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ORIGINAL RESEARCH

Student Perceptions and Effectiveness of Video-Based Flipped Classroom for Improving Medical Physiology Teaching at AUSOM

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Background: Medical education has shifted from traditional teaching methods to interactive learning, emphasizing student engagement and critical thinking for enhanced problem-solving skills. There is a growing shift toward active learning strategies, such as the flipped classroom model, in the current medical education settings.

Methods: A quasi-experimental study was conducted in the Physiology course of basic sciences at Avalon University School of Medicine, Curacao, using a video-based flipped classroom (VBFC) model. Hundred short instructional videos were created and integrated into 65 Physiology sessions. Pre- and post-implementation surveys assessed students' perceptions and the effectiveness of VBFC. Grade comparison of students was analyzed using paired to evaluate learning outcomes between VBFC and traditional lecture formats.

Results: The VBFC in physiology courses revealed promising results, improving student performance and engagement. Physiology scores, which were significantly lower than the overall course scores before introducing the VBFC approach ($p = 0.0216$), showed improvement and aligned with the overall scores following its implementation. Students demonstrated a positive attitude toward this method, indicating that video-based pre-class learning was effective. Survey responses consistently reflected agreement with the advantages of this approach. In particular, students expressed strong agreement regarding three key aspects: the appropriate length of each video, the quality and usefulness of the 1 to 5 follow-up questions accompanying each video, and the importance of sustaining this teaching method.

Conclusion: The flipped classroom model supported student engagement and promoted self-directed learning, potentially aiding in the understanding of subjects like physiology. Grounded in Piaget's cognitive development theory, this approach promotes abstract thinking, logical reasoning, and problem-solving skills. Despite limitations such as small sample size and study duration, the results suggest the flipped classroom model can significantly enhance medical students' outcomes in physiology.

Keywords: active learning, flipped classroom, interactive learning, medical education, Piaget's theory, student-centered education

Introduction

Medical education is transforming from traditional teaching methods, with a growing emphasis on interactive learning methods that foster critical thinking and student engagement.[1] This shift was inevitable, mainly due to the reduced attention span of individuals as a consequence of the influence of social media in the new digital world, and to enhance problem-solving skills and critical thinking.[2] Furthermore, accreditation standards in medical education globally now mandate that medical programs provide opportunities for students to engage in active learning environments.[3] These settings are designed to foster the development of lifetime learning abilities, which are essential for application in clinical practice.[3] In medical schools worldwide, the most commonly used teaching-learning strategies include lectures,

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demonstrations, tutorials, lab sessions, clinical and hospital postings, which are sometimes added with seminars, debates, role play, and small group discussions.[4] Even though they can engage students, medical educators are exploring new ways to make learning more active and effective by shifting away from passive lectures and towards active learning strategies to foster the capability of deep learning among medical students.[5] This shift greatly allows for more meaningful use of classroom interactions, as students become prepared to actively engage with the material at a higher cognitive level. The teaching and learning strategies utilized in medical education should aim to accomplish an advanced level of lower-order cognitive processes, such as memory recall, as outlined in Bloom's Taxonomy of the Cognitive Domain. In traditional lectures, classroom time is devoted to lower levels of cognitive work, such as remembering and understanding factual knowledge, with the students passively receiving information from the teacher. In contrast, the flipped classroom model leverages the time students and teachers spend together to engage in higher-order cognitive tasks of Bloom's taxonomy, such as applying, analyzing, evaluating, and synthesizing knowledge.[6] In a flipped classroom, students typically learn the basic material on their own using videos or reading materials outside of class and utilize class hours for more active learning that promotes deeper understanding and critical thinking.

