positive attitudes of blended and virtual learning strategies. In addition, the study sets out for supervisors the general guidelines and best practices for training mathematics teachers on how to plan lessons effectively using blended and virtual techniques.

Modern education is not limited to an emphasis on only problem-solving; it also focuses on solving a problem by utilizing creative methods (Maskur et al., 2020). Creative thinking represents one of the important outcomes of the learning and teaching process (Selvy et al., 2020).

In teaching some subjects online (such as history, religion, geography), teachers assign pages for the students to read from the text book, give them little hints and instructions, and lead them to practice, with almost no effort for the teacher, but in mathematics, teachers need to deliver instruction through an online platform, interact with students at distance, provide feedback, maintain communication and a relationship with the students, and in order to achieve all that, the blended and flipped approaches are essential (Moreno-Guerrero et al., 2020) .

The main question of this study is: Are there any substantial differences at α = 0.05 between the score means of 10th grade female students on a mathematical creative thinking prequiz and postquiz, and can this difference be ascribed to the 3D virtual worlds, the real world, or the traditional method?

LITERATURE REVIEW

Flipped Learning: 3D Virtual Worlds Method

3D virtual worlds (3D VWs) are 3D computer simulations that are categorized into three grades based on the degree of immersion (Chang & Hwang, 2018). This is the degree to which a person recognizes that they are interacting with the virtual environment instead of the real environment, i.e., the level in which a person is conscious of the difference between reality and virtual reality. In our study, the 3D VWs was a three-component teaching technique that utilized the 3D-HUBs software and 3D videos designed to be suitable with the Electromagnetics chapter in the 10th grade mathematics book. The teaching material was the third component where the chapter was redesigned as a step-by-step guide. We deployed the 3D VWs as a teaching method of flipped learning.

Blended Learning: Real-World Problems Method

Achieving the learning outcomes by exposing students to real-world problems while enticing them to center their attention on finding solutions rather than the problem itself is known as Blended Learning (Desai, 2018). However, in our current study, blended learning refers to the exercises utilized with the experimental group.

Previous Studies

Harb (2013) discussed the blended and flipped methods and highlighted the impact of the blended learning strategy. The participants in that study were 60 8th grade students from private schools. The students were divided into a control group and experimental group. An accomplishment exam was used as a tool for collecting data. The results denoted a significant difference at α = 0.05 between the scores mean of the two groups in instant accomplishment, supporting the experimental group.

Alsalhi et al. (2019) looked at the impact of blended learning on secondary students' success and readiness to use the internet in the learning process. An achievement exam and a six-dimensional attitude scale were used to assess students' attitudes toward blended learning. A total of 107 pupils in the 9th grade from a Turkish secondary school took part in the study. The outcomes revealed significant differences at α = 0.05 between the groups.

Al-Qatawneh et al. (2020) investigated the impact of blended learning on students in the secondary stage and their reflections upon it. Such reflections were measured by an accomplishment quiz and a questionnaire. Two vocational schools in Amman participated in the study. The selection process depended on random cluster sampling. One of the schools was the control group, with 22 students, whereas the other school was the experimental group, with 17 students and followed the blended learning strategy. The outcomes revealed that there was no significant difference.

El Omari et al. (2016) designed a training course in teaching science utilizing the blended learning method to improve students' cognitive thinking. The paper included 140 male and female 9th grade students from two UNRWA schools in Palestine, who were separated into four classes. Two classes were experimental, and the other two classes represented the control group. An assessment exam was used to assess the students' cognitive thinking skills. The outcomes stated a significant difference at α = 0.05 linked to the impact of the blended learning training program.

Ümit Yapici and Akbayin (2012) analyzed the impact of blended learning on the enhancement level of secondary stage students in biology.

