Implementación de aula invertida en un curso propedéutico de habilidad matemática en bachillerato

Implementation of Flipped Classroom in a propaedeutic course of mathematical skill in high school

http://dx.doi.org/10.32870/Ap.v10n1.1149

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Palabras clave
Aula invertida, educación media superior, TIC, educación matemática

RESUMEN

Presentamos un estudio descriptivo con alcance cuantitativo cuyo objetivo es comprobar la efectividad del método de aula invertida como una estrategia tecnopedagógica para mejorar el rendimiento en la habilidad matemática en estudiantes aspirantes para ingresar al bachillerato. El diseño de esta investigación fue cuasi-experimental y participaron 101 estudiantes en dos grupos (control y experimental). Un pretest fue aplicado a ambos grupos sobre habilidad matemática antes de iniciar la intervención de la estrategia de aula invertida y un postest en ambos grupos al finalizar. El curso se llevó a cabo durante dos semanas con una duración total de 24 horas y 75 minutos. Después de examinar los resultados observados mediante análisis descriptivos y paramétricos no se revelaron diferencias significativas.

Keywords
Flipped classroom, upper secondary education, ICT, mathematics education

ABSTRACT

A descriptive study with quantitative scope was carried out where the objective was to verify the effectiveness of the Flipped Classroom method as a techno pedagogical strategy to improve the performance in mathematical ability in students aspiring to enter high school. The design of this research was quasi experimental in which 101 students participated in two groups (comparison and intervention). A test was applied to both groups on Mathematical Skill before and after the Flipped Classroom intervention. The course was made for two weeks with a total duration of 24 hours and 75 minutes. After examining the results using descriptive and parametric analyzes, it was found that there were no significant differences.

Received: March 29, 2017
Accepted: September 9, 2017
Online Published: March 30, 2018

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INTRODUCTION

As documented in national and international assessments (Organization for Economic Cooperation and Development [OCDE, [Spanish acronym]], 2012, 2016, The Ministry of Public Education [SEP, Spanish acronym], 2013), the results obtained by High School Mexican students in mathematical skills are low percentage wise. As highlighted by the SEP (2014), it is clear that the comprehension of mathematics is essential for the students to develop their generic, disciplinary and professional competences which constitute the profile to graduate from secondary education (EMS, [Spanish acronym]). However, if the students fail to acquire said learning, it can be inferred that they might graduate from EMS without the desirable profile, and since this a cross-curricular competency, it will also cause them learning problems in professional studies,

If we assume that they will pursue some professional career. Given this situation, the National Careers Service proposes a list of cross-curricular competences that every student should master: commitment, responsibility, decision-making, interpersonal communication, flexibility, time management, leadership, creativity and problem solving, teamwork and work under pressure ((Burns, 2016; National Soft Skills Association, 2016).

Low academic achievement in mathematics may stem from certain factors such as the complexity of the contents, study habits, deficiencies in basic competences, the teacher's didactic strategies or techno-pedagogical methods used by teachers, among others. Given the foregoing conditions, it is essential to test the teaching process of this discipline with different teaching methods in order for the students entering or studying high school increase their level of competence in mathematics given the complexity of the contents that have been taught in a traditional manner.

In regard to the latter, there is a diversity of methods, modalities and techno-pedagogical strategies that support the teaching-learning process. Such is the case of the *flipped classroom* model (or inverted teaching), a viable option successfully tested and which empirical evidence are documented (Love *et al*., 2014; Rivero, 2014; Aronson, Arfstrom & Tam, 2013; Bretzmann, 2013; Fitzpatrick, 2012; Flumerfelt & Green, 2013; Fulton, 2013; García-Barrera, 2013; Larsen, 2013; Santiago, 2013; Strayer, 2012).

