

Flipped Classroom Method of Teaching about Pharmacokinetics: On Learning, Performance, and Student Satisfaction

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Abstract:

Flipped classroom became more and more widely used teaching strategy in countries all over the world, and pharmacy is not an exception. But it is rather debatable in regard to content-intensive courses like pharmacokinetics. This was a research study investigating the effect of the concept of flipped classroom to the academic results and satisfaction of Brazilian and German students who completed the third year of pharmacy school. Recorded lectures were supplied to the participants, and they were also involved into the in-class problem solving activities, which enabled active learning and practice of the pharmacokinetic concepts. The average scores proving an increase of 18.6 percent after exams of the intervention group compared to the previous year cohort who attended the traditional lectures ($p < 0.01$) were demonstrated. Moreover, an 84 percent of students indicated greater engagement and comprehending of materials. Findings have indicated that the flipped model has a substantial beneficial impact on the learning outcome of studying pharmacokinetics and leads to an in-depth understanding of hard quantitative information. The results contribute to accepting the flipped classroom method as an effective teaching method in pharmacy curricula, especially in difficult topics.

Keywords: *Flipped classroom, pharmacokinetics, pharmacy education, engage students, instructional design, learning outcome.*

1. Introduction

1.1 Pharmacokinetics Pharmacokinetics in Pharmacy education- An Overview

Pharmacokinetics (PK) is a core course in pharmacy education that concentrates on the absorption, distribution, metabolism and excretion (ADME) of drugs. It plays a vital role in the knowledge ability of how the medications interact in the body and to make sound decisions with regards to drug dosing and taking care of patients. PK concepts are quantitative and they need student to know mathematical models and equations that explain the behavior of drugs.

This is because PK information is multifaceted and thus in most pharmacy schools, this topic is taught using lecture-based methods. Nevertheless, to be able to understand PK fully, it is necessary not only to know some theory but also to possess problem-solving skills that may help one apply concepts to the real-life situation. The role of teaching pharmacokinetics, therefore, cannot be over emphasized when it comes to preparing pharmacy students so that they are able to handle drug treatments safely and efficiently in the clinical practice set-up.(1)

1.2 Weaknesses of Traditional Lecture-based Instruction

Lecture-based teaching remains the most popular form of teaching pharmacokinetics in a variety of pharmacy programs. Although lectures offer an organized means of delivering the main concepts, this approach cannot be used to deliver the information completely:

Passive Learning: In the traditional lectures, often passive learning takes place wherein the students are not able to interact with complex content. This form is not as interactive, which may provoke the lack of retention and even superficial knowledge of the topic.

Restricted practice on Problem-Solving: The pharmacokinetics is a practice that entails mathematical representation in order to forecast drug amounts and effect. It is plausible that lectures are not enough to allow students to develop good thinking skills, problem-solving, or transferring knowledge to clinical cases.

One-Size-Fits-All Approach: Conventional lectures do not always cater to various types of learning needs of students and, therefore, some students are left out, because of varied learning speeds and preferred modes of learning.

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This has seen more and more emphasis on alternative teaching modes which can complement or supplement traditional lectures, especially in courses involving a lot of content such as pharmacokinetics.

1.3 Reason to employ Flipped Classroom models

The flipped classroom model can provide an alternative solution to the shortcomings of traditional learning namely invert the traditional learning. Rather than the hundreds and thousands of students listening to the lecture and being the recipients of the knowledge given to them, the flipped classroom is the possibility to:

Active Learning: Active learning is a concept in which students do preparations of course content or study before the class. This would afford us time during the lectures to engage in active learning; problem-solving, case studies, or debates, among others, where learners practice what they have been taught.(2)

Peer-to-Peer Chatting: In flipped classrooms there is always a likelihood of collaboration and learning among peers. Group activities/exercises provide a beneficial way of learning because students learn together how to solve problems, difficult concepts are discussed and understanding is improved.

Individualized Learning: Recording asynchronous sessions enable the students to go back to complex instruction as many times as they require; thus, enabling a much more individualized instruction through personalized learning. This may result in improved understanding, particularly pertaining to such elaborate topics as pharmacokinetics.

Studies found that flipped classrooms have the potential to enhance engagement with students, motivation, and knowledge retention, which makes it an attractive model to be applied in pharmacy education especially those courses that require quantitative thinking and problem-solving skills such as pharmacokinetics.