Table 1. Correlation Coefficient and Cronbach's Alpha of Creative Thinking Skills

Creative Thinking Skill	No. of Questions	Validity		Reliability
		Pearson Correlation	Sig	Cronbach's Alpha
Fluency	10	0.82	0.000*	0.91
Flexibility	10	0.77	0.000*	0.81
Originality	10	0.74	0.000*	0.85
Overall	10	0.78	0.000*	0.86

Fifty-one students were randomly selected from a private secondary school and were divided into two groups: 26 students were in the experimental group, and 25 students were in the control group. An accomplishment quiz and a questionnaire that measured students' reflections upon blended learning were used. The outcomes highlighted a significant difference at α = 0.05 in the scores mean of the accomplishment quiz between the groups on the side of the experimental group. Positive reflections upon blended learning were indicated as well in the study's outcomes.

METHODOLOGY

Research Design

The quantitative approach was followed in the current study. Data collection has been made via testing instrument. The quasi-experimental design was applied to investigate effect of blended learning and flipped learning strategies on acquiring students mathematical creative thinking skills

Participants

The sample of the study was selected using judgmental sampling. It consisted of 540 female students who were divided into three groups: two were experimental and the third was control. Each group had 180 tenth-grade female students. The place in this research is in Private School, Amman, Jordan.

Research Instruments

A mathematical creative thinking quiz was deployed (as a prequiz and postquiz) in the current study as its instrument. This 30-question quiz was structured in a way that measures originality, flexibility, and fluency. Ten experts validated the instrument and their comments were followed to enhance the quiz. Then the instrument was directed to 30 students as a pilot sample. The instrument highlighted a correlation coefficient at 0.78, which indicated a level of validity that permits the instrument's execution. The Half Split method was used to verify the instrument's reliability, which yielded a Cronbach's Alpha Coefficient of 0.86, which pinpoints good reliability. Validity and reliability are shown in Table 1.

DATA ANALYSIS

Examining the impact of the flipped and blended methods (Independent Variables) on students' acquisition of mathematical thinking (Dependent Variable with Three levels), the Kolmogorov-Smirnov Test was deployed to examine the normality distribution, which indicated that the sample is normally distributed with D(540) = 0.083, p = 200.

To detect any differences between the groups, their standard deviations and means of their performance were figured. The MANCOVA test was deployed to check if differences were influenced by any outside variables. To cancel out the influence of any outside variables, standard deviations and adjusted means were scrutinized and least significant difference (LSD) tests were carried out to detect the impact of each teaching method.

FINDINGS

The main question of the current study is: Are there any significant differences at α = 0.05 between the score means of 10th grade female students on a mathematical creative thinking prequiz and postquiz, and can this difference be ascribed to the 3D virtual worlds, the real world, or the traditional method?

As shown in Tables 2–5, the three groups' standard deviations, means, and multivariance analysis (MANCOVA) of their performance were calculated in order to answer this question.

Table 2. The Means and Standard Deviations in the Creative Thinking Quiz According to the Teaching Method

Creative Thinking Skill	Teaching Method	No. of students	Prequiz		Postquiz	
			Mean	S.D.	Mean	S.D.
Fluency	Traditional Method	180	31.50	6.87	37.56	6.61
	Real World	180	34.72	6.03	45.33	7.35
	Virtual Worlds	180	33.89	6.96	48.67	11.14
Flexibility	Traditional Method	180	24.78	8.60	30.00	7.90
	Real World	180	24.61	6.91	37.78	10.14
	Virtual Worlds	180	25.61	7.65	41.44	10.29
Originality	Traditional Method	180	28.72	10.42	36.22	9.15
	Real World	180	30.78	10.21	45.00	13.93
	Virtual Worlds	180	29.56	10.53	47.00	12.41
Total score	Traditional Method	180	85.00	24.28	103.78	21.03
	Real World	180	90.11	20.80	127.80	25.20
	Virtual Worlds	180	89.06	30.48	137.10	30.48

Table 2 indicates that obvious differences between the means of the three groups do exist. The means of the 3D VWs groups and the real-world groups were better than that of the traditional method group. The students of the 3D VWs method accomplished the top mean in the mathematical creative thinking quiz as a whole (137.10) and the quiz parts of originality (29.56), flexibility (25.61), and fluency (33.89).