The flipped classroom method is a techno-pedagogical model that has been experimented since the year 2000 (Lage, Platt & Treglia, 2000); however, it has been popularized by Bergmann and Sams (2012). This method consists in transferring the work of certain learning processes outside the classroom and it is the student who, at home or in an extracurricular space, performs the academic activities; uses the actual classroom time to facilitate and develop other processes aimed at acquiring knowledge and practice. The basic components that make up a flipped classroom are the competences proposed on the topic to be developed by the student; student-centered learning; the student shows higher skills of thought of analysis, synthesis and assessment (Bristol, 2014) and the teacher becomes a guide or tutor.

According to the reasoning set out in the foregoing paragraph, it was essential and feasible to conduct this study with students that graduated from high school who aspired to enroll at an EMS institution incorporated to the Directorate General of Technological and Industrial Education (DGETI, [Spanish acronym]). The participating students enrolled in a propaedeutic course in mathematical skills that, on successful completion, would allow them to enroll at the senior high school level. This allowed us to identify the possibility to implement the flipped classroom method with the purpose of increasing the candidates' learning. Given the documented evidence of low achievement by the international assessment agencies, the question of our research arises: What is the difference in the academic achievement of the students that enrolled in the flipped classroom course and those that enrolled in a traditional classroom?

LITERATURE REVISION

Mathematics comprehension is decisive to develop skills such as logical thought and metacognition since these also allow other processes (Peñalva, 2010).On the one hand, the logical thought contributes substantially to the solution of several problems posed to the human being in his adaptation (Blanco, 2013; Piaget, 1979), as well as it bears a narrow relation with language from a genetic (Vigotsky, 1934), structural (Deaño, 1999; Falguera & Martínez, 1999; Seiffert, 1973) and pathological (Goldstein, 1948) standpoint. On the other hand, metacognition refers to the thought processes and the ability to know them and reflect upon them, i.e., meaningful learning (Alterio & Ruiz, 2010; Ausubel, Novak & Hanesian, 1983; Flavell, 1976).

The issue with mathematics has been studied for decades and different factors have been considered such as anxiety and attitude toward mathematics (Martínez-Artero & Nortes, 2014; Sánchez, Segovia & Miñán, 2011), low achievement (Cueli *et al*., 2014; Carvajal, Mosquera & Artamónova, 2009; Moreira-Mora, 2009; Martínez, 2008; Barbero *et al*., 2007) and failure (Castañeda & Álvarez, 2004). Therefore, it is necessary to look for new alternatives to teach mathematics and, in accordance with current trends, to integrate Information and Communication Technology (ICTs) for better achievement.

Lately, new teaching models that integrate ICTs have been implemented, i.e., models in which, in one way or another, technology intervenes as a support for the teacher and student as well. Some of these models are: *b-learning* or semi onsite learning, *e-learning* or virtual learning, *m-*

learning or mobile electronic learning, *u-learning* or ubiquitous learning and *flipped classroom* or inverted classroom.

With the *e-learning* model, new ways of introducing ICTs started to develop in the teaching-learning process; this is due to the fact that *e-learning*, according to Pascual (2003) and Bartolomé (2008), dealt with a crisis caused mainly by the inadequacy of the formative model and the follow-up or supervision of the student through tutorships; the fact of not taking into consideration the emotional aspect and the erroneous interpretation of the environment in regard to the course standardization since it is taught in different places where the students' cultural and socioeconomic context varies (Islas, 2014); therefore, *b-learning* arises to attend these opportunity areas.

New models have a lot in common with the latter since, according to Bartolomé (2008), it is a way to learn that combines onsite teaching with the use of virtual technology. Along these lines, Islas (2014) mentions that the semi onsite modality offers a combination of resources, technologies, virtual and non virtual learning technologies, onsite and distance learning in different proportions and situations.

The characteristics of the semi-onsite modality have set standards so other models may adapt to specific strategies such as the flipped classroom in which the students have the study material they must revise before class so during class time they may consolidate their knowledge through activities and exercises in the presence of the teacher who will dispel doubts and guide them in solving said exercises.

Likewise, this definition supports Bergmann and Sams (2012)'s theory. These authors have been recognized as pioneers of this methodology since 2006; notwithstanding the fact that this method had been experimented with years ago (Lage *et al*., 2000). Given the results obtained, the flipped classroom has been implemented in the United States and in other countries, including Mexico.