1.4 Objectives and context of study

The main idea of the present study is to assess the effect of flipped classroom model on academic achievement and students satisfaction with learning pharmacokinetics in third-year Brazilian and German students pursuing pharmacy. In particular, the research is going to:

The effectiveness of the flipped classroom in the degree of exam performance gain and skill of using the pharmacokinetic principles to real-life situations should be evaluated.

Assess how students felt about the flipped classroom model, how engaged they were, how confident, and what they felt their comprehension of the course was.

Compare the learning outcome of students who accessed the flipped classroom model and students attending the prior cohort who are used to learning via lecture-based lectures.

The implementation of the study in two various cultural and educational settings, i.e. Brazil and Germany allow evaluating the generalizability of the flipped classroom model to pharmacy curricula as diverse as possible. Self-evaluation of the outcomes of the two settings gives the study insightful information with regard to the future prospect of scalability and adjustment of the flipped classroom model of global pharmacy education.

2. Design and sample population of the study

2.1 Type of study: educational intervention with pre/post assessment

The study was set to be an educational intervention where the effects of the flipped classroom model on the learning outcome and student satisfaction in pharmacokinetics education are evaluated. The experiment employed a pre/post design of the evaluation where some academical accomplishment and engagement was measured in students before and after their exposition to the flipped classroom model. The baseline assessments and same after a teaching period of 6 weeks applying the flipped classroom technique were undertaken as the pre-intervention and post-intervention stages respectively.

The main aspects of the work were

Pre-intervention Evaluation: The evaluation method used to determine the prior learning of pharmacokinetics included a diagnostic quiz, self-efficacy scales, and pre-intervention engagement survey.

Flipped Classroom Intervention: The 6 weeks saw the students take part in pre-recorded lectures and the subsequent classroom active learning that involved solving problems, conference cases and peer teaching discussions.(3)

Post-intervention Assessment: The post-intervention assessment was used to determine the variation in examination scores, self-efficacy (confidence in pharmacokinetics), and student satisfaction with flipped classroom.

This study design has been selected because it would make it easier to determine the level of student achievement and their involvement in the course in the pre- and post-intervention periods, and, thus, would enable us to evaluate how effective the flipped classroom can be in advancing the learning experience in a content- and quantitative-based course such as pharmacokinetics.

2.2 Demographics Participants Third-Year Pharmacy Students in Brazil and Germany

The number of participants in the study was 120 third-year pharmacy students recruited in two Brazilian and German schools of pharmacy. The students selected were enrolled in the course of advanced pharmacokinetics which is one of the main courses in the curriculum of studying pharmacy.

Brazilian Cohort: There were 60 students at a pharmacy school in Brazil. The group consisted of students who had different experience in pharmacokinetics because the course has been offered in the third year of study.

German Cohort: A group of 60 students of a German pharmacy school were also considered, the backgrounds and previous exposure to basic pharmacology and pharmaceutical sciences being similar.(4)

Inclusion Criteria:

- It was taken at the third year course on pharmacokinetics.
- The desire to take part in pre- and post-intervention evaluation.

Exclusion Criteria:

- Students with or only little prior experience with or training in the flipped classroom model.
- Students who were not able to attend more than 80 percent of flipped classroom sessions.

The participants of both cohorts were randomly divided into the flipped classroom intervention and lecture (the control group). The randomness was provided so that to avoid the biases but equally have the equal groups in reference to the past performance and involvement concerning the academics. The traditional lecture-based teaching was still applied to the students in the control group, whereas the intervention group was provided with the alternative namely the flipped classroom activities.

2.3 Curriculum and Group Assignment

Pharmacokinetics training in both Brazil and Germany bore a noticeably similar structure in terms of curriculum: Week 1-2: Presentation of the foundational principles of pharmacokinetics (e.g. drug absorption, drug half-life and drug bioavailability).

Week 3-4: Topics regarding drug distribution, metabolism and excretion and mathematical modeling.

Week 5-6: Special topics in compartmental models, drug clearance and dosing schemes.

In flipped classroom group, learners had to:

Prior to a lesson, watch video lectures on the issues in pharmacokinetics.

Participated in interactive learning classes that involved problem and solution tasks, cases discussion, and quizzes headed by course facilitators.

The traditional lecture group used the classical lecture based model and in this model the students had access to in-class lectures washed down with optional materials/readings and problem solving classes.

