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Investigating the Efficacy of Flipped Classroom Approach on Students' Performance in Digestion, Respiration, and Circulatory System in Selected Schools of Burundi

RESEARCH

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ABSTRACT

This study examined the efficacy of the flipped classroom (FC) approach on students' performance in digestion, respiration, and circulatory system in selected schools in Burundi. Specifically, it aimed to evaluate the impact of the approach on academic achievement, explore students' perceptions and experiences, and assess teachers' views on its implementation. Data collection included pre-tests, post-tests, and a questionnaire. Statistical analyses such as paired *t*-tests, independent *t*-tests, and Analysis of Covariance (ANCOVA) were used to assess the impact. Results showed a significant improvement in the performance of students in the experimental groups compared to the control groups, confirming the efficacy of the FC approach. Additionally, both students and teachers expressed positive perceptions, highlighting its potential in enhancing engagement, understanding, and retention of biological concepts.

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Flipped classroom approach; biology education; student performance; students' perceptions; teachers' perceptions; constructivism; explanatory sequential design

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1. INTRODUCTION

The 21st century's rapidly developing technologies have an impact on numerous fields, including training and education. The development of learning environments and new learning requirements keeps up with the rapid growth of technology (Ozdamli & Asiksoy, 2016). In this era, people are expected to actively create new ways of obtaining knowledge, using technology to advance science and innovation, as opposed to passively absorbing information that is offered to them (Sirakaya & Ozdemir, 2018). The importance of technology in the classroom cannot be overstated. Actually, learning new material has been easier for both teachers and pupils since computers were introduced into the classroom. The use of technology has made the process of teaching and learning more enjoyable (Raja & Nagasubramani, 2018). It is also commonly referred to as technology-enhanced instruction. Such a kind of instruction is relevant for numerous reasons. Learners want to proceed at their own speed (Dickson & Vasudeva, 2019). Then, education systems must adapt to the obligations that result in the transition from traditional to modern methods. For this reason, a well-designed educational system shouldn't restrict learning and should instead turn the conventional framework into a modern one that incorporates technology (Lesson, 2010). The flipped classroom (FC) approach is one of the newest educational strategies that are under investigation in the field of education in many corners around the world. Asia has led the world in research on flipped learning (Birgili, Seggie, & Oğuz, 2021).

The current study investigates the efficacy of the FC approach on students' performance in three topics taught in biology, including digestion, respiration, and the circulatory system, in selected schools of Burundi. The findings from this research are expected to highlight the potential benefits of integrating Information and Communication Technology (ICT) tools through the FC approach, ultimately enhancing students' engagement and understanding of biological concepts. Additionally, the insights gained are intended to serve as a valuable resource for educators seeking to adopt innovative teaching methodologies in their classrooms.

2. EMPIRICAL REVIEW

As a teaching approach that leverages the significant advantages of technology in the classroom, the FC is becoming more and more well-liked by learners and instructors (Jasman, Sulisetijono, & Mahanal, 2024). With the student at the center of the classroom and instructional practices put in place to create deep and lasting knowledge, the final stage of growth gave rise to the phrase "flipped learning" (Plešec Gasparič, 2017). Under the FC model, students view and listen to online videos, complete particular tasks, and get an understanding of the fundamentals of the information being taught. This prepares them to actively participate in the teaching process in the classroom (Zupanec et al., 2022). The FC approach increases the amount of time that students spend interacting with teachers, sets up an environment in which students take responsibility for their own education, shifts the teacher's role from one of instruction to one of guidance, integrates constructivist learning with teaching methods, allows each student to receive individual instruction, ensures consistency in learning through repetition, and keeps students from falling behind if they are absent from class (Ozdamli & Asiksoy, 2016). By using brief didactic videos to impart some of the material outside of the classroom, an FC often aims to increase the amount of time spent in class on activities that improve student learning (Barral, Ardi-Pastores, & Simmons, 2018). It reduces lecture time and increases class time for problem-solving, critical thinking, active learning, teamwork, and learning reinforcement (Ayçiçek & Yelken, 2018). Students who receive information outside of the classroom arrive at class prepared and eager to examine the subject matter in a relevant context. Students can access a variety of e-books at any time and from any location, watch films again, and read an infinite amount of scientific literature (Jasman, Sulisetijono, & Mahanal, 2024). According to Antonio (2022), this approach allows flexibility in expectations, timelines, and assessments of student learning, ensuring a more personalized and effective learning experience for students.

