THE FLIPPED CLASSROOM METHODOLOGY IN THE TEACHING OF GENETICS IN A BRAZILIAN PUBLIC SCHOOL

A METODOLOGIA DA SALA DE AULA INVERSA NO ENSINO DE GENÉTICA EM UMA ESCOLA PÚBLICA BRASILEIRA

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Abstract. The objective of the present study was to apply the Flipped Classroom Methodology (FCM) to teach Genetics in the senior year of a public high school, and to evaluate its effectiveness according to the performance of its students. Two didactic sequences were applied: one called Traditional Classroom (TC) and the other Flipped Classroom (FC). The students who were taught through FC dedicated more time to their studies, presenting greater ease to learn the contents. Some reported difficulty managing study time due to balancing study and work, and they had significantly higher scores than the students of the TC. We concluded that the FCM is effective in teaching genetics. However, the reality of many high school students from public schools includes the need to work to complement the family income, which can become an obstacle for the students' full development and motivation through this methodology.

Keywords: Genetics; High School; Flipped Classroom.

Resumo. Este estudo teve como objetivo aplicar a metodologia da sala de aula invertida (FCM) para abordar conteúdos de Genética no terceiro ano do ensino médio em uma escola pública e avaliar sua eficácia no desempenho escolar dos alunos. Foram aplicadas duas sequências didáticas, uma denominada Aula Tradicional (TC) e outra Aula Invertida (FC). Os alunos da turma FC dedicaram mais tempo ao estudo, apresentando maior facilidade para aprender os conteúdos. Alguns alunos da turma FC relataram dificuldades para administrar o tempo de estudo devido à necessidade de equilibrar o estudo e o trabalho. Os alunos da turma FC obtiveram pontuações significativamente mais altas do que os alunos do TC. Concluímos que a metodologia FCM pode ser eficaz no ensino de Genética, no entanto, a realidade de muitos alunos do ensino médio em escolas públicas inclui a necessidade de trabalhar para complementar a renda familiar, o que pode se tornar um obstáculo para o pleno desenvolvimento e motivação dos alunos com essa metodologia.

Palavras-chave: Genética, Ensino Médio, Sala de Aula Invertida.

INTRODUCTION

Teaching Biology is a complex task because its contents need contextualization and problematization. Authors claim that students' critical thinking and intellectual autonomy need to be worked on to relate the theoretical knowledge acquired in the various biological areas to their daily lives (Resende & Gomes, 2018).

Genetics is currently one of the most prominent branches of Biology when it comes to scientific production, innovative discoveries, and bioethical issues. Many different sectors of society, such as agriculture, livestock, food, and pharmaceutical industries, converge their interests in this area of knowledge (Brão & Pereira, 2015).

For Silva et al. (2019), the appropriation of knowledge in the field of Classical Genetics and modern Applied Genetics is essential for the formation of a critical citizen capable of decisions regarding ethically sensitive issues, such as cloning, gene therapy, genetically modified organisms, use of new technology for vaccine production, among others. However, Genetics is considered one of the most difficult content in

Biology in the view of students. The inclusion of practical activities and innovative methodologies can guarantee significant learning and the development of critical thinking (Resende & Gomes, 2018).

The teaching of Genetics in Brazil and the superficiality that its contents have been taught in high school have deprived young citizens of receiving an education with the necessary subsidies to become critical and active in society. It has been a recurring factor to teach genetics from an outdated point of view, besides being disconnected from students' reality (Leal et al., 2019).

The actual need is to reinvent the way of teaching and learning, either face-to-face or virtually, due to several social changes. Traditional teaching models are increasingly insufficient and demotivating. For Lopes (2015), the "way of learning has changed. What needs to change is the way of teaching".

New perspectives

Digital Information and Communication Technologies (DICT) have been a tool for diversifying teaching methodologies. For Valente (2014), these technologies can change the dynamics of the school and the classroom, such as the organization of school times and spaces, the relationships between the learner and the information, the interactions between students, and between students and teacher. The integration of DICT in classroom activities has made hybrid teaching possible. The Flipped Classroom Methodology (FCM) is one of the modalities that has been implemented both in primary and higher education.

The use of tools to make the learning process more effective and dynamic is important because they provide greater involvement of students in the restructuring of practice in escape from traditionalism, which, when exacerbated, can negatively contribute to learning (Melo & Carmo, 2009).

