Flipped classroom improves the results in Pathophysiology learning: results of a non-randomized controlled study

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Abstract

Background The flipped classroom has become increasingly popular in health professions education. The aim of this study is to analyze its effect on learning in a Pathophysiology course. **Methods** Flipped classroom was introduced to teach Respiratory Pathophysiology in 2018. The results obtained in the exam were compared with the results of previous year students and with the evolution in Blood Pathophysiology (given by the same teacher, in a traditional way). Comparisons between groups were done with the Student's T test. A survey was administered to the students after finishing the term. Results 201 students were examined in 2018 (and 229 in 2017). Gender distribution and the qualifications obtained in General Pathology were comparable between them. The results in Respiratory Pathophysiology were significantly better in 2018 than in 2017 (mean: 48 versus 42 over 100; $P=0.004$), but the results in Blood Pathophysiology were comparable between both groups. The improvement was significant only in students that obtained scores below the median (mean: 40 versus 33; $P=0.009$) and was more evident in male than in female students (mean: 52 versus 44; $P=0.010$) and in those who had the same age (were not older) than the rest of their classmates (mean 51 versus 44; $P=0.002$). Most students considered that flipped classroom was more attractive and helped them to learn more and with less effort. **Conclusions** Flipped classroom increases medical students' knowledge acquisitions in Pathophysiology. It benefits more to male students and those with lower qualifications who had not an academic delay.

Background

The flipped classroom (FC) is a student-centered pedagogical approach that is becoming increasingly popular in health professions education. It switches the traditional order of learning, that is initiated by a didactic lecture and is followed by a personal study. In the FC model, students receive the didactic material out of the classroom and discuss with their teacher during the formal teaching time. This approach increases active learning (1). It is aimed to help the students to become critical thinkers and to stimulate a deep understanding (2).

Several investigators have studied the potential effect of FC on learning and on students' satisfaction in health professions education. Two recent meta-analysis have reviewed published studies, obtaining different conclusions. Hew and Lo (3) reviewed the experience in health professions concluding that FC improves learning and is preferred by the students. On the other hand, Gillette *et al* (4) concluded that FC was associated with minimal gains in students' knowledge compared to lecture in Pharmacy education. A systematic review of the effectiveness of FC in medical education published in 2017 concluded that students were generally satisfied with the FC approach and FC improved their attitude, but the changes in knowledge and skill revealed mixed results. Some studies revealed positive findings, but others found minimal differences between FC and traditional lecture teaching approach (5).

Thus, the aim of this manuscript is to report our initial experience with FC in the teaching of Pathophysiology to third year medical students.

Conceptual framework

Teaching Pathophysiology in a large group (above 200 learners) is usually based on master classes. As active learning has been shown to improve students' performance (6) we decided to introduce active teaching in form of FC and to test its effects. The results of this method of active learning may depend on different characteristics of the learners. Our main objective is to improve the learning of all the students, mainly of those with worse performance. Thus, we studied the effect according to their gender and their previous academic results.

Materials And Methods

Participants and settings

Participants were third year medical students from the Universidad de Navarra (Pamplona, Spain). Medical curriculum in Universidad de Navarra is divided in six years (three pre-clinical and three clinical years). The curriculum is based on the achievement of competences. They were students from two consecutive years (219 in 2017-18 and 201 in 2018-19) who were enrolled in Pathophysiology course. Pathophysiology is a whole-year course divided in two four-month parts. The first part (September to December) includes cardiovascular, renal, respiratory and blood pathophysiology and the second part (January to April) includes neurological, endocrine and metabolism and liver and gastrointestinal pathophysiology. The faculties of this subject are members of the Department of Internal Medicine. In the first part, one of the staff members (JIH) teaches both Respiratory (RP) and Blood Pathophysiology (BP). At the end of the first part, in December, the students have an exam, and those who pass it with a qualification above 60 out of 100 do not need to be examined of this part in the final exam in May. This exam includes a test with 100 multiple-choice questions (25 of every of the four parts). The final score is obtained after subtracting one third of the number of wrong answers to the number of correct answers.

Intervention

In 2018, a FC method was used to teach RP. Several days before each session, the students received 3-4 videos of 5-7 minutes for each lesson. The videos consisted in the same presentation the teacher gave slides given in the 2017 lectures (that were given as a master class) and an audio that was recorded for 2018 with the slides used in the lectures. The students were allowed to send an e-mail to the teacher asking for a more detailed explanation of the doubtful points. The schema for every 45-50 minutes subsequent session was: 1) a 5-minute review of the lesson explained in the last session through 3-4 multiple-choice questions shown by the app Socrative (www.socrative.com); 2) explanation of the lesson of the day (30 minutes), restricted to the students' questions (sent via e-mail or asked in the classroom) and to the most important / difficult concepts according to the teacher's criterion (20-30 minutes); 3) presentation and discussion of a brief clinical case (5-10 minutes); and 4) review of the lesson through the comment of the multiple-choice questions about it that had been included in the last year exam.