Furthermore, the pioneers of this model, Bergmann and Sams, constantly reminded the teachers of their ability to modify the implementation of FC approach to fit their specific educational environment (Plešec Gasparič, 2017). Then, a well-designed interactive design and the promotion of social interaction in instruction are essential for the success of flip learning (Cevikbas & Kaiser, 2022). Professional educators continue to be a crucial component that makes flipped learning possible, even though their roles in FCs are less obvious (Bergmann & Sams, 2011). The role of educators is huge and complex when it comes to technology use since, while correctly used, it can make learning engaging for young students, it can also divert their attention once misused (Communications, 2014). According to Bergmann and Sams, the pioneers of this model, the flipped learning is not a concrete, practical learning method, but rather a synthesis of several effective teaching tactics used in various contexts by various instructors. There is no one-size-fits-all methodology in education (Plešec Gasparič, 2017).

2.1. IMPACT OF FC ON STUDENTS' PERFORMANCE IN BIOLOGY LEARNING

The FC approach has been shown as a successful teaching method that enhances academic achievement, fosters self-learning, and equips students with 21st-century abilities. It is worth valuable to investigate

the FC's potential and how it fits in biology teaching and learning (Jasman, Sulisetijono, & Mahanal, 2024). According to a research titled "Student learning in an accelerated introductory biology course," students' memory of fundamental ideas and comprehension of biology terminology in their first biology course improved as a result of the FC technique (Barral, Ardi-Pastores, & Simmons, 2018). Another study in a partially flipped cell biology course showed that engagement with material at home is partly responsible for the improvement in results (Bassett, Olbricht, & Shannon, 2020). Zupanec et al. (2022) found that students who received instruction in biology using an FC approach outperformed those who received traditional instruction in the post-test overall and in completing the activities pertaining to all three knowledge levels (applying, comprehending, and remembering). Similarly, Naciri et al. (2022) study stipulated that the performance of students in FC was significantly higher than in control group (CG). The same study stated that FC is a creative method that is crucial for raising the standard of education. Furthermore, according to a study done in Bhutan, findings revealed that the FC is a useful teaching strategy for improving biology students' interest and understanding (Dorji & Dorji, 2022). In the same line, Nwosisi et al. (2016) stipulated that engaging students in active learning during class time, the FC approach has been shown to enhance understanding and retention of complex biological concepts.

2.2. STUDENTS AND TEACHERS' PERCEPTIONS ON FC APPROACH

According to a study by Antonio (2022), respondents argued that FC provided flexibility and convenience and delivered more reinforcement. In a study conducted by Khayat et al. (2021), the findings showed that university students' perceptions of their classes and self-determination were significantly different in FC compared to regular instruction. In the same line, Fallah et al. (2020) found that the FC strategy raised students' academic eagerness and a sense of self-efficacy. A positive correlation between the FC approach and students' learning performance in a study conducted by Xiu & Thompson (2020) was also demonstrated. The same authors revealed that self-efficacy is a significant indicator of both academic achievement and perceptions of FC. In a study titled "Are flipped classrooms less stressful and more successful? An experimental study on college students," students in the experimental group (EG) felt less assignment stress than those in the CG (Aydin & Demirer, 2022). Results from a study conducted by Ayçiçk and Yelken (2018) stipulated that FC offers a cooperative learning approach through technology, particularly online video content. A very recent study by Eltahir & Alsalhi (2025) assessing students' engagement and motivation concluded that there was a significant difference between CG and EG, favoring EG, where students exposed to FC demonstrated greater improvement in motivation and knowledge than those in CG. According to the results of a study by Deng, Feng, & Shen (2024), in order to support student learning in a video-based FC, teachers should think about including questions in pre-class films and going over them at the start of in-class sessions. Fallah et al. (2020) stated that academic efficacy and reduced failure should be achieved by implementing the FC approach.