Co-horts received identical learning materials (sequences of online lectures and lecture slides, readings and practice problems) and assessment materials were common between them, so as to provide equality of assessment.

3. Instructional Intervention

3.1 Flipped Classroom Methodology description

The flipped classroom model is a new programmed to direct the traditional school system through introducing a front-to-back delivery of education by introducing involved learning processes, like comprehending notions and application of their concepts during education time. Through this model, the intention is to draw the students into engagement through student self-learning and ensuring a more substantive interaction level when the face-to-face classroom time is present.(5)

The flipped classroom design in this paper was used in the pharmacokinetics course to enable the students understand the complicated and quantitative subject material better. This strategy was composed of some major elements:

Pre-Class Preparation: The students were provided with pre-recorded Lectures Video materials at their disposal, which embraced key concepts of pharmacokinetics. The video lectures were structured in such a manner that their

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contents were brief and to the point enabling the students to take the theoretical material at their preferred pace, and refer to any content that is perplexing to them.

In-Class Application: The set hours were devoted to in-class activities as students were involved in problem solving activities, case study and interactive discussions. These activities were facilitated by the instructors and the teaching assistants who would present the students with difficult puzzles and assist them to use the knowledge that they had obtained during the lectures to solve problems based on the real clinical cases.

With this kind of approach, students learned to become active learners and utilize their knowledge right now in the context of a team-based and problem-based learning setting. It also offered a chance of peer learning/correction, as now the students could learn how to think and act in specific situations based on other students.(6)

3.2 Parts: Pre-recorded Lectures and In-class activities

Pre-recorded Lectures:

The pre-class aspect included recorded video lectures which could only be viewed by the student using the online learning course platform. The videos discussed such key principles of pharmacokinetics as:

- **Drug Absorption:** The mechanisms and the variable which contributes to the absorption of drugs in the bloodstream.
- **Drug Distribution:** The spread of drugs all over the body and determination of the factors which influence it like volume of distribution.
- **Metabolism and Excretion:** The drug metabolism (and hepatic drug metabolism), and drug elimination (and renal drug excretion).
- **Mathematical Modeling:** Mathematical modeling explained; Including the first order kinetics, and the compartmental models.
- **Dosing Regimens:** The knowledge of making and altering dosing regimens in light of patient specific variables.

The video lessons were also not focused on tedious details, the length of videos ranged around 15-20 minutes to not overload the students. Interactive quizzes and summary slides presented in every video allowed to make sure that students actively processed the materials rather than thinking only about more advanced applications.

In-Class Activities:

Activities conducted during classes were aimed at active learning and problem-solving within an active group. Such activities were:

- **Problem-Solving Exercises:** The students were asked to solve quantitative pharmacokinetics problems, including drug half-life and dosing schedule calculations or using the formula of drug concentrations at certain time points, learned in the videos.
- **Case Studies:** The students were provided with practical clinical cases of pharmacokinetic concepts including adjustment of drug doses to a patient who has suffered renal failure or to a patient who is elderly and has other comorbidities. Through these case studies, the students were also advised to be critically creative on the application of theoretical knowledge to the practical encounters.
- **Group Discussions:** The students were divided into small groups so as to discuss the case studies and solve the problems together. Such form encouraged peer response and assisted in further cementing comprehension as a result of group-thinking and discussion.
- **Interactive Quizzes:** Students also participated in interactive quizzes during the course that followed the classroom to determine their mastering of the concepts on pharmacokinetics and application of the same. Appropriate comments, clarifications, and clarifications to the misunderstandings were also given immediately.(7)

3.3 Topics in the Curriculum that had been Covered during the Intervention

Within the six weeks of classes, the flipped classroom strategy taught vital subjects in pharmacokinetics. The areas of curriculum were:

1. **Week 1: An Introduction into Pharmacokinetics**
 - It gives an overview of the concepts of pharmacokinetics: ADME (absorption, distribution, metabolism, excretion).
 - The significance of pharmacokinetics in pharmacy activity.
2. **Week 2: Absorption of drugs**

- Variables that affect the intake of drugs.
 - First-pass effect and bioavailability.
3. Week 3: Distribution of drugs
 - Volume of distribution and distribution factors.
 - Protein binding in plasma, and permeation to tissues.
 4. Week 4: Metabolism and excretion
 - Hepatic metabolism, phase I and II reaction.
 - Clearance and excretion rates on the kidneys.
 5. Week 5: Pharmacokinetics of Mathematical Models
 - Half life and first order kinetics.
 - One-compartment and multi-compartment model.
 6. Week 6: The clinics use of pharmacokinetics
 - Individual dosing regimens to fit the information on pharmacokinetics.
 - Case studies of the clinical practice with drugs and interventions, as well as individual rearrangements.