The same teacher explained BP, without using videos. The schema of the sessions was similar, but the explanation of the lesson of the day was given as a master class in a standard fashion. The students had the slides used for the explanation several days before the session. In 2017, the same teacher had explained RP and BP the same lessons, but all both were given as a master class in a standard fashion. The results of this year were used as control.

The staff members of the Department of Internal Medicine were also the teachers of General Pathology (GP) in the second year. This four-month course is an introduction to Pathophysiology and is mostly devoted to the explanation of Etiology and Pathogenesis of disease.

We studied whether the potential improvement in the results with the flipped learning were related with age, gender and previous academic performance, evaluated as the results obtained in General Pathology (above / below the median).

Survey

The students were offered a survey about the FC method. The response to it was voluntary and anonymous. They had six weeks to respond to it, between the end of the sessions and the publication of the results of the December exam, including Christmas holidays. The survey is presented in table 1.

Ethics statement

The study was approved by the School of Medicine of the Universidad de Navarra and by the Ethics Committee for Research of the Universidad de Navarra (project 2018-112). Students were not compensated for their participation in the study. They did not give their informed consent. Data of the students were recorded in a coded database, without personal information.

Statistical analysis

All the statistical analyses were done with the software SPSS version 20. For all tests, a P value below 0.05 was considered as statistically significant. Continuous variables are expressed as mean (standard error of mean) and categorical variables as number (percentage). Comparisons between groups were done with the Chi-square test (categorical variables) and Student's t test for independent series (continuous variables), after checking their normal distribution using the Kolmogorov-Smirnov test and their variance homogeneity with the Levene's test. A P value below 0.05 was considered as statistically significant. In the analysis of factors associated to the improvement of the results after FC, Bonferroni correction was applied; thus, a P value below 0.017 was considered statistically significant for this analysis.

Results

In 2017 and 2018, 229 and 201 students were enrolled in the Pathophysiology course and did the December exam, respectively. They were balanced according to their genders and the results they had obtained in GP (Table 2 1). Most of the students were 20 years old when they started their third year (i.e. born in 1997 in the 2017-18 year), but a proportion of them were older. The proportion of students older than 20 years was higher in 2018 than in 2017.

Comparison of the results in the control and intervention group.

The results obtained in the December exam in RP and BP are shown in table 3 2. There was an improvement in the results in RP, but not in BP. The proportion of students that obtained a score above 60% (the minimum score to pass the December exam) in RP increased from 22% to 29% ($P=0.077$), and decreased from 33% to 31% in BP ($P=0.757$).

Effect of the flipped classroom according to the academic results, and gender and age

With the aim of investigate whether the FC method benefits more to students with better or worse academic level, we divided the classes according to their performance in GP in the previous year (above or below the median). The results in BP did not change in 2018, as compared with the results of 2017. The results in RP after applying the FC significantly improved in students who scored below the median in GP (Table 3 4).

The improvement in the results in RP was significant in male students, but not in female students (Table 4 5). The results of male students in RP in 2018 were significantly better than the results of female students. There were no significant differences in the rest of the comparisons between genders neither in 2017 nor in 2018 (Table 5 6).

The improvement of the results in RP after applying the FC was significant in 20-year-old students but not in older students (table 7). The results in BP and in GP were not significantly different either in younger or in older students. As the proportion of students below the median was higher in the group in older students than in the group of younger students, we did a post-hoc analysis within the group of students below the median. Twenty-year-old students that were below the median obtained better results in RP in 2018 than in 2017 (43.3 (0.9) versus 34.3 (1.9); $P=0.002$), but not in BP or in GP (data not shown). Older students that were below the median did not obtain significantly different results in BP, RP or GP in 2018 as compared with 2017 (data not shown). The maximum improvement in RP results was obtained in male, 20-year-old students who were below the median. Their score improved from 36.8 (2.6) in 2017 to 50.6 (2.9) in 2018 ($P=0.001$).

Students' survey

Twenty students responded to the survey about the FC method (Table 8 6). Eleven (55%) of them said that it contributed to increasing their interest for the course. Fifteen (75%) said that this method helped them to increase their learning. Most students expressed that the method made the topic easier to understand, but some of them disliked it because it was more time-consuming and made it necessary to study every day the lesson of the day. Seventy-five percent of the students wanted to receive more learning with this method, depending on the teacher and the topic.

