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Evaluating the Effectiveness of Flipped vs. Traditional Classrooms in Teaching Microorganisms to Middle School Students

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Abstract:
In the evolving field of science education, effectively teaching complex subjects like microorganisms poses significant challenges, particularly given the constraints of limited class time. This case study explores the efficacy of two instructional methods—the Flipped Classroom (FC) and the Traditional Classroom (TC)—in enhancing middle school students' understanding of microorganisms. To assess these methods, the study compared pre-test and post-test scores from two groups: one receiving instruction through the FC model and the other through the TC approach. The FC method involves students engaging with lecture content online prior to class, which then allows class time to be devoted to interactive, application-based activities. The study's results indicate that both instructional strategies significantly improved students' comprehension of microorganisms. However, the FC approach showed a slight edge in effectiveness, suggesting it offers a more flexible and engaging framework for teaching this subject. These findings underscore the potential benefits of the Flipped Classroom model in addressing the challenges of limited instructional time and enhancing student participation and understanding in science education. This research highlights the value of innovative pedagogical strategies in fostering deeper student engagement and appreciation for scientific concepts.

Keywords: Flipped Classroom, Traditional Classroom, Acquisition, Microorganism, Life and Earth Sciences

Introduction

In recent years, the Moroccan education system has undergone a significant transformation by embracing the competency-based approach. This shift places a strong emphasis on knowledge construction rather

than mere knowledge transmission, fostering a more holistic and engaging learning experience for students. However, this evolution has posed a unique challenge, particularly in scientific disciplines such as life sciences and earth sciences. These subjects often require time-intensive learning activities to facilitate a deeper understanding of complex concepts.

One glaring illustration of this challenge can be found in the context of teaching microorganisms, a fundamental topic in biology. Official instructions mandate a strict time limit of just 2 hours to ensure that students acquire essential knowledge about microorganisms. This presents an intriguing dilemma: How can educators effectively implement competency-based teaching methodologies within such limited time constraints? This article delves into this pressing issue, exploring innovative strategies and pedagogical approaches that aim to strike a balance between the pursuit of competency-based education and the constraints imposed by predetermined timeframes.

"Flipped classroom", also known as the "flipped learning" approach, is an educational strategy that reverses the traditional teaching sequence by flipping the roles of in-class activities and homework assignments. In a flipped classroom, students begin by accessing course content, often in the form of videos, readings, or online resources, before coming to class [1]. When students are in the classroom, the time is dedicated to hands-on activities, problem-solving, group discussions, and other interactive activities, overseen by the teacher [2].

The core idea behind the flipped classroom is to enable students to actively engage in the learning process, using the class as a place for application, discussion, and clarification of concepts, rather than merely a venue for knowledge transmission. This approach aims to promote better comprehension, encourage critical thinking, and personalize learning by allowing students to progress at their own pace [3]. In the following paragraph, we present some findings that make flipped classroom the focus of their research, specifically targeting those related to the teaching of scientific subjects.

(Lo and Hew 2021) examined comparative studies published between 2011 and 2020 to summarize the effects of the flipped classroom compared to the traditional classroom on the three dimensions of student engagement, which are behavior, cognition, and emotion. The results show that the flipped classroom approach can increase behavioral engagement such as interaction, attention, and participation, emotional engagement such as satisfaction, cognitive engagement such as understanding mathematics and preference for challenges.

A meta-analysis of 25 articles asserts that the flipped classroom is more effective than the traditional classroom in achieving learning outcomes for secondary school students. The results also show that the effect size is larger for STEM subjects (science, technology, engineering, mathematics) than for language and sociology subjects. The effect size was also higher in studies with a shorter duration than in long-term studies. [4], [5]

An analysis of 50 publications on the flipped classroom among K-12 students revealed exciting results on learning activities, student achievement, and other parameters. The findings showed that frequent learning activities, such as educational videos during the pre-class phase and small group activities in class, coupled with a diversity of pre-class and in-class activities, were all key factors dependent on the teacher's creativity. Moreover, the flipped classroom not only improved students' personal and academic skills but also fostered higher engagement levels [6].

While the impact on students' learning outcomes ranged from neutral to positive, no study has ever found a negative impact. These compelling results highlight the effectiveness of the flipped classroom model in promoting better learning outcomes for K-12 students [7], [8].

According to a meta-analysis, the flipped classroom method has consistently been shown to elevate students' knowledge and attitudes toward math. That's not all; the benefits extend beyond math, with students exhibiting higher levels of collaboration, autonomy, self-regulated learning, and academic performance [9], [10].