In video video-based flipped classroom, teachers provide students with lecture videos to be watched from home, and students have access to class content to be learned in a self-paced manner before class, and the following day in the class hour, students can apply the learned concepts in active sessions guided by the teacher.[7] Here, the teacher acts as a guide or facilitator rather than an information provider.[6] By incorporating the Flipped Classroom method, the teacher-centered approach of didactic lectures can be significantly shifted to a student-centered approach, making the teaching-learning process more effective and interesting. A flipped classroom allows students to independently learn foundational concepts as required homework, assimilate and accommodate that knowledge through problem-solving, discussion, or debates, engage in critical thinking opportunities, and apply knowledge in the presence of an instructor or facilitator during class time.[8] This approach has been shown to enhance interactive learning, critical thinking, and problem-solving skills, equipping students with accurate clinical diagnosis and formulating appropriate management of patients during the clinical rotations and beyond.[9] It requires students to be more active and engaged with the subject matter, as opposed to passive listening in traditional lecture-based classrooms.[10] With the growth of technology, pre-class assignments are usually delivered via video lectures; however, many other innovations have been explored, implemented, and evaluated.[11,12] Currently, medical education uses the flipped classroom method, which was used in the humanities for many years.[13] FC is effective in improving students' performance in multiple disciplines.[14,15]

Studying physiology serves as a bridge between pre-clinical knowledge and clinical practice in medical education. Integrating physiological principles with pathophysiological concepts requires a high level of cognitive ability concerning Bloom's taxonomy. The integrated approach to medical education, incorporating the flipped classroom model, not only enhances the ability to acquire relevant medical knowledge but also helps the development of analytical thinking, problem-solving abilities, and applying theoretical knowledge to clinical scenarios.

However, until now, there are limited references on applications of the Video Based Flipped Classroom (VBFC) model for carefully assessing the effectiveness of learning in basic medical sciences, especially in physiology classes. So, we conducted this study to evaluate the acceptability, perception, and effectiveness of VBFC for improving medical physiology teaching. This study aims to explore students' perceptions regarding flipped classrooms and to find out their effectiveness in physiology courses at Avalon University School of Medicine, Curacao.

Materials and Methods

A quasi-experimental study was conducted in the physiology course in basic sciences at Avalon University School of Medicine (AUSOM), Curacao, a Caribbean medical school offering a Doctor of Medicine (MD) program. The quasi-experimental design is selected for this flipped classroom study primarily due to the practical limitations of randomization in real educational settings, and students are already assigned to specific classes or sections. Randomly redistributing them into new groups for research purposes could disrupt existing schedules and academic fairness. Furthermore, the students are admitted to the school following rigorous admission screening with standard predefined qualifications, which ensures that both groups of students have the same characteristics at the beginning of the research. The program has five semesters (MD1-MD5) of basic science courses conducted on the island of Curacao, and students do clinical rotations in

teaching hospitals in the USA. The Human Structure and Function (HSF) 1 module of MD1 spanned 15 weeks and included a total of 210 lectures, of which 65 sessions were on Physiology and were delivered using the video-based flipped classroom (VBFC) model. Avalon University's research and ethics committee approved the study and received permission to use students' grades for research purposes while maintaining anonymity.

Surveys were conducted pre- and post-implementation on students' perceptions of the VBFC. The VBFC model was implemented as part of the standard curriculum in the HSF 1 and 2 courses. All students enrolled in HSF 1 and 2 were considered participants for grade analysis, while survey participation was voluntary. A total of 65 Physiology sessions were delivered, supported by 100 instructional videos aligned with specific learning objectives. The pre-implementation survey was administered two weeks before the implementation of VBFC, and the post-implementation survey was conducted two weeks after its completion. Surveys were validated through expert panel review and Cronbach's alpha for reliability. This process ensured content appropriateness, internal consistency, and construct clarity of the instrument before deployment in the study. Student engagement was monitored through the learning management system of the school by tracking video view completion and MCQ responses. The post-implementation survey was completed only by students in HSF 1 and 2 who experienced the VBFC model.