3. AIM AND RESEARCH OBJECTIVES

As the study sought to investigate the efficacy of FC approach on students' performance in digestion, respiration, and circulatory system, the following objectives were formulated:

1) To evaluate the impact of the FC approach on students' performance in digestion, respiration, and circulatory system.
2) To explore students' perceptions and experiences regarding the use of the FC approach in biology learning.
3) To explore teachers' perceptions regarding the use of the FC approach in biology education.

4. METHODOLOGY

4.1. POPULATION, SAMPLE, AND SAMPLING METHOD

Three schools were purposively chosen for this study based on the availability of the computer labs. For this study, convenience sampling was adopted while choosing the schools to be involved in the study. This method works well for a study if you want to find out what people think and feel, if you want to run a test of your survey, and if you want to create specific theories being investigated in future research (Lavrakas, 2013). One school (Lycee du Saint Esprit) has served for the pilot study, and the other two for the real study. Kigutu International Academy (KIA) and Lycee d'Excellence Ngagara (LEN) were the two schools that were selected for the study. The population of this study was composed of 78 students of Senior Four and three biology teachers in the selected schools. Two parallel classrooms in the Biologie- Chimie et Science de la Terre (BCST) combination were chosen to carry out the study. Senior Four students participated in the study because the concerned topics (digestion, respiration, and the circulatory system) are taught at that level in the Burundian educational system. All students in the selected classroom were involved either in the CG or EG.

4.2. INSTRUMENTS' VALIDITY AND RELIABILITY

Reliability is the extent to which a phenomenon's measurement produces a constant and reliable

outcome (Carmines & Zeller, 1979). The data generated by the instrument should be accurate in representing the population being studied, and it should also be consistent across time. In this study, two methods were used to validate the instruments. First, it was validated by education specialists at University of Rwanda who received a copy to review and check whether the instruments capture the intended information. Second, in order to ascertain whether all of the instruments were readily understood and accurate, the researcher conducted a pilot study to check if all instruments were working correctly. Piloting can also boost validity, trustworthiness, and reliability, which is important when creating the final versions of the data collection tools (Newby, 2010). The questionnaires were revised and adjusted in light of feedback from the pilot study to increase the reliability of the data collection instruments. Additionally, since the instruction language of Burundi is French, teachers and students were responding in that language. Combining several quantitative and qualitative data collection methods offered the chance to validate and compare the results from various sources. Cohen, Manion, & Morrison (2011) stated that taking such actions may improve the study instruments' internal validity.

4.3. DATA COLLECTION AND ANALYSIS

The study used pre- and post-tests to measure the student's performance before and after intervention. The pre-test was composed of 25 open questions that helped to see general knowledge of the students about the topics. These questions reflected different levels of Bloom's taxonomy, including remembering, understanding, and analysis. A crucial aspect of the quasi-experimental research involves utilizing pre-testing or prior achievement analysis to determine group equivalency (McDonough, 2017). In the post-test, questions were different from the ones used in the pre-test and included closed-ended questions, structured questions reflecting different levels, such as remembering, understanding, analysis, and application. Figure 1 shows KIA students taking the post-test, both in CG and EG.

Qualitative data was collected using questionnaires after the intervention. Forms to collect this data were only given to students who participated in the EG. The questionnaire consisted of 10 questions, combining both open-ended and semi-structured questions related to students' perceptions. The one designed for teachers had 12 questions. The results from this survey were used to seek any relationship between the perceptions and attitudes toward FC approach and the post-test results. Triangulation was used to enhance the production of stronger and deeper information about research questions.