The results of a recent study conducted by [11] suggest that flipping the classroom is a promising educational approach for boosting students' learning efficiency in physiology courses. Not only that, but it also facilitates long-term learning in medical courses. Another study by [12] claims that the use of flipped classrooms through Near Peer Education has led to higher average knowledge scores. However, it did not have any significant impact on knowledge retention. In the same vein, [13] found that while the flipped classroom approach had a positive effect on short-term knowledge acquisition, it had no significant effect on long-term knowledge retention. However, there are some challenges for students and instructors, such as student capacity, lack of preparation, low motivation to watch pre-recorded videos, and low interaction. [14].

Researchers such as [15] show that viewing video sequences before the classroom lecture prompts students to think about course concepts and perform better on exercises. Others look for solutions to maximize the benefits by improving the preparatory part, such as a study whose results argue that creating a more synchronous/collaborative online learning environment can improve the out-of-class component of a flipped classroom; and thus help improve the overall oral/auditory learning of the student's EFL [16].

National studies also show that the flipped classroom improves student learning in a variety of disciplines (health, engineering, education…etc.) [17], [18], [19]. Other studies have found that the flipped classroom has a positive impact on student motivation [20], but [21] state that the efficacy of this strategy on learning is still unknown and requires more research to confirm.

The results of our literature search show that at the international level, the majority of studies focus on upper-grade learners, especially in the subjects of mathematics, technology, and engineering; and that studies at the national level do the same, moreover no comparative study between the traditional classroom and the flipped classroom has been conducted with middle school students to elucidate the effects of this approach on learning especially in life and earth science so the present study attempts to fill this gap based on the following hypothesis :

The flipped classroom approach to teaching Microorganism lesson in middle school will be more effective than traditional classroom teaching in student learning.

Methodology

To contrast the flipped classroom approach with the traditional classroom method, we utilize Bloom's revised taxonomy of educational objectives, a hierarchical list of six objectives ranging from lower to higher cognitive skills: remember, comprehend, apply, analyze, evaluate, and create. This framework provides a useful tool for comparing the two pedagogical approaches, and we examine definitions that are closely aligned with our research.

Therefore, throughout this article, we consider the flipped classroom to be the pedagogical approach that aims to achieve pedagogical objectives in two phases [22], [23], [24] :

- A pre-class phase during which the student must individually achieve the low cognitive cost instructional objectives by exploiting the materials available before the classroom session.

- An in-class phase during which the student and these colleagues must achieve the high cognitive cost instructional objectives by completing appropriate learning activities and taking advantage of their teacher's assistance.

We also regard the traditional classroom to be a pedagogical approach in which the majority of pedagogical objectives are achieved in the presence of the teacher and through in-class activities. However, if the student fails, the remaining goals must be completed solely by the student through homework.[25].

Experimentation

The experimental design used in this study involved a comparative analysis of two groups: a control group and a test group.

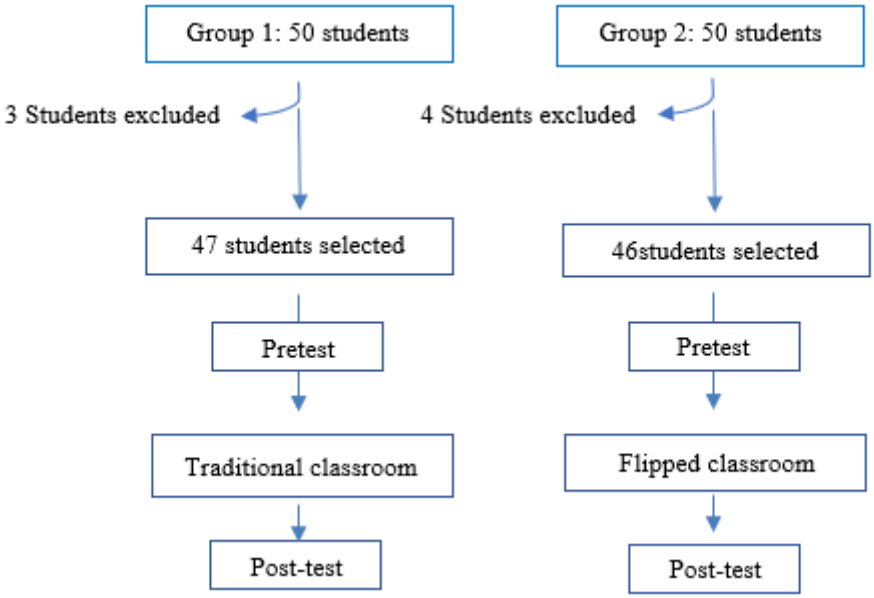

Fig. 1. Design of the Experimentation

The methodology involved delivering a microorganism lesson to two groups of students using different teaching methods: the flipped classroom for the test group and the traditional classroom for the control group. Before receiving the resources on microorganisms, the FC group took the pre-test, while the TC group took it just before the lesson began. Both groups took the pre-test without prior notification of taking the same test again.