The pre-implementation survey was paper-based, whereas the post-implementation survey was web-based, utilizing SurveyMonkey. Both survey questionnaire responses were based on the Likert scale (1 – strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree, and 5 – strongly agree). A pre-implementation survey was conducted for all the basic science students at Avalon University School of Medicine. The printed questionnaire was distributed to all the students and provided one week to fill out and submit their responses. In our present study design, after the pre-implementation survey, in the following semester, VBFC was implemented for the physiology part of the Human Structure and Function (HSF) course. Hundred pre-recorded instructional videos were created, each lasting approximately 10 minutes and aligned with specific learning objectives for the physiology course, and validated by the subject expert. These videos were uploaded to the institution's Learning Management System (LMS) and were accessible asynchronously to the students. The video is followed by 1 to 5 multiple-choice questions (MCQs), and the faculty has the facility to monitor the engagement of the students for VBFC. The MCQs used in this study were directly aligned with the core concepts and learning objectives presented in the provided videos. Each question was designed to assess specific knowledge or critical thinking skills targeted by the corresponding video segment. The validation and reliability process to prove that the video content is truly related to the MCQ involved a two-step process, starting with expert review by a panel of subject matter experts who reviewed the videos and corresponding questions to evaluate content validity, later by item analysis of the questions. This strategy ensured that each question accurately reflects the intended learning outcomes presented in the videos.

After the implementation of the VBFC teaching methodology, a post-implementation survey consisting of questions related to the acceptability and general perception of the flipped classroom model was conducted. A post-implementation questionnaire survey comprising 10 questions was conducted among the students of both MD1 and MD2 to determine students' opinions regarding the VBFC teaching at the end of the course.

The post-implementation survey was conducted for MD1 and MD2 students who received the flipped classroom in physiology courses. The survey was available for students for one week with a voluntary and anonymous participation option. For the post-implementation survey, students were provided opportunities to submit descriptive comments. The confidentiality of the collected data was maintained by the investigators. Post-implementation survey data were stored on the University IT department's central server, with no direct access granted to investigators or faculty. Investigators received aggregated responses from the IT department via SurveyMonkey. No student identifiers were collected or disclosed. As participants in this survey, the students were expected to have prior knowledge about the flipped classroom.

Class hours were primarily used for active learning with group discussions, followed by in-class formative assessments with feedback. Student grades were obtained by investigators through the Student Information System (SIS). The final grades of the physiology course examination, which was conducted concurrently in the same semester, were explored to assess the impact of VBFC teaching on the learning of the physiology courses. The investigators received the grade averages from the IT department without the students' names. The grades of HSF 1 and HSF 2 courses, which include Anatomy, physiology, Histology, and Embryology in the MD 1 and MD 2 semesters, respectively, were also

analyzed to assess the effectiveness of VBFC teaching. Isolated Physiology exam grades were compared with total grades of the HSF course using a paired *t*-test.

Results

A total of 64 out of 109 students, with a response rate of 58.71%, participated in the cross-sectional pre-implementation opinion survey, among whom most of the students either agreed or strongly agreed to implement a flipped classroom in Avalon University. The results of students' responses to various pre-implementation survey questions related to the flipped classroom model are provided in Table 1. The calculation of the mean and median for each question presented in Table 1 provides a summary of the descriptive statistics for the survey responses. 73% of the students agreed that viewing the lecture in advance helps them prepare for class, as the mean is high (4.39) and the median is 5, indicating strong agreement. For the question "I think watching videos at home will be overloading on studies" students were neutral to slightly disagree on this point, suggesting that while some may feel overwhelmed, it is not a major concern for most (Mean: 2.80, SD: 1.12, Median: 3). Likewise, 54% of the respondents agreed that viewing the lecture is important for class participation, as shown by the relatively high mean 3.92. Students tend to agree, though less strongly, that the flipped classroom could be effective, which is evident from the mean (3.60) and median of 4. Overall, there was positive support for the flipped classroom model. There were mild concerns about the workload (Q2), with some variability in responses regarding mandatory participation (Q7). Students seem optimistic that the flipped classroom will help them perform better (Q8) and interact more with instructors (Q9), with several responses strongly advocating for its implementation (Q10).

Most students believed that the flipped model would help them in exams, with a similar mean and median (Mean: 3.81, SD: 1.10, Median: 4). Students generally supported the execution of the flipped classroom, as evident from the mean near 4.