Descriptive and inferential statistical tests were used to analyze and interpret quantitative data from pre- and post-tests. Qualitative data related to perceptions were interpreted in terms of percentages. The study adopted an explanatory sequential design in mixed-method research to collect data. The study helped to establish a relationship between quantitative and qualitative data. To interpret results, this study used the Shapiro–Wilk test to check the normality of the data. In addition, a test of homogeneity of variance was run to check if the CG and EG were homogenous in the pre-test scores. After assuming the normal distribution and the homogeneity of variance in the pre-test scores in all groups at both schools, parametric tests were used to interpret and draw inferences between variables. Then, paired *t*-tests were used to compare the outcomes from pre- and post-tests within groups. These tests were used to seek if there was improvement in all students regardless of the teaching approach used by the teachers. Furthermore, independent *t*-tests between groups were used to compare means and check for any significant difference among them. Finally, ANCOVA was used to adjust for any influence of the prior knowledge on the post-test results.

Figure 1 KIA students sitting for the post-test.

5. ETHICAL CONSIDERATION

Ethical considerations were considered in this study with reference to participant permission, the right to withdraw or decline participation at any time during the study, and confidentiality and anonymity of data. Consent forms were designed and presented to the teachers. After ample explanations on the nature and importance of the study, all of them signed and accepted to participate. Participants were informed that participation was on a voluntary basis and that if they wished to withdraw, they could do so, and no charges/punishment were associated with it. Participants had the possibility to fill out the forms anonymously. The study included children under 16 years. For this category, the permission was gotten from the school administration, and students were explained the nature of the study and the importance of their participation in the research. In the concerned classrooms, all students accepted to contribute to the research with enthusiasm. Data collected in hard copies is stored in a secure place, and the soft data is now stored on Google Drive for more security in case the computer gets damaged. The data collected is confidential and requires a conservation in a way that no one else can consult it except for a special case known by the institutions that have provided the research permission.

6. RATIONALE OF THE STUDY

This study will add to the current conversation on the use of technology in education, the teaching methods that work, especially in environments with limited resources like Burundi. The goal of instruction is for pupils to comprehend the material and perform better. However, there is no evidence to suggest that ICT is currently being used in the country's public school system. There are some privately run secondary schools that provide instruction in the fundamentals of computers for productivity software like word processing and spreadsheets. Computers are not used for teaching or learning; rather, they are used for administrative tasks (Hare, 2007). Since there is very little information on the use of technology in Burundian education, this study is valuable in that it will provide additional inputs on the novel approach and investigate whether it can affect students' academic progress. Findings from this study would inform educational policymakers, curriculum developers, and educators about the potential benefits of incorporating the FC approach into biology curricula, ultimately enhancing students' learning outcomes. Schools equipped with computers should get inspired by these findings and take advantage to engage students in their lessons by creating a vibrant learning environment where students get the opportunity to learn and thrive.

7. FINDINGS

7.1. IMPACT OF FC APPROACH ON STUDENTS' PERFORMANCE

In the current research, conclusive interpretations and analyses were done by running independent *t*-tests and ANCOVA. The study revealed a significant difference between CG and EG, where the EG outperformed the CG. This was found at both schools where the study was conducted. Tables 1 and 2 show the results of independent *t*-tests run to compare the difference of means in the post-test scores at KIA.

Table 1 presents the independent *t*-test results, comparing the CG and EG at KIA. The mean difference between groups is shown to be 6.000. These results indicate that there is no homogeneity of variance between CG and EG in post-test scores [$t(28) = 2.852$; $p < 0.05$]. Then, the results are significantly different between groups. The EG outperformed the CG significantly in the post-test. This suggests that the FC approach would have a positive impact on students' performance.

Similarly, the independent *t*-test was conducted for the same purpose as at LEN. The following are the outcomes from this test. Table 2 shows the results.