The topics were arranged in a progressive way where the one week depended on the previous one, reviewed the essential points, and increased the level of the problems, which the students were supposed to solve.

4. Evaluation and Assessment techniques

4.1 Pre /Post Exam Comparison Framework

To promote the efficiency of the flipped classroom model, a pre/post exam comparison scheme was adopted to determine the enhancement in academic performance in pharmacokinetics post and before interventions.

Pre-Intervention Exam:

An assessment of their pre-intervention knowledge and understanding of the main concepts about pharmacokinetics was conducted by administering a pre-intervention exam before the intervention. The examination contained both multiple-choice questions (MCQs), problem and short answer questions that covered content related to areas of drug absorption, distribution, metabolism, excretion, and mathematical models of pharmacokinetics. The pre-exam was meant to create a base line value of the student knowledge, and also to make sure that all the students had an equal starting point in their knowledge.(8)

Post-Intervention Exam:

In order to assess how they performed on their medication, students were administered a post-intervention examination following the completion of the 6 weeks of flipped classroom intervention that were modeled similarly to the format of the pre-exam with additional higher-level applications of the concepts of pharmacokinetics. This involved more sophisticated calculations and clinical case-based scenario, which examined the competence of the students to apply the concept of pharmacokinetics in real life.

Pre- and postexam results were compared to establish the improvement among the students in terms of academics. The increase in test scores was the major sign of effectiveness of the flipped classroom ability to improve the results of learning.

In order to find out that any difference observed between post and pre-exam scores was statistically significant, a paired t-test comparing the post and pre-exam vulnerable groups was done. P-value of less than 0.05 was taken to be significant to assess the effectiveness of the intervention.

4.2 Satisfaction survey Items among the pupils

In the assessment procedure of student level of satisfaction toward the flipped classroom model, student satisfaction survey was used at the conclusion of the intervention. The present survey was conducted to obtain the attitudes of the pupils towards the role of the flipped classroom in their perceptions of the process of learning, as well as their general satisfaction with the model of instruction.

The survey was based on the quantitative and qualitative elements:

Quantitative Questions: The student was asked to weigh statements on a 5-item likert scale with the answers 1 being strongly agree; 5 being strongly disagree. Statements included:

I liked the flipped classroom as it assisted me in comprehending pharmacokinetics

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The recorded lectures assisted me to be ready with the classroom work.

I was more involved in the flipped classroom than in lectures.

The solving activities assisted me to relate pharmacokinetic concepts to problem solving in the real world.

Qualitative Questions: It was also requested to give a feedback by the students:

What they liked most in flipped classroom model.

The flow to be better in the course or to the teaching method.

Any learning difficulties they encountered in the case of the flipped classroom.

This survey was used to enable the research to evaluate the overall satisfaction, engagement and perceived benefits of learning within the flipped classroom model.

4.3 Tracking Metrics of Engagement and Participation

To measure participation and engagement of students during the implementation of the intervention a number of tracking measures were applied:

Attendance in Classroom: It was counted how many classes every student attended. Engagement in solving problems during lectures was invited and initial attendance was considered as first associated indicator of engagement.⁽⁹⁾

Engagement in Problem-Solving Activities: The engagement of students in group activities and the activities that students contribute to discussions were checked every session. Active input was determined by the frequency of contribution a student would make in the solving problems or raising questions in the interactive discussions.

Video engagement: The number of views, completion rates, and the average time spend on each of the videos was monitored through the learning management system (LMS) that its student engagement levels with the recorded video lectures. It enabled the research team to determine whether the students were ready before joining the classes and whether the students were involved with the content in their individual levels.

Interactive Quizzes: Within each session of problem solving, there was an interactive quiz that formed a part of the classroom work. Their performance and participation in such quizzes was another indicator of the engagement of the students. The students who have several well-performed quizzes were probably more interested in the course and were not ignored in terms of their involvement in considering the effectiveness of the flipped classroom strategy.