After the pre-implementation survey, the flipped classroom method was implemented for HSF1 and 2 students. The final exam scores of the HSF1 course were compared with the standalone physiology scores (Table 2). The average score of the HSF 1 final examination in June 2018 without VBFC was 59.63, with a standalone physiology score of 54.37

Table 1 Pre-Implementation Survey Results

	Questions	Mean ± SD	Median
Q1	Viewing the lecture before the scheduled class will prepare me for the class activity.	4.39 ±.95	5
Q2	I think watching videos at home will be overloading on studies.	2.80 ± 1.12	3
Q3	Viewing the pre-recorded lecture is essential for successful participation in the class activity.	3.92 ±.98	4
Q4	The instructor should make meaningful connections between the topics in the pre-recorded lecture and the class activity.	4.38 ±.88	5
Q5	The flipped classroom model will be an effective implementation compared to other teaching methods at AUSOM.	3.60 ± 1.06	4
Q6	I would prefer being able to view the lecture before the scheduled class as opposed to a live class lecture.	3.61 ± 1.08	4
Q7	The instructor should make student participation mandatory in the in-class activity.	3.81 ± 1.11	4
Q8	I believe the Flipped Classroom will give me the confidence to address the learned topics on the final examination.	3.81 ± 1.10	4
Q9	I think the Flipped Classroom will encourage more interaction between students and faculty members in class.	3.91 ± 1.02	4
Q10	I wish the Flipped Classroom were implemented in AUSOM.	3.73 ± 1.04	4

Table 2 Mean Scores of Students

	Examination	The Mean Score in HSF (Total Including Anatomy, Physiology, Histology & Embryology)	The Mean Score in Physiology	Mean Diff	SD	P-value
1	HSF 1 Exam June 2018 (without VBFC)	59.63	54.37	5.2621	7.53	t (13) = 2.614, p = 0.0216 Significantly different at p<0.05
2	HSF 2 Exam Oct 2018 (with VBFC), the same students who took HSF 1 in June 2018	69.56	66.27	3.29	5.83	t (8) = 1.693, p = 0.129 Not significantly different (p>0.05)

Abbreviations: HSF, Human structure and function course – it includes Anatomy, Physiology, Histology, and Embryology; VBFC, Video-based flipped classroom.

(mean difference – 5.26). HSF 1 final Exam June 2018 scores without VBFC were compared with Physiology using a paired *t*-test and it was found that there is a statistically significant (t-2.614, p - 0.0216) difference in the scores, stating that the physiology scores of the students were low when we compared it with the overall score of HSF1 (Table 2). The HSF 2 Oct 2018 final examination score with the implementation of VBFC was 69.56 with a standalone physiology score of 66.27 (mean difference −3.29). The same students' final exam scores in HSF 2 Oct 2018 with the implementation of VBFC were again compared with standalone physiology scores using paired t-tests and were not statistically significant (t-1.693, p = 0.129 (P>0.05)), meaning that the physiology score improved when comparing the overall score in HSF2. These results imply that before the implementation of VBFC, the physiology grades were significantly lower than the overall HSF grades, but the implementation of VBFC in physiology alone raised the physiology score to the level of the overall HSF grade. It also signifies that among the subjects of HSF, physiology is perceived as a challenging course by the students compared to other subjects of HSF, such as Anatomy, Histology, and Embryology. The lack of significant difference between physiology subject grades to the total HSF grades after the execution of VBFC for the physiology course alone shows that students have improved physiology learning capacity equivalent to other subjects.

The response rate for the post-implementation survey was 100%, and all 26 students participated in the survey; 18 were MD1 and 8 were MD2 students, comprising nearly 62% female students. A vast majority of the students opined that viewing the video lecture before the scheduled class prepared them for the class activity, with a mean value of 3.73 and a median of 4 (SD 0.96). The mean of 3.73 shows general agreement, and the median of 4 suggests that this teaching method is positively received. 88% of the respondents agree that the pre-class video duration of fewer than 10 minutes for each topic that was used for the flipped classroom was optimal, which is evident from the mean value of 4.15 for the second question. There is strong agreement that short videos of less than 10 minutes are optimal. The low standard deviation (0.61) shows consistency in the responses, and the mean of 4.15 indicates that most students find the video length appropriate. The shorter length of the videos was greatly appreciated by the students, evidenced by these descriptive comments. "Small length videos make it easier to take breaks", "Short and precise is good", "If the purpose of the video is to help us to be familiar with the concept, less than 10 minutes would be logical" and "it's good if it is less time so, we can concentrate more, and we won't distract". It is interesting to note that most of the respondents agreed that viewing the pre-recorded lecture was essential for successful participation in the in-class activity and helped them to answer the questions during the in-class activity, whereas only a few were neutral or disagreed with the same (Table 3).