The FCM, also known as Flipped Classroom, consists of an active learning method which the purpose is to invert the way the contents are worked in the classroom. What would traditionally be done in the classroom is done at home, and what is traditionally done as homework can be done in the classroom (Bergman & Sams, 2012). In this way, the teacher previously provides all the content through an online platform or printed material so that students can study before class. The classroom becomes the place to work on the contents already learned by the students, carrying out practical activities such as problem solving and projects, group discussion, and laboratory practices (Valente, 2014). Through these activities, students exercise what was learned at home with the teacher's guidance (Bissoli et al., 2018; Silva, 2021).

Faced with the need to experiment with teaching tools that provide meaningful and effective learning, the present study sought to answer the question: Can the use of the FCM improve the learning of Genetics in a public High School? Therefore, the main objective of this work was to investigate the effectiveness and applicability of an active strategy to teach a content of great relevance and complexity.

MATERIAL AND METHODS

This interventional, longitudinal study, with a quantitative and qualitative approach, with convenience sampling, was carried out in a state school, located in the city of Coronel Fabriciano, state of Minas Gerais. The School serves high school students with full and regular education.

Two classes of the senior year of high school were randomly selected for the present study and one was called Traditional Classroom (TC, n = 25) and the other one Flipped Classroom (FC, n = 34). The study was approved by the Ethics Committee in Research with Human Beings of the Federal University of Juiz de Fora under protocol CAC: 3,481,013. To carry out the research, the Free and Informed Consent Term (FICT) was signed by those responsible for the underage students. The Free and Informed Assent Term (FIAT) was signed by all participating students.

Two different didactic sequences were applied, one for each class. These sequences were carried out over six weeks (which is the approximate duration of a school term) during the third term. The content of Genetics was chosen because it is considered difficult to understand, as reported by Rezende and Gomes (2018). As a basis for the study, the textbook normally used by the classes was selected: Mendonça, V. L. Biologia: o ser humano, genética, evolução. Editora AJS, v. 3, p. 1-384, 2016.

Two weeks after the beginning and at the end of the six weeks of application of the didactic sequences, the students carried out individual assessments to verify their learning. The student who obtained a grade greater than or equal to 6 of the total value of the assessment was considered approved. This criterion was adopted for the analysis of the results.

For the TC, a didactic sequence was prepared (Table 1) using the lecture as the main methodology, in which the teacher is the protagonist and the students behave mostly as listeners, having, however, freedom

to question and give their opinion during the exhibition (Bonini- Rocha et al., 2014). The lectures were given by the same teacher in two 50-minute classes per week held at the school.

Table 1. Didactic sequence for Traditional Classroom (TC).

TEACHING SEQUENCE TRADITIONAL CLASSROOM			
WEEK	**THEME**	**ACTIONS IN CLASSROOM**	**ACTIONS AT HOME**
1	DNA – Structure and replication	- Lecture on DNA and its structure: Nucleotides, bonds and nitrogenous bases.	- Represent the structure of a DNA nucleotide with colored paper and glue. - Represent the structure of a hypothetical DNA segment in the notebook and its duplication process.
2	Transcription and translation	- Lecture on transcription and translation. - After-school quiz.	- Watch the animation on the link: https://www.youtube.com/watch?v=6nxRxoGME_I - Production of a mental map or summary of the content studied.
3	Mendel and his experiments	- Expository class: a) Biography of Mendel and his experiments. b) Terms used in the study of genetics.	Textbook activities page 149.
4	Mendel's First Law	- Expository class: a) Dialogued resolution of activities on Mendel's first law. b) Probability in genetics. - Correction of home activities.	Textbook activities page 150 and 151.
5	Multiple alleles – inheritance of blood groups	- Expository class: a) Sex-linked inheritance. b) Assembly and interpretation of pedigree. - Correction of home activities.	List of exercises (situations about forensic problems).
6	Sex linked inheritance	- Expository class: a) X-linked inheritance. b) Y-linked inheritance. c) Inheritance influenced by sex. d) pedigrees. - Correction of home activities.	List of review exercises.

For the FC, the FCM didactic sequence was developed (Table 2), and free materials available on the internet, the textbook adopted by the school itself and the author's own materials (exercise lists and stationery materials) were used to support it. The analysis and choice of video lessons proposed for home study took into account the relevance and accuracy of the content and language, whether it was simple, clear and free of copyright. The activities with the FC were carried out in fixed groups of four students. The members of the groups were chosen randomly by the students themselves so that they would feel comfortable with their classmates, which would facilitate communication and probably increase the group's performance.

The WhatsApp was the mobile messenger app chosen for communication, and was well accepted by students. During the research, students were encouraged to talk to their colleagues to exchange ideas, debate about the content, and interact with the teacher. In this interaction process, all students participating in the research stated that they encountered no difficulties handling the digital tools used in the present study.