The FC group took their post-test immediately before the second part of their flipped classroom experience, where they eagerly delved deeper into the subject matter with their teacher in the physical classroom. In contrast, the TC group took their post-test three days after receiving the lesson on microorganisms.

Afterward, we compared the results between and within groups to assess the effectiveness of each teaching method in terms of learning. The sample was selected based on ethical considerations and high-quality standards, resulting in a varying number of participants.

Sample

A total of 93 students (48,38% males, 51,61% females) from the third year of high school were chosen at random to attend the JABIR IBN HAYYAN (middle school in Fès run by the Fès Meknès Regional

Academy of Education and Training). These students were randomly assigned to one of four classes: A, B, C, and D. The classes A (N = 23), and B (N = 24) received traditional instruction, and the two classes combined formed the traditional group (TC); the classes C (N=23) and D (N=23) received flipped instruction, and the two classes combined formed the flipped classroom group (FC).
It was necessary to divide the groups into no more than 25 students each to comply with educational standards.

Material

To be used during the pre-class phase, a 6:30-minute video pedagogical sequence targeting well-defined goals related to microorganisms was developed and shared with flipped classroom students via various available media (USB, social networks, YouTube).

- The PowerPoint presentation used in the video sequence was also used in the traditional lesson during the classroom session.
- IBM SPSS version 2020 software is used to conduct the necessary statistical tests and to analyze the findings.
- MICROSOFT EXCEL version 20 We also use MICROSOFT EXCEL version 20 to present descriptive data in tables and graphs.

At two separate times, a specific test was created to assess students' knowledge of microorganisms (before and after the treatment). The exam has four educational goals:

- Define microorganisms
- Determine the conditions in which microorganisms live.
- Understand the various kinds of microorganisms.
- Understand the pathogenic properties of microorganisms.

These four objectives do not go beyond the first two levels of Bloom's revised taxonomy (Remember and Understand) because these are the two lowest cognitive cost levels that the student can achieve by watching the video sequence alone.
Before starting the experiment, this test was previously tested on a sample of 40 students (47% males, 53% females) with the same characteristics as the study sample to approve its validity and reliability.
The Test of knowledge acquisition validity was assessed using three methods. Firstly, content validity was ensured by adhering to the official national guidelines for the specific knowledge targeted in each lesson and the methods used by teachers to evaluate them. Secondly, the construct validity was confirmed through the opinions of five specialists, including two educational inspectors of LES (life and earth sciences) and three colleagues who teach LES in the same college laboratory. They all agreed that the Test of knowledge acquisition measures the intended knowledge. Finally, criterion validity was established by comparing the scores of a sample of 40 students' pre-tests with the scores given by three teachers, using the score provided as a reference evaluation.

Table. 1. Descriptive Statistics of the Results of Criterion Validity

	N	Minimum	Maximum	Mean	Std. Deviation
baseline score	40	.50	9.50	4.8000	2.08720
Score given_teacher_1	40	.50	9.50	4.7750	2.04736
Score_given_teacher_2	40	.00	10.00	5.0625	2.54495

Score_given_teacher_3	40	.00	10.00	4.9000	2.14596
Valid N (listwise)	38				

The descriptive results show that the test has criterion validity since the corrections of the 3 teachers are almost the same as the baseline score.
To measure the reliability of the Test of knowledge acquisition, the sample of 40 students was tested twice using an internal consistency test (Cronbach's alpha).

Table. 2. Descriptive Statistics of Reliability Results of Knowledge Acquisition Test.

	N	Minimum	Maximum	Mean	Std. Deviation
Tested_1st_time	40	0,50	9,50	4,8000	2,08720
Tested_2nd_time	40	1,00	9,00	4,8750	1,96687
Valid N (listwise)	40				

Table. 3. Reliability Result of knowledge Acquisition Test

Cronbach's Alpha	N of Items
0,973	2

The Cronbach's alpha test yielded a score of 0,973 exceeding the 0,8 threshold, indicating that the Test of knowledge acquisition is highly reliable.