Most of the information on this topic is to be found in the United States given the large number of schools that have used this method. The literature on the cases found mentions that the flipped classroom methodology was applied to groups of low achievement students with favorable results; moreover, it can be applied to any subject. Likewise, different publications give evidence of what this methodology implies and the decision to implement it depends exclusively of the teacher or the institution in question. Furthermore, different studies describe the use of applying this methodology to special groups (Flumerfelt & Green, 2013) or to students of any subject (Gaughan, 2014).

In Mexico, there are sites, forums and blogs that discuss this topic and publish different articles on the results of implementing the flipped classroom. The Instituto Tecnológico y de Estudios Superiores de

Monterrey (ITESM, [Spanish acronym for Monterrey Technological and Higher Education Institute]) and Tecmilenio have been officially using this methodology since 2013 as teaching method for their courses (Santiago, 2013). There are many institutions that have adopted the structure of this model without defining it as such.

GENERAL OBJECTIVE

To prove the efficiency of the flipped classroom method as a techno-pedagogical strategy to improve achievement in mathematical skills in students who aspire studying senior high school.

HYPOTHESIS

H0: The implementation of the techno-pedagogical strategy of the flipped classroom in students that aspire to study senior high school and who are enrolled in the propaedeutic course does **not** increase significantly the academic achievement in mathematical skills.
H1: The implementation of the techno-pedagogical strategy of the flipped classroom in students that aspire to study senior high school enrolled in the propaedeutic course **does** increase significantly the academic achievement in mathematical skills.

METHODOLOGY

We conducted a cross-sectional descriptive-type study with a quantitative approach. The design of the research was almost experimental with test-post-test and intact groups. In regard to participants, the study was carried out at a campus belonging to the DGETI system of Cajeme, a southern municipality in the State of Sonora, Mexico. We opted for a non probabilistic sampling with convenience approach. The students selected had graduated from high school and they were to enroll in senior high school (EMS, Spanish acronym) for the August 2016- January 2017 cycle. We worked with two groups, one experimental of 52 students: 26 (50%) female and 26 (50%) male, with an average of 14.27 years of age; and a control group of 49 students, 26 (53%) female and 23 (47%) male, with an average of 14.76 years of age. Both instruments used were developed *ex professo* and were applied to measure mathematical skills; said instruments were used as pre and post-tests and the opinion on the site that contained the study material.

We considered Kim *et al.* (2014)'s proposal as the design of the method used for the intervention, which focuses on the implementation of the flipped classroom (See Figure 1). In our research, the Department of Education and Culture defined the agenda and the course exercises; hence, we only worked with the design of an online platform to introduce the study considering the proposal aforementioned.

Figure 1. Elements that contribute to a successful learning environment: cognitive presence, social presence, teacher's presence and student's presence (Translation of the proposal shown by Kim *et al*., 2014).

For the intervention and application of instruments, we considered the propaedeutic course of mathematical skills given from August 8 to 18, 2016, to students newly enrolled in the August 2016 – January 2017 cycle of senior high school. Given the foregoing, we requested a permit before the relevant authorities and it was accepted by the Centro de Estudios Tecnológicos Industriales y de Servicios [Technological Industrial Studies and Services Center] number 69; we guaranteed them the seriousness of the study and the confidentiality of the information obtained.

The Intervention Procedure

To carry out the intervention, we worked on the design of a web site through a platform that allowed us sharing files and videos for free. At the bottom of the page, we made known the purpose of the propaedeutic courses and of the flipped classroom; moreover, we provided links where those interested could get more information on this methodology.

After entering the page of the topic chosen, we showed the audiovisual or reading material to be studied; this section contained all the topics and sub-topics of each module (See Table 1); every sub-topic was a hyperlink to videos and recap exercises.