Table 2. Didactic sequence for Flipped Classroom (FC).

TEACHING SEQUENCE FLIPPED CLASSROOM			
WEEK	**THEME**	**ACTIONS IN CLASSROOM**	**ACTIONS AT HOME**
1	DNA – Structure and replication	- Represent the structure of a DNA nucleotide with colored paper and glue. - Represent a DNA molecule using colored paper and glue. - Time to ask questions.	- Study the structure of DNA and its duplication in the following sources: a) Textbook, pages 200 to 206. b) Video lessons on the links: https://youtu.be/hvKWk4jEGmY https://youtu.be/dqj1LO5iqv0

			c) Reading the content on the link: https://descomplica.com.br/blog/biologia/o-que-e-sintese-proteica/ d) Production of a mental map or summary of the content studied.
2	Transcription and translation	- Make a poster with the transcription and translation of a DNA segment. - Clear doubts. - After-school quiz.	Study transcription and translation from the following sources: a) Textbook pages 200 to 206. b) Video lessons on the links: https://youtu.be/ywMYH1D8OTc https://youtu.be/cFVkLot3zVw c) Animation on the link: https://www.youtube.com/watch?v=6nxRxoGME_I d) Make a written summary of the content in the notebook.
3	Mendel and his experiments	- Prepare small balls of green and yellow paper to represent the pea seeds of Mendel's experiments on a poster. - Respond to a directed study on Mendel's life and experiments. - Time to ask questions.	Study the biography of Gregor Mendel and his experiments using the following sources: a) Documentary in the link: https://www.youtube.com/watch?v=tRFN7lSmhFg&t=1041s b) Video lessons on the links: https://www.youtube.com/watch?v=prA82ejgMiA&list=PLYpCEfhkB4LXoYK8GdipDJrMJ8zjcRnH3&index=1 https://www.youtube.com/watch?v=2rqEmRrtkYc&t=318s c) Write Mendel's biography in the notebook. d) Answer the pre-class questionnaire.
4	Mendel's First Law	- List of group activities. - Completion of activities. - Time to ask questions.	1) Study Mendel's first law, in the following sources: a) Texts: https://www.biologianet.com/genetica/primeira-lei-mendel.htm https://www.stoodi.com.br/blog/2018/06/20/primeira-lei-de-mendel/ b) Video lessons on the link: https://www.youtube.com/watch?v=
5	Multiple alleles – inheritance of blood groups	- Solve at least three situations about forensic problems from the list of exercises involving inheritance of blood groups. Swap the activities done between the groups. - Each group should present a problem situation and its solution to the class. - Time to ask questions.	Study the topics below: What are blood types? https://www.youtube.com/watch?v=907ws2kX4Zo The legacy of the ABO system: https://www.youtube.com/watch?v=WBrIhmLmdI8 RH System: https://www.youtube.com/watch?v=QFDLFbl69Ss Heredogramas:https://www.youtube.com/watch?v=8nPQhC_ZxEo Watch the video lessons and prepare a comparative chart between blood groups.
6	Sex linked inheritance	- Assembly of a pedigree of two hypothetical families: one with the color blindness gene and the other with the hemophilia gene. - Presentation of the pedigree to the class. - Time to ask questions.	Study sex-linked inheritance content through the following materials: a) Video lessons: https://youtu.be/1o7weCgWFCE https://www.youtube.com/watch?v=fcn4AsKUq6s b) Reading: https://blogdoenem.com.br/biologia-genetica-heranca-sexo/ c) Resolution of activities from the textbook page 207.

The activities intended for completion at home for both didactic sequences were later discussed and corrected in the classroom. At the beginning and the end of the respective approaches, the students carried out an evaluation.

The statistical program R Core Team (2020) was used to evaluate quantitative data, analyzing the performance within the same class and between classes, comparing them through the evaluation scores. A qualitative analysis was also carried out through anonymous questionnaires. The chi-square test for proportion was applied to compare the percentage of TC and FC approved in the initial and final assessments. A significance level of 5% was considered. Shapiro-Wilk normality test was performed to verify if the data had a normal distribution. The Wilcoxon test for paired data was applied to compare the TC and FC scores in the initial and final assessments.

RESULTS

An initial and final assessment was carried out for both classes (TC and FC). The teacher corrected the homework assignments in the subsequent class, and the students used the corrected material to study and take the final test. Table 3 shows the number of students who obtained a grade greater than or equal to 6 for approval in both assessments.