Furthermore, nearly half of the respondents prefer to view the lecture before the scheduled class instead of a live class lecture. It is noteworthy that only a few of the respondents neither agree nor disagree with this question. 81% of the students believe that VBFC gave them the confidence to address the learned topics on the final examination. Students generally agreed that this method boosts their confidence for exams. The relatively high mean (3.81) and median of 4 show support for this belief. These findings, in turn, reflect the effectiveness of the Video-Based Flipped Classroom for Improving Medical Physiology Teaching. The majority of the MD1 and 2 students also contemplate that the newly implemented flipped classroom teaching method in Avalon University School of Medicine encourages more interaction between students and faculty members in the class. In contrast, only a negligible percentage of respondents strongly

Table 3 Post-Implementation Survey Results

	Questions	Mean ± SD	Median
Q1	Viewing the video lecture before the scheduled class has prepared me for the class activity.	3.73 ± 0.96	4
Q2	The pre-class video duration of fewer than 10 minutes for each topic was optimal.	4.15 ± 0.61	4
Q3	The questions (1 to 5 in number) that followed each video allowed me to understand the content better.	4.15 ± 0.67	4
Q4	Viewing the pre-recorded lecture is essential for successful participation in in-class activities and helps me to answer the questions during in-class activities.	3.46 ±1.14	4
Q5	The instructor made meaningful connections between the topics in the pre-recorded lecture and the in-class activity and provided feedback after the in-class formative assessments.	3.96±0.66	4
Q6	I prefer being able to view the lecture before the scheduled class as opposed to a live class lecture.	3.56 ±1.04	4
Q7	The instructor should make student participation mandatory in the in-class and out-of-class activities.	3.42±1.21	3.5
Q8	I believe this teaching method will give me the confidence to address the learned topics on the final examination.	3.81±0.85	4
Q9	I think this teaching method will encourage more interaction between students and faculty members in the class.	4.00±0.94	4
Q10	I wish in AUSOM, more lectures were conducted in this method in which the students are exposed to the lecture content in a video format, followed by 1 to 5 questions for understanding purposes, before coming to class, and the class hours are utilized more for interactive learning followed by in-class formative assessment with feedback.	4.15±0.88	4

disagree with this statement. However, the standard deviation of 0.94 suggests some variance in the perception of improved interaction. Moreover, a predominant portion of respondents wish to implement the innovative VBFC, incorporating short formative assessments with feedback during class hours to improve all basic medical science teaching-learning processes. It is worth mentioning that only a small group of respondents disagreed or strongly disagreed with the question or did not wish to implement this teaching method. In the survey, students consistently endorsed the benefits of this teaching method. They expressed strong agreement across three key aspects: the appropriate duration of each video, the quality and relevance of the videos, and the usefulness of the one to five formative questions following each video. Additionally, students emphasized the need to continue implementing this method in future teaching sessions.

Discussion

Our findings showed that during the pre-implementation survey, students were very interested in implementing flipped classrooms, and they strongly believed that the discussion by the teachers during in-class activity is greatly impactful. Students did not think that watching videos before the class and prereading assignments were a burden or point of concern for them. A mean score of 2.8± 1.12 showed that even though students do not have difficulty watching videos, it also implies that shorter-duration videos might help them. A median score of 5 for viewing videos before class during the survey showed that the students are interested in self-paced learning, which is in line with other studies.[16]

Physiology is a core subject for medical students, and its study is essential for understanding the human body's functions, developing clinical observation skills, recognizing the significance of patient care, learning the foundational language of medicine, interpreting diagnostic tests, and specializing in various medical fields. Traditional methods of teaching physiology, such as lectures and laboratory work, have recently faced challenges and criticism.[17] In VBFC, students are involved with the material outside of class before in-person sessions.[4] Students then apply their knowledge through instructor-guided simulations or problem-based learning activities during class. Our present study found that the

VBFC approach for physiology showed promising results in augmenting students' learning experience and exam performance by fostering self-directed learning in their studies.