Table 3 denotes that, according to the teaching method, the F value of fluency was 10.865 with

Table 3. MANCOVA of the Study Groups in the Mathematical Creative Thinking Quiz

Source of Variation	Creative Thinking	Sum of Squares	Df	Mean of Squares	F-value	Sig.	Scheduled Value
Teaching Method	Fluency	663.478	2	331.740	* 10.865	0.000	3.94
	Flexibility	848.651	2	424.280	* 11.219	0.000	
	Originality	774.853	2	387.426	* 5.550	0.007	
	Total	6813.766	2	3406.883	* 16.586	0.000	
Error	Fluency	1465.530	48	30.532			
	Flexibility	1815.205	48	37.817			
	Originality	3350.591	48	69.804			
	Total	9859.633	48	205.400			
Adjusted Total	Fluency	4940.815	53	93.223			
	Flexibility	5843.648	53	110.257			
	Originality	8522.370	53	160.799			
	Total	44768.537	53	844.689			

Table 4. Adjusted Means of the Study Groups in the Mathematical Creative Thinking Quiz

Creative Thinking	Teaching Method	No. of Students	Adjusted Mean	Standard Error
Fluency	Traditional Method	180	39.443	1.347
	Real World	180	43.910	1.348
	Virtual Worlds	180	48.202	1.307
Flexibility	Traditional Method	180	30.944	1.500
	Real World	180	37.192	1.501
	Virtual Worlds	180	40.808	1.455
Originality	Traditional Method	180	37.590	2.037
	Real World	180	43.622	2.039
	Virtual Worlds	180	47.010	1.977
Total Score	Traditional Method	180	107.977	3.455
	Real World	180	124.725	3.497
	Virtual Worlds	180	136.021	3.391

sig. = 0.000. This shows there was a significant difference in the performance of the three groups in fluency on the side of the VWs.

As for the F value of flexibility in the VWs, it was 11.219 with sig. = 0.000. This shows there was a significant difference in the three groups in flexibility on the side of the VWs. Yet, when it comes to originality, the VWs was 5.550 with sig. = 0.007, which shows there was significant difference in the three groups in originality on the side of the VWs.

Thus, the top means of the VWs group were influenced by perplexing variables that required figuring the adjusted standard deviations and means to cancel out the influence of these confusing variables.

Table 4 shows that the adjusted performance means of the group that deployed the VWs were the top in originality (48.202), flexibility (40.808), fluency (47.010), and total score (136.021). The adjusted performance means of the real-world group followed as 43.910, 37.192, 43.622, and 124.725 respectively. However, the lowest adjusted means were for the 2D traditional method control group and were respectively 39.443, 30.944, 37.590, and 107.977.

Table 5. LSD Test for Post Comparisons among the Adjusted Means in the Mathematical Creative Thinking Quiz

Creative Thinking Skill	Teaching Method	Adjusted Mean	Traditional Method		Real Words	
			Mean Diff	Sig	Mean Diff	Sig
Fluency	Traditional Method	39.443				
	Real World	43.910	4.467*	0.028		
	Virtual Worlds	48.202	8.759*	0.000	4.292*	0.027
Flexibility	Traditional Method	30.944				
	Real World	37.192	6.249*	0.006		
	Virtual Worlds	40.808	9.865*	0.000	3.616	0.091
Originality	Traditional Method	37.590				
	Real World	43.622	6.031*	0.048		
	Virtual Worlds	47.010	9.419*	0.002	3.388	0.240
Total score	Traditional Method	107.977				
	Real World	124.725	16.747*	0.002		
	Virtual Worlds	136.021	28.043*	0.000	11.296*	0.025

Traditional Method vs. Real-World Method

Table 5 highlights that there was a significant difference between the group that studied mathematics using the real world and the control group. The difference was 4.467 in fluency at 0.028 on the side of the real world. As for flexibility, the difference was 6.249 at 0.006 on the side of the real world, while the difference was 6.031 at 0.048 concerning originality. In total score, the difference was 16.747 at 0.002 on the side of the real world.