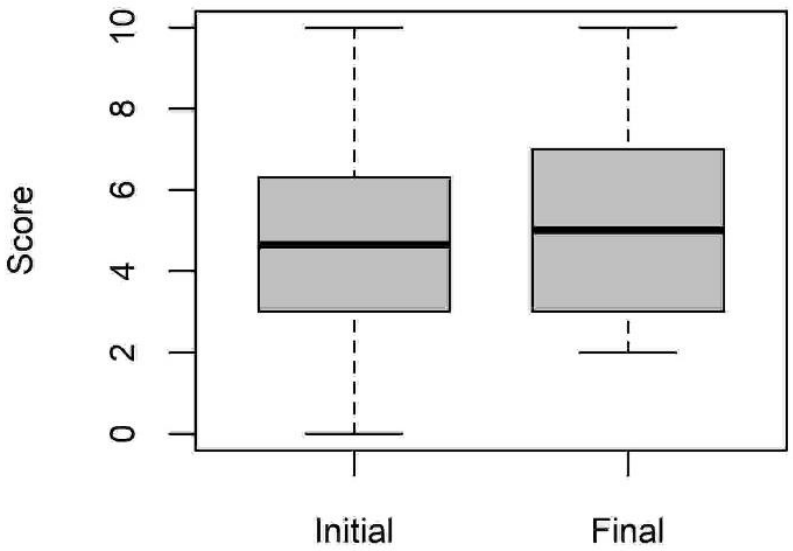
Table 3. Distribution of students who obtained a grade greater than or equal to 6 in the initial and final assessments in the TRADITIONAL CLASSROOM (TC) and FLIPPED CLASSROOM (FC).

CLASS	WITH AVERAGE (≥ 6) IN THE INITIAL EVALUATION		WITH AVERAGE (≥ 6) IN THE FINAL EVALUATION		INCREASE
	n	%	n	%	%
TC (n = 25)	7	28	9	36	8
FC (n = 34)	15	44	24	70	26
	p = 0.32		p = 0.017		

Chi-square test at 5% significance level.

No difference was observed when comparing the scores of both groups in the first assessment. In the second assessment, there was an improvement in the performance of the FC group compared to the TC, with an increase of 26% of students with an average greater than or equal to 6.0 (p = 0.017).

Graph 1 compares the results of the initial and final assessments carried out by the traditional classroom.

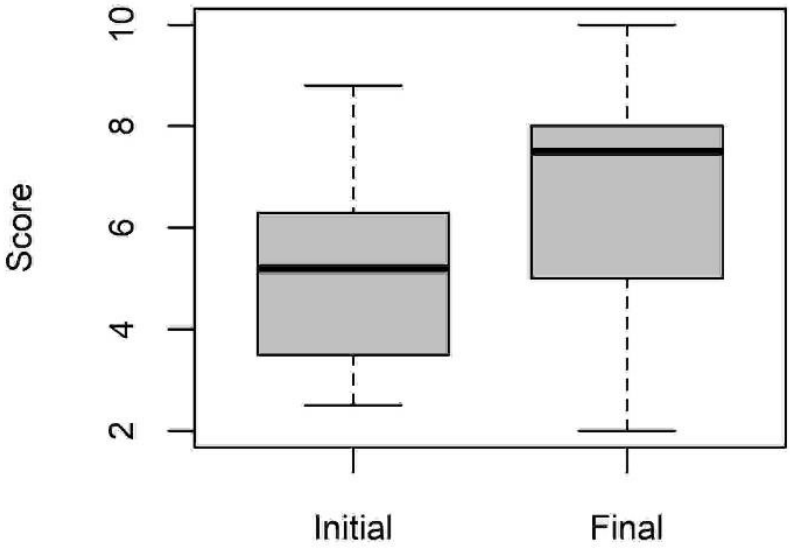


Wilcoxon test for paired data (p > 0.05).

Graph 1. Comparison between the initial and final evaluation scores of the TRADITIONAL CLASSROOM (TC).

The data presented in Graph 1 show no statistical difference between the initial and the final assessment grades of the class in which the content was taught with lectures in the traditional way, with scores average lower than 6.0 points being observed in both tests.