In our present study, the physiology part of the HSF course employed a flipped classroom model, while the other subjects used traditional didactic lectures. This innovative approach to teaching physiology resulted in significantly improved student performance, indicating that the flipped classroom method is particularly advantageous for mastering complex subjects. In the present study, students improved their physiology score and became equivalent to the overall HSF score when compared with the scores without VBFC which in turn is in line with a study conducted by Ziqi Liu et al on the physiology courses for medical students.[18] The complexity of physiology is further underscored by the consistently lower scores achieved by students in this discipline compared to their performance in the other areas of the HSF course. These findings suggest that the interactive and student-centered nature of the flipped classroom effectively supports the understanding of intricate physiological concepts, thereby enhancing overall academic outcomes in this challenging subject.

Piaget's theory of cognitive development has significant implications for medical education, especially when integrated with modern teaching methodologies for active learning approaches, including flipped classrooms. In this way, learners can think abstractly, reason logically, and engage in problem-solving.[19] These are the cognitive skills necessary for diagnosing, treatment planning, and dealing with uncertainties in clinical practice. We strongly believe that the improvement in physiology learning has happened because of Self-paced Learning (Pre-Class Materials and Assimilation), Active Learning in Class (Accommodation), and Promoting Abstract Thought (in-class quizzes).

In our results, except for the comparison between the physiology score and the total HSF score, all other comparisons revealed no statistically significant differences in student performance. This suggests that the VBFC approach does not lead to a generalized improvement in substantial learning gains across all subjects. Rather, it appears to specifically enhance the physiology scores of certain students, aligning with their learning styles and capacities.[20]

Moreover, the findings suggest that the implementation of the VBFC model may have supported students in demonstrating their academic abilities in physiology. This indicates that the VBFC approach could be a helpful strategy in facilitating learning and performance in subjects like physiology.[10] Furthermore, findings from the post-implementation survey indicated an improvement in both student performance and course satisfaction following the introduction of the VBFC. These results align with previous studies conducted in other medical schools, further supporting the effectiveness of this instructional approach.[21] A mean score of 4.15 ± 0.88 for the question asking if the students want this type of VBFC for other lectures indicates that students are satisfied and willing to undergo this learning method for all other courses. This is important data for the curriculum committee and academic leaders to make necessary recommendations.[12,22,23] Our execution of VBFC for physiology topics has successfully established a promising framework for utilizing technology to optimize students' time and enhance their satisfaction with the essential didactic learning components of the clerkship.

Wanner and Palmer (2015) examined faculty perspectives on flipped classrooms in higher education and found that faculty expressed concerns regarding various challenges, including the significant time investment and increased workload required to implement this teaching approach in their courses.[24] Students also liked the concept of short videos, as evidenced by the descriptive comments provided in the results section.

Conclusion

As elucidated through the framework of Piaget's theory of constructivism, students enhanced their Physiology scores by engaging in the processes of accommodation and assimilation. However, this study has certain limitations, including a small sample size and a short duration of implementation. Therefore, before drawing definitive conclusions regarding the effectiveness of the VBFC method, larger-scale and longer-term studies are warranted. Even though the results cannot be generalized based on the results from a single institution, the findings from this study look encouraging in implementing the flipped classroom teaching methods in basic science courses, especially in courses like Physiology.

The limitations of this study include a small sample size and a low survey response rate. Diverse learning styles were not accounted for, which may affect student engagement, as some learners prefer direct instruction over the flipped

classroom model. Additionally, limited teaching methods such as didactic lectures, cadaveric dissections, and histology labs may also have influenced students' overall learning experiences.

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Disclosure

The authors declare no conflicts of interest related to this work. They have no financial or personal relationships that could influence the research presented in this manuscript.

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