Table 2 presents the independent *t*-test results, comparing the CG and EG at LEN. The mean difference is revealed to be 4.3958 between the two groups. These results indicate that there is no homogeneity of variance between CG and EG in post-test scores [$t(46) = 2.466$, $p < 0.05$]. Then, there is a significant difference between the

TEST		*F*	Sig.	*T*	df	*p*	MEAN DIFFERENCE	STD. ERROR DIFFERENCE	95% CONFIDENCE INTERVAL OF THE DIFFERENCE	
									LOWER	UPPER
		Levene's test for equality of variances		*t*-test for equality of means						
Post-test	Equal variances assumed	1.755	0,196	−2.786	28	0.009	−6.0000	2.1533	−10.4108	−1.5892
	Equal variances not assumed			−2.852	26,888	0.008	−6.0000	2.1041	−10.3181	−1.6819

Table 1 Independent *t*-test to compare post-test scores between CG and EG at KIA.

means of the two groups. In summary, based on the results from the independent *t*-tests, there is enough support to state that EGs outperformed significantly the CGs at both schools. These results suggest that the FC approach would have a positive impact on students' performance.

Table 3 shows the results obtained for ANCOVA test. This test was used to determine any influence of prior knowledge among groups on the post-test results at KIA.

The results from the ANCOVA test show that between the groups, there was a significant difference in post-test scores adjusted according to pre-test scores [$F(1, 27) = 9.319, p < 0.05$]. In other words, students' post-test scores adjusted according to pre-test scores were different; the post-test scores in the EG were higher than those in the CG. As a result of the analysis, this study found the effect size to be $\eta^2 = 0.257$, indicating a very high effect size power of FC on students' performance. The $\eta^2 = .257$ shows that about 25.7% of the variance in post-test scores was influenced by the teaching method, which is a large effect size, suggesting that the FC approach had a strong positive impact on learning outcomes.

Similarly, at LEN, the ANCOVA test was used for the same purpose as in the previous paragraph. Table 4 shows the outcomes of this test.

Table 4 shows that between the groups, there was a significant difference in post-test scores while controlling for the pre-test scores [$F(1, 45) = 16.601, p < 0.05$]. In other words, students' post-test scores adjusted according to pre-test scores were different; the post-test scores in the FC group were higher than those in the CG. In addition, this study found the effect size to be $\eta^2 = 0.269$, indicating a high effect size. The $\eta^2 = 0.269$ shows that about 26.9% of the variance in post-test scores was due to the teaching method, suggesting that the FC approach had a strong positive impact on learning outcomes.

7.2. DISCUSSION

From all the above results, the current study concluded that students who have been exposed to the FC approach significantly outperformed those who were taught with traditional methods after controlling for prior knowledge (pre-test scores). Results from the current study are

TEST		*F*	Sig.	*T*	df	*p*	MEAN DIFFERENCE	STD. ERROR DIFFERENCE	95% CONFIDENCE INTERVAL OF THE DIFFERENCE	
									LOWER	UPPER
		Levene's test for equality of variances		*t*-test for equality of means						
Post-test	Equal variances assumed	0.616	0.436	−2.466	46	0.017	−4.3958	1.7828	−7.9844	−0.8073
	Equal variances not assumed			−2.466	44.901	0.018	−4.3958	1.7828	−7.9868	−0.8049

Table 2 Independent *t*-test to compare post-test scores between CG and EG at LEN.

DEPENDENT VARIABLE: POST-TEST						
SOURCE	SUM OF SQUARES	df	MEAN SQUARE	*F*	*p*	η^2
Pre-test	168.414	1	168.414	5.677	0.024	0.174
Group	276.451	1	276.451	9.319	0.005	0.257
Error	800.961	27	29.665			
Total	30911.250	30				
Corrected total	1238.175	29				

Table 3 ANCOVA test results at KIA.