Table 1. Topics and sub-topics of the propaedeutic course

Topics	Sub-topics
1. Numerical Systems	1.1 Classification of real numbers
	1.1.1 Natural numbers
	1.1.2 Integers
	1.1.3 Rational numbers
	1.1.3.1 Common rationales
	1.1.3.2 Proper and improper fractions
	1.1.4 Irrational numbers
	1.1.5 Real numbers
	1.2 Number line
	1.2.1 What is a number line?
	1.2.2 Localization of real number on the number line
	1.2.3 Magnitude relation between real numbers
2. Basic Arithmetic Operations	2.1 Operations with integers
	2.1.1 Additions
	2.1.2 Subtractions
	2.1.3 Multiplication
	2.1.4 Division
	2.1.5 Hierarchy of Operations
	2.2 Irrational numbers
	2.2.1 Prime numbers
	2.2.1.1 Divisibility criteria
	2.2.1.2 Break down of prime factors
	2.2.1.3 Fractions Simplification

	2.2.1.4 Least common multiple
	2.2.1.5 Greatest common divisor
	2.2.2 Operations with rational fractions
	2.2.2.1 Addition of rational fractions
	2.2.2.2 Subtraction of fractions
	2.2.2.3 Mixed Operations of addition and subtraction of fractions
	2.2.2.4 Multiplication of rational numbers
	2.2.2.5 Division of fractional numbers
	2.2.3 Operations with decimals
	2.2.3.1 Addition of decimals
	2.2.3.2 Subtraction of decimals
	2.2.3.3 Multiplication of decimals
	2.2.3.4 Division of decimals
3. Powers and roots	3.1 Powers
	3.1.1 Properties of powers
	3.2 Radicals
	3.2.1 Properties of radicals
	3.2.2 Transformation of fractional powers to radicals and vice versa
	3.2.3 Simplification of radicals
	3.2.4 Addition and subtraction with radicals

Source: Developed by the author.

At the campus, we were allowed two groups which were designed by the person in charge of the Tutorship and Social Work Department. One was the experimental group and the other, the control one. First, we explained to the students that their participation in the study would not affect their admission process and we ensured them to keep the results anonymous. Before starting applying the pretest instrument, we asked the students' authorization to participate by means of an informed consent letter; once the students had accepted, we applied the pretest to both groups (experimental and control groups).

On the following day, we made the URL site address known to the participants where they could consult the study material of the course. We visited the campus computer center and we explained the procedure to access the site and the importance of reviewing the study material before class since the class time would be used to dispel doubts and solve exercises on the topics already studied.

The remaining days were used to work in the classroom with exercises corresponding to each topic according to the course manual provided by the institution. Every day before starting the class, there was a recap with questions on the topics students had seen previously. At the end of the course, we applied the post-test assessment to the two participating groups. We also asked the students of the experimental group to respond to the instrument of opinion survey on the site created for the course.

Since the flipped classroom methodology involves activities that are carried out before, during and outside the class, it was necessary to select the technological resources used in the teaching-learning process. This methodology contributed to change the performance of activities that would normally be done in class, i.e., now, the student is committed to study the material provided on the topics of the course which will be worked on in class. Given the foregoing, it was important that the participants know the strategy and form of work before starting. We searched for the best way to motivate them since their participation was highly valuable to the strategy success.

Lastly, in regard to the data processing, we resorted to the 21 version SPSS statistical program, in which descriptive and parametric analyses were conducted and the t Student test was applied.

ANALYSIS AND DISCUSSION OF RESULTS

After capturing the data in the software mentioned, we obtained the descriptive results of the pretest assessment with the mathematical skills instrument of the experimental and control groups (See Table 2). We do not observe differences between the two groups since the means are very similar, with less than two point difference.

Table 2. Descriptive statistics of the pre-test of the mathematical skill assessment of the experimental and control groups

	Pretest					
Grupos	N	M	SD	Mdn	Mín.	Máx.
Experimental	48	26.01	9.45	24.32	13.51	56.76
Control	43	27.90	10.32	27.02	8.11	54.05
Total	91	26.90	9.86	24.32	8.11	56.76

Source: Developed by the author.