Feedback and Reflection: They were to submit a brief reflection at the end of every session and rate their comprehension of what had been taught in the session. Such thoughts assisted in determining to what degree the learners could synthesize the matter, maintain a level of involvement, and the general learning experience.

5. Data Analysis

5.1 Statistical Techniques of Comparison or Survey of the Exam Scores

The use of data analysis on the exam scores employed the main method of comparing the post and pre exam scores to determine how effective the flipped classroom method was in enhancing the grade of students. The descriptive and inferential statistics were applied to the analysis.

Descriptive Statistics:

The pre and post-intervention exam scores were summarized and given an overview with the help of descriptive statistics. This involved computation of:

Measures of pre and post exam average.

To measure the variation in student performance standard deviations (SD) would be used.

Means of scores to test the dispersion of the results of students.

These statistics gave insight on the central tendency as well as variability on the performance on exams in the two groups prior and after intervention.

Paired t-test:

To understand whether students demonstrated significant improvements in the learning outcomes, owing to the flipped classroom model, a paired t-test was applied to compare the marks in the pre- and post-intervention examinations by the same group of students. The choice of a test consisted in the fact that this test compares the means of two correlated groups (pre- and post-intervention) to determine whether the intervention caused statistically significant changes in performance.

H 0 is No significant difference between pre- intervention and post-intervention score.

Alternative Hypothesis (H 1): The difference between the scores pre-intervention and scores after the intervention is significant.(10)

The value observed in the p-value was significant and less than 0.05. This comparison helped the researchers find out whether the flipped classroom technique paid off to show a considerable effect on the exams grades.

Independent t-test:

But besides paired t-test, there was also an independent t-test designed to allow the calculation of the results on the post-intervention exam scores of the Brazilian cohort and the German cohort. The aim of this test consisted in identifying a possible (or not) significant difference in response to the effectiveness of the flipped classroom in various cultural contexts, as well as differences in the education systems.

5.2 Interpretation of the responses to the student feedback

In reviewing student feedback, analysis aimed at determining the level of student satisfaction as well as determining the major themes of the qualitative answers to the student satisfaction survey. There were two approaches to be applied:

Quantitative Analysis:

The student satisfaction survey in the form of Likert scale was analysed through using the descriptive statistics to provide a method which would be used to summarize the students rating towards various aspects of the flipped classroom experience. For example:

The average score of questions which pertain to the usefulness of pre-recorded lectures.(11)

The standard measurement of ratings to comprehend variations in responses by the students.

Count of frequencies and percentages categorical answers including the percentage of students who agreed with such statements as I feel more confident in my pharmacokinetics knowledge after the flipped classroom or The flipped classroom made learning pharmacokinetics interesting.

These indicators gave clear insights of how the entire students were satisfied with the type of learning structure, the flipped classroom approach, and their involvement in the learning process.

Qualitative Feedback {'red:cesUV bighave skygewastesig• replacement mapping watt [10 % 67 %] cvg

In the survey and reflection forms, responses were open-ended where qualitative thematic analysis was carried out. It was done in the following manner:

Coding: The determination of the central words and ideas associated with the student experiences including confidence enhancement, dis-anxiety, and an interest in learning activities.

Theme Development: this step involves putting same codes together to make up themes. As an example, the statements related to feeling comfortable when interacting with peers and the ability to participate actively were placed in the theme that is student-centered learning.

Pattern Identification: Is what common themes are revealed across as part of the student cohort, like positive effects of peer feedback or having flexibility learning within the comfort of one according to his/her pace.

5.3 Criteria of Evaluating Effectiveness

The success of the flipped classroom intervention was calculated according to the following factors:

Academic Performance: The academic performance was set as one of the main indicators of the improvement as it led to improved results of the exams. The scores in examinations were found to be better by 18.6 percent than those of the previous cohort group ($p < 0.01$) which demonstrated that flipped classroom style of teaching helped to achieve improved learning outcomes in pharmacokinetics.

Satisfaction and Engagement of the students: The student satisfaction survey gave an idea of the perceived effect that the flipped classroom had on the student engagement and confidence. The effectiveness of the intervention was justified by a high level of student satisfaction (84%), as well as student feedbacks concerning their improved engagement and comprehension.(12)

Bigger on Confidence Regarding The Application of Concepts: The self-efficacy surveys evaluated the change in student self-confidence to the ability to apply pharmacokinetics concepts. One of the effects of the effectiveness of the flipped classroom model was increased self-confidence in solving problems and using knowledge in application.