Results

Table. 4. Descriptive Statistics of the Experiment Results

Group	N	Min	Max	Mean		Std. Deviation	Variance
				Statistic	Std. Error		
Pretest of TC	47	0,50	9,50	4,74	,27	1,89	3,57
Post-test of TC	47	5,00	17,00	10,31	,40	2,80	7,87
Pretest of FC	46	1,00	6,50	3,57	,16	1,09	1,20
Post-test of FC	46	6,00	15,00	10,15	,30	2,07	4,31
Valid N (listwise)	46						

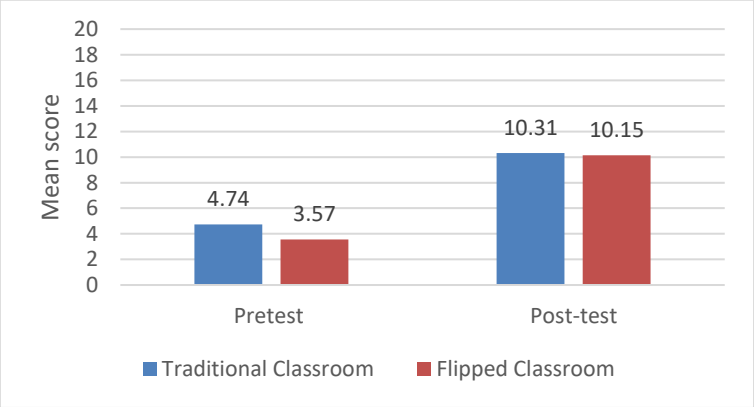

Fig. 2. Comparison of Mean Pre-Test and Post-Test Scores Between the Traditional Classroom and Flipped Classroom.

According to the graph below, the pattern is the same. For all the classes in our sample, the average score obtained in the post-test is much higher than the average score obtained in the pre-test. Moreover, we notice that the average of the pre-test and the post-test in the traditional classes are slightly higher than the average of the flipped classes. Is this difference statistically significant?

Before conducting the t-test, we assessed the normality using the SHAPIRO-WILK test. The results indicated that the data followed a normal distribution. Additionally, we considered the results of Levene's test to assess the equality of variances when interpreting the outcomes of the t-test.

Table. 5. Normality Test Results

Group		**Shapiro-Wilk statistic**		
		Statistic	**df**	**Sig**
TC	**Pretest**	0,964	47	0,158
	Post-test	0,973	47	0,356
FC	**pretest**	0,955	46	0,074
	Post-test	0,977	46	0,494

Table. 6. Comparison of Mean Pre-Test and Post-Test Scores Between the Traditional Classroom and Flipped Classroom Student Groups Using Paired Samples T-Test

Teaching Method		**Mean**	**N**	**SD**	**Mean difference**	**df**	**T**	**sig**
Traditional Classroom	**Pretest score**	4,7447	47	1,89	5,57	46	-12,507	0,000
	Post-test score	10,3191	47	2,80				
Flipped Classroom	**Pretest score**	3,5761	46	1,09	6,57	45	-35,022	0,000
	Post-test score	10,1522	46	2,07				

According to the results of the student's t-test, both the TC and FC groups demonstrated a significant improvement in their mean post-test scores compared to their respective pre-test scores. The p-values were well below the accepted threshold of 0.05, indicating the effectiveness of both teaching methods in enhancing students' knowledge regarding the micro-organisms lesson.

Additionally, the mean difference between the FC and TC groups indicates that FC has a more substantial positive impact (mean difference of 6,57) compared to TC (mean difference of 5.57). These findings suggest that FC may be more beneficial than the traditional classroom approach in enhancing knowledge during the retention of knowledge in microorganism.

So, we develop 2 hypotheses:

The students in the traditional class have a stronger foundation of prior knowledge regarding the microorganism lesson compared to the students in the flipped class.

The flipped classroom approach enables students to better retain knowledge in microorganism compared to the traditional classroom approach.

Table. 7. Comparison of Mean Pre-Test Scores Between TC and FC Using Independent Samples T-Test

	Group	N	Mean	SD	Levene's test for equality of variances		df	T	sig
					f	sig			
Pretest score	**Traditional classroom**	47	4,744	1,890	7,990	0,06	91	3,637	0,000
	Flipped classroom	46	3,576	1,095					

According to the independent sample t-test results, the P-value for the pre-test was 0.000, demonstrating a statistically significant difference between the two classes. Consequently, we confirm the first hypothesis and deduce that prior to the experiment, students in the traditional class had a more substantial foundation of prior knowledge regarding the microorganism lesson compared to their counterparts in the flipped class.