DEPENDENT VARIABLE: POST-TEST						
SOURCE	SUM OF SQUARES	df	MEAN SQUARE	*F*	*p*	η^2
Pre-test	788.707	1	788.707	36.751	0.000	0.450
Group	356.280	1	356.280	16.601	0.000	0.269
Error	965.741	45	21.461			
Total	38534.250	48				
Corrected total	1986.328	47				

Table 4 ANCOVA test results at LEN.

in line with those of Sirakaya & Ozdemir (2018) in that study titled "The Effect of a Flipped Classroom Model on Academic Achievement, Self-Directed Learning Readiness, Motivation And Retention"; the researchers noticed that there was a significant difference between post-test mean scores of the experimental and CGs on general academic achievement [$t(64) = 3.47$, $p < 0.05$]. This finding indicated that the FC model has the effect of increasing students' achievement. As a result of the analysis, this study found the effect size to be $\eta^2 = 0.159$. This value indicated a high-level of effect power (Sirakaya & Ozdemir, 2018). Similar findings to the current study were also obtained from a research conducted by Fallah et al. (2020) where they used ANCOVA to measure the efficacy of the FC approach. Their findings showed that EG outperformed CG significantly ($p < 0.0001$). The study stipulated that students' academic enthusiasm and self-efficacy increased as a result of the FC approach. It went on to point out that students' failure could be reduced and academic efficacy increased by implementing the FC approach. Furthermore, a study by Nwosisi et al. (2016) stipulated that engaging students in active learning during class time, the FC approach has been shown to enhance understanding and retention of complex biological concepts. In a study conducted by Casem (2016), there was no significant difference in CG and EG; however, while calculating each group's growth (gain score), they discovered that on average, the EG outgrew the CG up by 9.67%.

In another study focusing on the efficacy of FC in math, students in FCs improved their scores by 0.165 standard deviations when compared to traditional lecture settings. After adjusting for student-level baseline factors, the outcomes revealed a positive effect of FC in math classes by roughly 0.3 standard deviations. The FC approach showed positive effects for both complex questions requiring problem-solving and rote questions involving memorization (Setren et al., n.d.). Findings of the current study are in the same line as those of a study conducted by Khayat et al. (2021), who noticed that students in FC participated with greater competence and confidence since they had already studied the course material and prepared before class. They completed the learning exercises with purpose, gave them some consideration, and had access to some opportunities for self-learning.

7.3. DISCUSSION ON STUDENTS AND TEACHERS' PERCEPTIONS ABOUT FC APPROACH

The results from the survey demonstrated positive perceptions of students' learning in biology. In fact, 85% of the students acknowledged that the new teaching approach has increased the interactions with peers and the teacher; 92.5% believed that it helped them understand more the content; 97.5% of the students would recommend it to their teachers. In the same line, all the teachers exhibited opinions that support the efficacy of the FC approach in biology learning and teaching. In fact, 100% of the teachers believed that the FC approach has increased their interactions with their students during class time. All of them would like to use it whenever there is a possibility. Nwosisi et al. (2016) conducted a survey on students' perceptions on FC and found out that 94% liked the approach and 72% indicated that the FC helped them learn the material better. Findings of this study are similar to those from a study conducted by Khayat et al. (2021). Those findings showed that university students' perceptions of their classes and self-determination were significantly different in FC compared to regular instruction. A very recent study by Eltahir & Alsalhi (2025) assessing students' engagement and motivation concluded that there was a significant difference between CG and EG, favoring EG, where students exposed to FC demonstrated greater improvement in motivation and knowledge than those in CG. The study went on, stating that the FC method could enhance undergraduates' academic performance, motivation, and understanding.

8. CONCLUSION AND RECOMMENDATIONS

Using pre- and post-tests, the study concluded that there was a significant difference in post-test scores between the two groups at both schools; EG outperformed the CG. Perceptions regarding the FC approach were significantly in favor of the FC approach. Then, the study helped establish a relationship between the results from quantitative and qualitative data. In fact, the higher performance obtained in EG can be linked to the students' positive perceptions with respect to the FC approach. The study recommended to policymakers in education to promote it and to all stakeholders in education to keep updating their learning and teaching methods, ultimately by integrating ICT tools to boost motivation and engagement in learners.

DATA ACCESSIBILITY STATEMENT

All the data generated or analyzed in this study are available from the corresponding author on reasonable request.

ETHICS AND CONSENT

All the authors consented to participate and publish the outcomes of the current study.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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