Traditional Method vs. Virtual Worlds Method

Table 5 also shows that the VWs group and the control group had a significant difference. The difference was 8.759 at 0.000 in fluency on the side of the VWs. For flexibility, the difference was 9.865 at 0.000 on the side of the VWs. As for originality, the difference was 9.419 at 0.002 on the side of the VWs. As for the total score of the mathematical creative thinking quiz, the difference was 28.043 at 0.000 on the side of the VWs.

Real-World Method vs. Virtual Worlds Method

There was a substantial difference in fluency between the groups, as seen in Table 5. The difference was 4.292 with sig. = 0.027 on the side of the VWs. As for flexibility, the difference between the groups was 3.616 with sig. = 0.091, which was not significant at $\alpha = 0.05$. The difference between the groups in originality was 3.388 with sig. = 0.240, hence not significant at $\alpha = 0.05$. In the total score, the difference between the groups was 11.296 with sig. = 0.025, which was significant at $\alpha = 0.05$ on the side of the VWs.

DISCUSSION

Analyzing the results of the group that used the VWs, the following sections discuss the impact of virtual worlds on each part of the creative thinking quiz.

Impact on Fluency

Students who used the VWs in blended learning got the top means on fluency questions (Reisoğlu et al., 2017). The method's role of offering simple steps is responsible for such a significant difference. This enhanced the student-teacher interaction and the student-student interaction (Cho et al., 2015). The number of the class activities' responses indicates such an enhanced interaction. Mathematical creative thinking is enriched by real-world exercises, which leads to improved fluency. As a result, students who utilized the traditional method received lower grades than those who employed the real-world method (York, 2019).

Impact on Flexibility

Students who used blended and flipped methods got the top means in flexibility (Zhang et al., 2017). The differences were substantial because they revealed the strategies' merits in increasing students' creative thinking. To solve mathematical problems in blended and flipped methods, students deal with a broad range of exercises that lead them to think differently (Halasa et al., 2020). Unlike the traditional method, which makes students think in a predetermined manner, students acquire thinking flexibility by following the modern learning method. Because such exercises lead to the students being more flexible thinkers as they employ either the flipped learning or the blended learning, there is an absence of differences between the means of these two methods.

Impact on Originality

Students who used blended and flipped methods got the top means on the originality questions. These methods incorporate a wide variety of visionary exercises that require students to think outside the box to achieve more innovative solutions (Leveaux et al., 2019). Students acquire mere abstract information while using the traditional method. The nature of such exercises that concentrate on finding innovative solutions to various problems is responsible for the absence of differences in the means of blended and flipped methods (Lin et al., 2017).

Impact on Mathematical Creative Thinking

In flipped learning, students who utilized VWs exhibited the highest levels of mathematical creative thinking. Its importance stems from the fact that it exemplifies this method's ability to foster a creative learning environment (Burton & Martin, 2017). Because of the method's potential to provide creative learning procedures that include originality, flexibility, and fluency, this is the case (Hu et al., 2016).

CONCLUSION

Based on the research results and discussions, we conclude that blended-flipped learning have a positive impact on acquiring creative thinking skills in mathematics for 10th grade students. Moreover, there was a significant difference in mathematics creative thinking, especially in fluency, between the flipped-learning group and the blended-learning group. Significant differences in originality and flexibility did not exist between the flipped-learning group and the blended-learning group.

RECOMMENDATIONS

We recommend training mathematics teachers on creative thinking skills and increasing the use of flipped and blended learning in mathematics teaching, as well as conducting future studies about the impact of flipped and blended learning on mathematical skills for students in different educational stages.

STUDY LIMITATIONS

The study was confined to female students in 10th grade from a private school in Amman, and it was conducted during the second semester of the academic year 2019/2020. The degree of reliability and validity of the instruments, as well as the degrees of objectivity in the responses provided by the study participants, limit the applicability of the results.

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AUTHORS CONTRIBUTION

The responsibility of the first author is to analyze the data, revise the paper, and make study improvements. The responsibility of the second author was the literature review, referencing and collecting data, and fine-tuning the phrasing of the paper.

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