After applying the pre-test on the mathematical skills assessment in both groups, we realized that the mean in the dimension of numerical successions was higher in the experimental groups; the same occurred with the dimension of the application of problems and algebra. The dimensions of sets, arithmetic and algebra had higher means in the control group (See Table 3).

Table 3. Descriptive statistics per dimension in the pre-test of the mathematical skills assessment of the experimental and control groups

Dimensión	Grupo experimental (n=48)					Grupo control (n=43)				
	M	SD	Mdn	Mín.	Máx.	M	SD	Mdn	Mín.	Máx.
Sucesiones numéricas	39.06	19.23	50.00	0.0	75.00	36.62	29.04	25.00	0.0	100
Problemas de aplicación	28.47	15.35	33.33	0.0	66.67	25.58	14.85	22.22	0.0	55.56
Conjuntos	29.16	33.94	0.0	0.0	100	48.83	35.33	50.00	0.0	100

Aritmética	22.65	15.39	25.00	0.0	50.0	28.77	17.99	25.00	0.0	75.0
Geometría	24.70	16.33	21.42	0.0	57.14	30.23	17.93	25.00	0.0	75.0
Álgebra	19.64	17.83	14.28	0.0	85.71	17.05	16.85	16.66	0.0	66.67
Total	26.01	9.45	24.32	13.51	56.76	27.90	10.32	27.02	8.11	54.05

Source: Developed by the author.

In Table 4, once the post-test mathematical skills assessment had been carried out, the results showed a three point difference in the control group.

Table 4. Descriptive statistics in the post-test of the mathematical skills assessment of the experimental and control groups

	Post-test					
Grupos	N	M	SD	Mdn	Mín.	Máx.
Experimental	48	25.45	7.84	24.32	10.81	51.35
Control	43	28.72	9.09	27.02	16.22	59.46
Total	91	26.99	8.57	27.02	10.81	59.46

Fuente: elaboración propia.

According to Table 5, the experimental group obtained a higher score in the dimension of numerical successions with a five point mean difference, while the control group obtained higher means in the other dimensions.

Table 5. Descriptive statistics per dimension in the post-test of the mathematical skills assessment of the experimental and control groups

Dimensión	Grupo experimental (n=48)					Grupo control (n=43)				
	M	SD	Mdn	Mín.	Máx.	M	SD	Mdn	Mín.	Máx.
Sucesiones numéricas	40.10	25.12	50.00	0.0	75.0	34.88	23.86	50.00	0.0	75.0
Problemas de aplicación	26.85	13.52	22.22	0.0	55.56	31.78	15.44	33.33	0.0	55.56
Conjuntos	21.87	32.46	0.0	0.0	100	31.39	34.54	50.00	0.0	100
Aritmética	23.43	12.53	25.00	0.0	50.0	25.87	14.53	25.00	0.0	62.50
Geometría	27.67	18.96	28.57	0.0	71.43	32.89	17.78	28.57	0.0	71.43
Álgebra	16.36	12.84	14.28	0.0	42.86	19.60	16.20	14.28	0.0	85.71
Total	25.45	7.84	24.32	10.81	51.35	28.72	9.09	27.02	16.22	59.46

Fuente: elaboración propia.

To review the difference in means of both the pre-test and post-test, we used the Student t test (See Table 6); no significant differences were registered since the *p* resulting values were .05 higher, to the exception of the set dimension.

Table 6. Comparison of means between the experimental and control groups in the pre-test mathematical skills assessment

Dimensión	Grupo experimental (n=48)			Grupo control (n=43)			Experimental frente a control	
	M	SD	Mdn	M	SD	Mdn	T	p
Sucesiones numéricas	39.06	19.23	50.00	36.62	29.04	25.00	.466	.643
Problemas de aplicación	28.47	15.35	33.33	25.58	14.85	22.22	.910	.365
Conjuntos	29.16	33.94	0.0	48.83	35.33	50.00	-2.707	.008
Aritmética	22.65	15.39	25.00	28.77	17.99	25.00	-1.749	.084
Geometría	24.70	16.33	21.42	30.23	17.93	25.00	-1.539	.127
Álgebra	19.64	17.83	14.28	17.05	16.85	16.66	.709	.480
Total	26.01	9.45	24.32	27.90	10.32	27.02	-.913	.364

Fuente: elaboración propia.