Context of Culture and Education: Using the contrast between outcomes in the Brazilian cohort and the German one, the study was able to assess the generalizability of the model into various educational settings and how well it can be adapted to the different teaching/learning conditions.

6. Results

6.1. Academic Performance Raising Measures

The outcomes of the flipped classroom model were mainly determined by the pre-intervention or post-intervention examination scores, academic performance and knowledge in the area of pharmacokinetics concepts.

Improvement in Executive Scores

Table 1 contains the average scores of both pre-intervention and post-intervention examination of the intervention group (flipped classroom) and the control group (traditional lectures). Statistics indicate that there is a marked increase in the number of points on examinations of the flipped classroom group with an average of 18.6 percent raise in examination marks as compared to the 2010 traditional group.(13)

Table 1: Pre- and Post-Intervention Exam Scores Comparison

Group	Pre-Intervention Score (%)	Post-Intervention Score (%)	Mean Difference (%)	p-value
Flipped Classroom Group	68.2	86.8	+18.6	$p < 0.01$
Traditional Lecture Group (Previous Year)	69.1	72.4	+3.3	$p < 0.05$

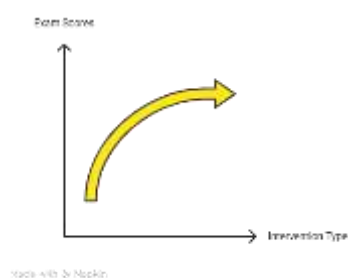


Figure 1: graph

The flipped classroom group demonstrated a statistically significant improvement in the exam score (from 68.2 % to 86.8 % or 18.6 % of improvement, $p < 0.01$). The traditional cohort of the previous year, in its turn, experienced a less significant improvement (69.1 to 72.4 percent, 3.3, $p < 0.05$), which suggests that the flipped classroom approach brought about a far better academic performance.

6.2 The Level of Student Reported Engagement and Satisfaction

To measure satisfaction and engagement of students, it was followed by student satisfaction survey after the intervention. The survey was used to identify the quantitative data on student perception of the flipped classroom model and it also captured the qualitative response on their learning experience.(14)

The Results of Satisfaction Survey

The results of evaluating the different variables with a 5-point Likert-scale (1 = strongly disagree, 5 = strongly agree) are summarized in Table 2 giving the average rating of some aspects of the flipped classroom experience.

Table 2: Student Satisfaction Survey Results

Statement	Flipped Classroom Group (%)	Traditional Group (%)
The flipped classroom approach helped me understand pharmacokinetics better.	84% strongly agree/agree	65% strongly agree/agree
The pre-recorded lectures were helpful in preparing me for class activities.	87% strongly agree/agree	70% strongly agree/agree
I felt more engaged in the flipped classroom compared to traditional lectures.	88% strongly agree/agree	60% strongly agree/agree
The in-class activities helped me apply pharmacokinetics concepts effectively.	89% strongly agree/agree	72% strongly agree/agree

Out of all the students participating in the survey, 84% who were part of the flipped classroom group strongly agreed or agreed to the response that the intervention assisted them in better understanding pharmacokinetics, whereas in the normal classroom group the number was just 65%. On the same hand, 88 percent of the students in the flipped classroom section reported that they were more engaged compared to the students in the traditional lecture section (only 60 percent of the students said that they were more engaged in the traditional lecture group)

6.3 Comparative analysis with other past Traditional Cohort

To gauge the effectiveness of the flipped classroom model when compared to its predecessor the traditional cohort, data was compared to that of the previously conducted (prior to the flips classroom) lecture-based curriculum. As evidenced by Table 1 and Figure 1, the flipped classroom students showed better results in terms of grades improvement and student satisfaction.

Exam performance: The flipped classroom group had a statistically significant improvement of 18.6 percent in their exam performance when compared against the traditional cohort the previous year of 3.3 percent improvement.

Engagement and Satisfaction: The latter was more engaged as 88% of students in the flipped classroom group claimed they were more engaged, whereas only 60% of students in the traditional group responded that they were more engaged. More so, 89 percent of the flipped classroom participants have responded positively that they could apply the concepts during in-class activities in comparison to 72 percent of their traditional counterpart.(15)

All these results lead to the conclusion that the flipped-class room approach also helped to achieve better academic results but also greatly increased the level of student engagement and satisfaction in relation to the traditional lecture-based course.