Table. 8. Comparison of Mean Post-Test Scores Between TC and FC Using Independent Samples T-Test

	Group	N	Mean	SD	Levene's test for equality of variances		df	T	sig
					f	sig			
Post-test score	**Traditional classroom**	47	10,31	2,80	5,977	0,16	91	0,32	0,745
	Flipped classroom	46	10,15	2,07					

The independent sample t-test also revealed a P-value of 0.745 for the post-test, suggesting that the difference in mean scores between the traditional class (10.31/20) and the flipped class (10.15) was not statistically significant. Consequently, we could initially conclude that the effectiveness of flipped classrooms was not significantly different from that of traditional classrooms, and both teaching methods had a similar impact.

However, it's important to note that during the pre-test, we observed a difference in favor of the traditional class, indicating that students in the traditional class initially performed better. Despite this initial difference, in the post-test, the difference was not statistically significant. This finding leads us to reconsider our conclusion. We can accept the second hypothesis and consider the absence of a significant difference in the post-test as actually favoring the flipped class. It appears that the flipped classroom method allowed students to catch up and acquire knowledge in microorganism, leveling the playing field compared to the traditional class.

Discussion

The results of this study confirm previous findings on the effectiveness of the flipped classroom approach in teaching scientific subjects [26] and extend this observation to the teaching of microorganism, also showing that the positive effect on students' knowledge is replicated in college students.

In contrast to several studies explaining the effectiveness of the flipped classroom from the point of view of student results [4], our study shows that the flipped classroom is not more effective but more efficient because the students in both classes had the same results but those in the flipped classroom achieved this result by self-learning before the classroom session just by exploiting the pedagogical video [15], [27]. As a result, these students will have more time to engage in meaningful learning activities such as experiments and group discussions, which means that students in the flipped classroom are more likely to improve further in the classroom session than students in the traditional classroom, which requires a personal commitment to complete assignments individually at home to improve. Thus, it is believed that the flipped classroom can achieve both the lower and higher-level goals of Bloom's revised taxonomy.

The findings indicate that students can achieve educational goals at a low cognitive cost simply by taking advantage of adequate support, and with the evolution of digital tools dedicated to education and available to students, the opportunities to maximize the positive effect of this approach appear numerous [28].

This will allow the teacher to target more demanding objectives that require assistance, as well as allow students to be more responsible for their learning and more involved during class sessions by asking more specific questions and carrying out experiments that constitute the heart of this subject, which is no longer possible in traditional classrooms due to insufficient time volume for this subject in the college cycle, which forces the teacher to think about transmission rather than the construction of knowledge. [29] As a result, in the flipped classroom, this time in class will be more effectively utilized than in the traditional classroom [3], [9], [30].

The results of this study also show the reproducibility of the cognitive offloading effect, as the fact of having a significant difference during the pre-test between the students of the two classes in favor of the students of the traditional class may be since these students were more engaged during the pre-test than the students of the flipped class who knew beforehand that they would have access to the necessary materials [31].

The availability of materials and the possibility of accessing them at a frequency that is dependent on the cognitive differences between students [32] are two reassuring factors for the student in the flipped classroom that allow students to engage in non-demanding and flexible but effective learning processes [33]. However, the unavailability of this opportunity for students in the traditional classroom may result in learning processes that are demanding in terms of attention and commitment but are also effective[34].

The findings from this study indicate that educators may successfully confront the dilemma of implementing competency-based teaching approaches under restricted time limitations by exploring the potential of flipped classrooms. Flipped classrooms have demonstrated their efficacy as a viable pedagogical approach for subjects like microorganisms, and there is a possibility that they could be similarly beneficial for other subjects within the domains of life and earth sciences, where intricate learning activities frequently require substantial time investments. Further investigation is warranted to ascertain the applicability of flipped classrooms across a broader spectrum of topics within these fields.

Conclusion

After comparing the two pedagogical approaches in teaching microorganism to middle school students in Morocco, we find that the flipped classroom can be an interesting and more efficient approach than traditional teaching.

This research confirms the effectiveness of the videos used during the first phase of the flipped classroom; however, the evaluation test used to compare the two approaches concentrates only on the first two levels

(remember, understand). However, a specialized evaluation tool for the other levels of the taxonomy (apply, analyze, evaluate, create) appears to be required to better compare the flipped classroom and the traditional classroom.

Admittedly, the adoption of the flipped classroom approach in the teaching of life and earth sciences as well as other subjects will encounter challenges, especially in developing countries, but further research in the didactics of these subjects will help to overcome these challenges and maximize the benefits brought by this approach which is perfectly aligned with the new national education strategies, particularly in the digital age which requires innovative and integrative pedagogical approaches and digital tools that are constantly being improved.

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