After completing the intervention, we applied the post-test. Even when we noted differences in means, the *p* resulting values indicated no significant differences (See Table 7).

Table 7. Comparison of means between the experimental and control groups in the mathematical skills assessment

Dimensión	Grupo experimental (n=48)			Grupo control (n=43)			Experimental frente a control	
	M	SD	Mdn	M	SD	Mdn	T	p
Sucesiones numéricas	40.10	25.12	50.00	34.88	23.86	50.00	1.013	.314
Problemas de aplicación	26.85	13.52	22.22	31.78	15.44	33.33	-1.624	.108
Conjuntos	21.87	32.46	0.0	31.39	34.54	50.00	-1.355	.179
Aritmética	23.43	12.53	25.00	25.87	14.53	25.00	-.858	.393
Geometría	27.67	18.96	28.57	32.89	17.78	28.57	-1.348	.181
Álgebra	16.36	12.84	14.28	19.60	16.20	14.28	-1.060	.292
Total	25.45	7.84	24.32	28.72	9.09	27.02	-1.843	.069

Fuente: elaboración propia.

Lastly, we requested that the participating students answer the survey on the web site we used as platform to provide the study material. In general, we observed that the students were satisfied with the site. We should point out that they also mentioned needing the teacher's presence to explain the topics: only 29% of the students responded to have understood the topics through the videos presented. Likewise, the fact of seeing the lessons through videos sparked their interest on the topics (See Figure 2).

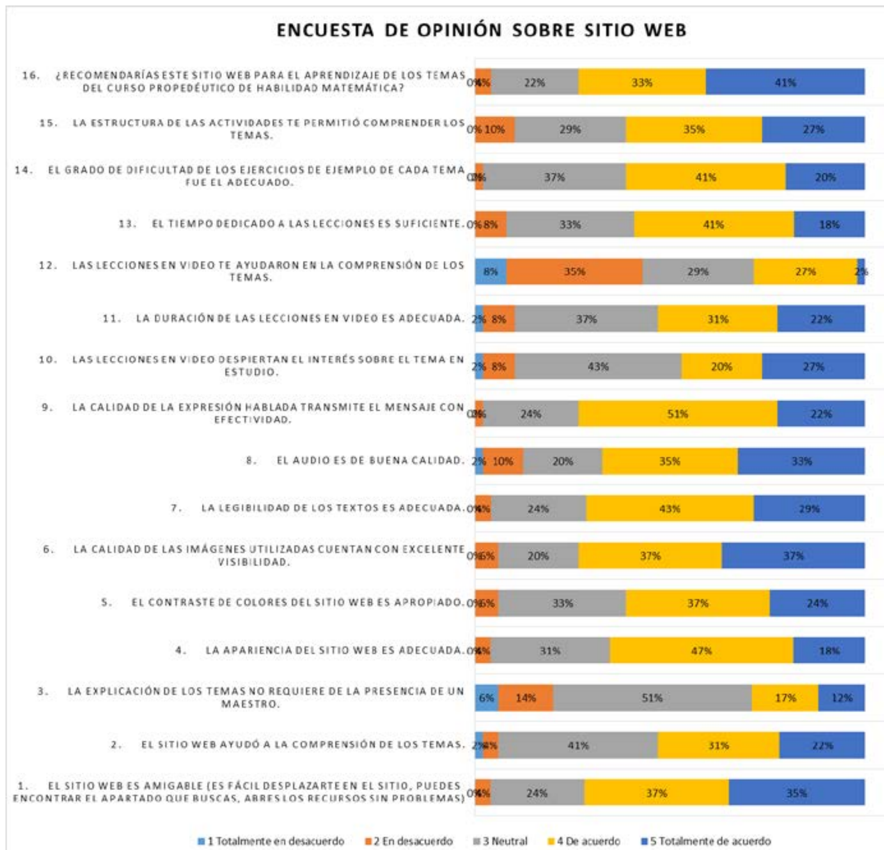

Figure 2. Results of the survey on the opinion about the web site.