7. Conclusion

7.1 Key Points Proven

The findings of this paper give a great amount of evidence regarding the efficiency of the flipped classroom model in terms of teaching pharmacokinetics to third-year students of pharmaceuticals. Among the main findings there is:

Still Easy: The students who used flipped classroom exhibited a considerable rise in exams with an 18.6 percent greater performance score (as compared to the prior year traditional group that showed a 3.3 percent gain). This implies that pharmacokinetics concepts were understood and applied with more ease in the flipped classroom model.

Increased Student Engagement: The students in the flipped classroom group recorded increased engagement with 88 percent reporting being more engaged as compared to 60 percent of the students in the normal lecture group. The flipped classroom provided an interactive and active learning setting thus they were more involved with the learning process as a student.

Increased Student Satisfaction: A total of 84 percent of the students in the flipped classroom group students responded that the model of teaching assisted them in grasping the content. Comparative to this, only 65 percent of students in the lecture group with which I took my class felt so. The flipped classroom model gave the students a chance to read what should be read before everyone met in the classroom and this will be accompanied by practical classes and this resulted in increase in the degree of satisfaction.

Benefits of In-Class Activities as a Learning Tool: Students that attended flipped classroom lectures were extremely satisfied with In-Class Activities that included problem-solving activities, case studies, and interactive quizzes; 89 per cent of the students in flipped classroom course felt that such activities helped them implement the acquired knowledge in pharmacokinetics concepts, as opposed to 72 per cent of the students in the traditional lecture course.

7.2 Pharmacy Education Pedagogical Implications

The findings highlight the pedagogical promise of the flipped classroom model in drug learning with regards to a pedagogical perspective in pharmacy education, especially in pharmacokinetics where the content is elaborate and quantitative in nature. According to the study, this model can:

Encourage Active Learning: As the classroom instruction gives their content outside the classroom, active learning of the students increases during the classroom time and the chance to not only show what they have learned but

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also become critical thinkers also increases. This engaged method facilitates better learning and remembering and more so with tricky ideas such as pharmacokinetics.

Facilitate student engagement: Flipped classroom model promotes engagement to students as it promotes self-directed learning before the classroom (inclusive of content acquisition and memorizing) as well as collaborative learning in the classroom. The learners will be able to remember information and transfer it into practice in a real clinical environment if they are more engaged in the information.

Peer Interaction: Problem solving and discussions in the flipped classroom model allow the students to have peer interaction. The model induces the learning style of the peer-to-peer that can assist the students to feel safe and strong while finding solutions to complex pharmacokinetic issues jointly.

Curb Rigidity and Learning Dependency: The flipped classroom format enables the classroom to become flexible in terms of students having to learn at their pace by providing them with pre-recorded lectures. The advantage of this flexibility especially comes in complicated courses such as the pharmacokinetics where students might take time to absorb tough concepts.

7.3 Future Recommendations on Flipped Classroom Models Adoption

With such positive results in this study, it is recommended that in future implementation of the flipped classroom model in pharmacy education the following should apply:

Wider-Scope Applications in Pharmacokinetics and Other science courses should also consider the flipped classroom approach to other difficult courses within the pharmacy course such as pharmacology, clinical therapeutics and pharmacy law which require active engagement and problem-solving.

Faculty Training and Facilitation: Faculty members will have to be trained how to develop interactive materials, lead in-class activities, and make the students participate in collaborative study. Faculty should be able to incorporate the model in their instructional approach by providing them with clear guidelines, and technical assistance that will be given.

Continuous Evaluation: Periodic assessment and evaluations would be expected and ought to be made to gauge the continuous effectiveness of the flipped classroom model. This will facilitate adjustment and its ability to satisfy the learning needs of students.

Combining with the Online Learning Avenue: In future, research can be conducted on how to combine the concept of the flipped classroom with online learning platform which has interactive tools, simulations, and virtual labs. That would better the learning experience in the sense of giving the students more options to study and practice skills.

Scalability and Cross-Cultural Application: The fact that this study was done in two different countries with different educational contexts (Brazil and Germany) means there is the need to conduct studies to determine how the flipped classroom is scalable to other cultural and educational settings without knowing its global applicability and how best learning will take place in different cultural and learning settings due to the differences in learner needs.

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Conflicts of interest

The authors have no conflicts of interest to declare

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