Discussion

The results of this study confirm other authors' results about the positive effect of FC on medical students' learning, as compared with the traditional teaching (7-13). These results have been obtained in a large group with more than 200 learners. A recent systematic review about this topic reported samples that were much smaller than ours (5). These results have been confirmed in a recently published meta-analysis (3). The FC method of teaching increases active learning (1) and stimulate students to deep understanding (2). Despite all these results, other authors have not found such positive effect on learning (14-16) and a recent meta-analysis in Pharmacy education concluded that flipped classroom is associated with minimal gains in student knowledge compared to lecture (4). This may be due to different methods of flipped teaching used by different authors.

Interestingly, the benefit of FC was not universal. This improvement was found mainly in the students with results that were below the median level of the class. This finding is in agreement with the results of Gross et al. (17). This may be due to a higher availability of learning tools or because FC encourages the students to take a more active role on their learning and prepare their classes day to day instead of studying it just before the exams.

On the other side, older students, most of them below the median, did not improve by applying this active way of learning. We do not think that the different age is the primary reason for this difference, because most of them were just a year older than their classmates. It seems likely that the students with the worst results (those who have lost one year or did not pass the course in the previous year) do not improve with FC. It is also likely that FC is not so useful for the improvement of the best students (those above the median), because they are obtaining good results even with a less active way of learning. Thus, it seems that FC is especially useful for those students with mid-low results.

Another interesting finding is the different improvement according to genders. We have found a significant improvement with flipped learning only in male students. The results contrast with other authors' findings (17), that showed a more evident improvement in female students. In a similar way, female students obtained better academic achievements in a FC undergraduate science course (18) On the other hand, Carrick et al. (16) found that women scored higher than men in a traditional classroom

environment, but the differences disappeared in the online classroom. Differences between genders have also been found with the use of other teaching methods, like the writing of multiple-choice questions by the students (19). On the same way, the preference of teaching materials is different between genders (20). The differences in the results between genders with the FC may be related to the lack of physical interaction between men and women in the online format, as suggested by Carrick et al. (16) or to the exposition of a broader variety of learning tools, as suggested by Gross et al. (17). Recent studies have found that the learning interests of male and female students are different (21,22).

Other potential benefit of flipped teaching is the improvement of students' attitude. Several authors have found an improvement in this field (13,14,23), and the results of our study agree with them. According to the results of the survey, flipped teaching helped our students to be more interested on the topic and to increase their knowledge. The only drawback was that some students perceived that this learning methodology increased their time dedicated to study and forced them to study in a day-to-day rhythm. Other authors have also found that the students need more study time with the FC method (9).

Future studies should investigate whether FC and the different methods of applying it benefit differentially to students with different styles of learning. A recent study conducted in a FC-based undergraduate science course showed that divergers obtained higher academic achievement than convergers, accommodators and assimilators (18) pay attention to learners' adherence to FC protocols and to the long-term effects of FC with regard to knowledge retention and its transfer to professional practice of Medicine (5).

Limitations of the study

In our study, a single learner applied the new method in a single university. It may limit the generalizability of the results. Another limitation is the absence of randomization. The results of the intervention group were compared with the results obtained in a historic cohort of students. The improvement in the results in the topic that was given as FC and the lack of improvement in the topic explained by traditional lectures suggest that this improvement is due to the new methodology. Finally, the low proportion of respondents to our students survey (10%) does not allow obtaining a firm conclusion about the students' satisfaction with this new method, because a non-response bias cannot be excluded.

Conclusions

The use of flipped learning was followed by an improvement in the knowledge. Male students and those with scores below the median seem to benefit more of this learning method, while those who have an academic delay seem to benefit less of flipped learning.

Abbreviations

FC: Flipped classroom

RP: Respiratory Pathophysiology

BP: Blood Pathophysiology

GP: General Pathology

Declarations

Ethics approval and consent to participate

The study was approved by the School of Medicine of the Universidad de Navarra and by the Ethics Committee for Research of the Universidad de Navarra (project 2018-112).

Students were not compensated for their participation in the study. Some of the participants responded to a survey. The response was voluntary and anonymous.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contribution

Design of the study: JIH and JQ

Preparation of the pedagogical materials for flipped classroom and applying them: JIH

Creation of the database: JIH

Statistical analysis: JIH and JQ

Writing of the manuscript: JIH

Approval of the final version of the manuscript: JIH and JQ.

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Tables

Table 1. Survey that was sent to the students about the use of flipped classroom in Respiratory Pathophysiology.

The model of class used for Respiratory Pathophysiology is more enjoyable than the usual master class

- Completely agree
- Agree
- Neither agree nor disagree
- Disagree
- Completely disagree

The model of class used for Respiratory Pathophysiology contributes to the student increase his/her interest by the subject

- Completely agree
- Agree
- Neither agree nor disagree
- Disagree

- Completely disagree

The model of class used for Respiratory Pathophysiology contributes to an increased of learning

- Completely agree
- Agree
- Neither agree nor disagree
- Disagree
- Completely disagree

The model of class used for Respiratory Pathophysiology decreases the effort of learning

- Completely agree
- Agree
- Neither agree nor disagree
- Disagree
- Completely disagree

Would you like to find this model of class in other subject in the future?