DISCUSSION

In regard to mathematical skills, the results of this study did not show any significant differences between the experimental and control groups; this shows the similarity with a research conducted at Harvey Mudd College (Yong, Levy & Lape, 2015), which aimed at examining the impact of the flipped classroom in an introductory course on differential equations. In this research, a group with this methodology was compared to a group with interactive readings; the results showed that there were no significant changes during the first two years in variables such as learning, metacognitive or affective gains between the control and the experimental groups.

In another study on mixed methods (Strayer, 2012), learning environments of a flipped classroom on the Introduction to Statistics was compared to another subject given in a traditional way at the same university. The results showed that the students in the experimental group were less satisfied on how the class structure oriented them to the learning tasks of the course. One of the limitations Strayer (2012) showed was the fact that the teacher had two roles, teacher and researcher, and the way the students were not assigned randomly as it occurred in the implementation of the flipped classroom in our study.

Whillier and Lystad (2015) ‘s contributions point out that the intensive nature of a teaching block, in regard to the duration, poses unique problems for the adequate content delivery. Their study was designed to compare the delivery of an undergraduate neuroanatomy unit in a short summer school period, as a unit traditionally taught but using the flipped classroom; the objective was to assess the efficiency of this methodology in the intensive course classroom. Empirical evidence showed no significant differences between the two cohorts in regard to the final scores ($p = .259$), self-assessed knowledge ($p = .182$) or the general satisfaction with the course ($p = .892$). Given this situation, they inferred that in this study, the flipped classroom did not add any value to the experience. This could be merely because this methodology was not suitable to the intensive work mode even though there is still a lot to study in this regard.

By taking as reference the results of Whillier and Lystad (2015)’s study in comparison with those of our research, the scores were not improved since the means of the general scores only registered a three-point difference. Likewise, by taking into consideration the *p* value of each of the dimensions assessed, numerical successions ($p=.314$), application problems ($p=.108$), sets ($p=.179$), arithmetic ($p=.393$), geometry ($p=.181$) and algebra ($p=.292$), as well as the global result ($p=.069$), we did not find any significant statistical differences.

In another study, a systematic revision of 21 titles and summaries (Betihavas *et al.*, 2016) was made; the authors critically assessed the quality of the studies included. In regard to the latter, in five studies, the topics identified were: the results of academic achievement and the satisfaction of the student by implementing the flipped classroom. However, they point out that the use of this methodology in higher education nursing programs produced neutral or positive academic results and mixed satisfaction results; there was not even one study in this revision that identified the assessment of the implementation process of the flipped classroom methodology.

CONCLUSIONS

The objective of this study was to prove the effectiveness of the flipped classroom method as a techno-pedagogical strategy to improve achievement of mathematical skills in students who aspire to enroll in senior high school. The results we obtained before and after the intervention did not show any significant differences; this may be caused by several factors: lack of motivation, lack of computer or Internet connection equipment, socio-economic situation, little knowledge or skill in managing ICTs, anxiety, attitude and self-sufficiency about mathematics, content complexity, study habits, basic competence deficiencies, teacher's didactic strategies or techno-pedagogical methods used by professors, to mention only a few.

Given the foregoing, we formulate the following recommendations:

- Replicate the flipped classroom methods at other educational levels to continue documenting the field of middle education with technologies.

- Broaden the sample and use a probabilistic sample in order to generalize the results to the population of the university under study.

- Compare the results observed with others similar of institutions that have implemented the flipped classroom method in their curriculum.

- Take advantage of the students' technological competences to develop our techno-educational strategies in our educational centers.

- Make the students aware of the functioning of the flipped classroom, since, in general, students continued to expect that the teacher explain the class in the classroom.

- Train the teaching staff of institutions of obligatory education so they may use new techno-pedagogical methods in the teaching-learning processes.

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