- Yes
- Depending of the subject and the teacher
- Don't care
- No

Do you think the flipped classroom model should replace the use of master class?

- Yes
- Yes, but partially
- Don't care
- No

Table 2 1. Basal comparison of both groups of students

	2017 (control)	2018 (flippedintervention**)	P
Age			0.043
20 years	190 (83%)	150 (75%)	
> 20 years	39 (17%)	51 (25%)	
Gender			0.156
Male	73 (32%)	78 (39%)	
Female	156 (68%)	123 (61%)	
Results in General Pathology*	58.9 (0.9)	59.2 (0.9)	0.830

* over 100

**Intervention: Flipped classroom in Respiratory Pathophysiology.

Table 3 2. Comparison of the results obtained in Respiratory and Blood Pathophysiology in the control and in the intervention group*.

	2017 (control)	2018 (flippedintervention**)	P
Blood Pathophysiology	48.8 (1.4)	47.9 (1.4)	0.649
Respiratory Pathophysiology	42.1 (1.4)	48 (1.5)	0.004

*over 100

**Intervention: Flipped classroom in Respiratory Pathophysiology.

Table 4 3. Evaluation of the impact of flipped classroom in Respiratory Pathophysiology teaching in students above and below the median in General Pathology*.

	2017 (control)	2018 (flippedintervention**)	P
Blood Pathophysiology			
Below median			
Above median	39.4 (1.8)	38.2 (2.0)	0.647
	59.5 (1.8)	58.1 (1.8)	0.573
Respiratory Pathophysiology			
Below median			
Above median	32.9 (1.7)	39.8 (1.9)	0.009
	53.5 (1.9)	57.2 (2.2)	0.200

*over 100. Median score in General Pathology was 59 in 2017 and 60 in 2018.

**Intervention: Flipped classroom in Respiratory Pathophysiology.

Table 5 4. Evaluation of the impact of flipped classroom in the teaching of Respiratory Pathophysiology according to gender*.

	2017 (control)	2018 (flippedintervention**)	P
Blood Pathophysiology			
Male			
Female	52.0 (2.3)	48.7 (2.1)	0.301
	47.4 (1.7)	47.5 (1.9)	0.981
Respiratory Pathophysiology			
Male			
Female	44.1 (2.4)	52.5 (2.1)	0.010
	41.1 (1.7)	45.2 (2.0)	0.125

*over 100

**Intervention: Flipped classroom in Respiratory Pathophysiology.

Table 6 5. Comparison in the academic results between male and female students.*

	Male	Female	P
2017 (control)			
General Pathology	58.3 (1.7)	59.2 (1.0)	0.638
Blood	52.0 (2.3)	47.4 (1.7)	0.131
Respiratory	44.1 (2.4)	41.1 (1.7)	0.324
2018 (intervention**)			
General Pathology			
Blood	59.9 (1.5)	58.7 (1.2)	0.534
Respiratory	48.7 (2.1)	47.5 (1.9)	0.670
	52.5 (2.1)	45.1 (2.0)	0.014

*over 100

**Intervention: Flipped classroom in Respiratory Pathophysiology.

Table 7. Evolution of the academic results* between 20-year-old and older students after applying the flipped classroom method in Respiratory Pathophysiology in 2018.

	2017 (control)	2018 (intervention**)	P
20-year-old			
General Pathology	60.0 (0.9)	60.6 (1.0)	0.665
Blood Pathophysiology	50.2 (1.6)	49.8 (1.6)	0.888
Respiratory Pathophysiology	44.1 (1.5)	51.1 (1.6)	0.002
Older students			
General Pathology	52.6 (2.6)	53.5 (2.4)	0.789
Blood Pathophysiology	42.5 (3.0)	42.4 (2.7)	0.973
Respiratory Pathophysiology	32.5 (3.1)	38.9 (2.9)	0.142

*over 100

**Intervention: Flipped classroom in Respiratory Pathophysiology.

Table 8 6. Results of the survey about the flipped learning (20 respondents).

	Agree	Neither agree nor disagree	Disagree
Flipped method is more enjoyable	12 (60%)	7 (35%)	1 (5%)
Flipped method increases interest	11 (55%)	7 (35%)	2 (10%)
Flipped method increases learning	15 (75%)	5 (25%)	0 (0%)
Flipped method decreases the effort of learning	14 (70%)	4 (20%)	2 (10%)
Flipped method should substitute lectures (partially or totally)	15 (75%)	0 (0%)	5 (25%)