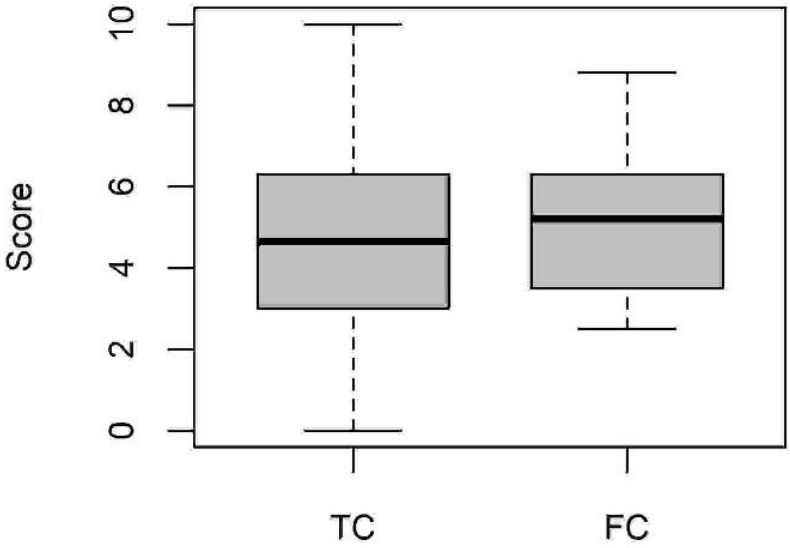
Graph 2 compares the results of the initial and final assessments carried out by the flipped classroom.



Wilcoxon test for paired data ($p < 0.05$).
Graph 2. Comparison between the initial and final evaluation scores of the FLIPPED CLASSROOM (FC).

The data in Graph 2 demonstrates a significant difference between the initial and final assessment scores in the class that developed the didactic sequence with the Flipped Classroom, with an average grade of less than 6.0 observed in the first evaluation and greater than 6.0 points in the second evaluation.

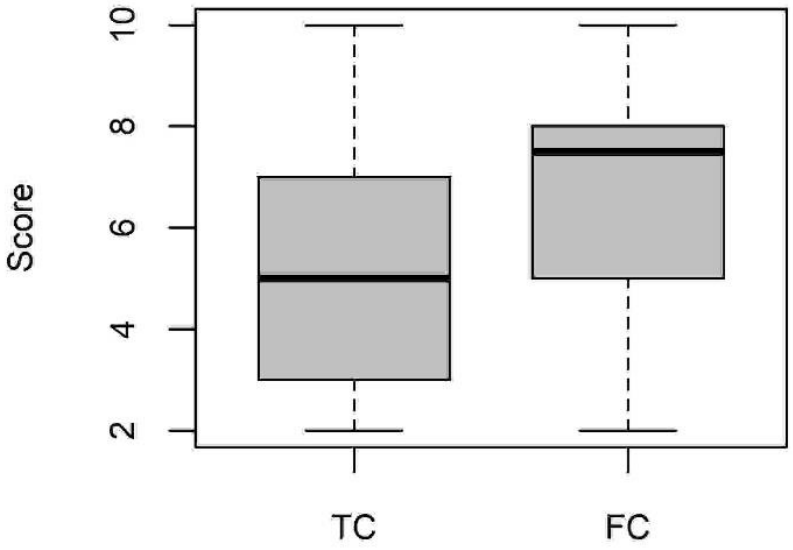
Graph 3 compares the results of the initial assessments carried out by the traditional classroom and the flipped classroom.



Wilcoxon test for paired data ($p > 0.05$).
Graph 3. Comparison of initial assessment scores between TRADITIONAL CLASSROOM (TC) and FLIPPED CLASSROOM (FC).

The data in Graph 3 demonstrate that there was no significant difference between the average grade of the initial assessments in both traditional classroom (TC) and flipped classroom (FC). In both groups, the values were below 6.0.

Graph 4 compares the results of the final assessments carried out by the traditional classroom and the flipped classroom.



Wilcoxon test for paired data ($p < 0.05$).
Graph 4. Comparison of final assessment scores between
TRADITIONAL CLASSROOM (TC) and FLIPPED CLASSROOM (FC).

The data in Graph 4 demonstrate a significant difference between the average grade of the final assessment and the flipped classroom (FC) with higher grades (≥ 6.0), showing how much this approach contributed to the students' performance.

After applying the didactic sequences and the written evaluations, the students answered a questionnaire about their study routine and the methodology used in their class during the research period, as shown in table 4.

Table 4. Questionnaire answers by the Traditional Classroom (TC).

1. What is your level of interest in Biology classes in genetics content? Rate it from 0 to 10, with 0 being no interest and 10 being very interested.	
The average grade was 7.64.	
2. Is the traditional way of teaching in which the teacher usually speaks, and the students listen and then do activities suitable for today? Yes or No?	
Yes - 64% and No - 36%	
3. Give suggestions on what can be modified to make Biology classes more interesting? (In this question, students could give more than one suggestion)	
Student suggestions	**number of answers**
More extroverted class	2
Practical classes	9
Class schedule change	2
Lessons with slides and schemes	2
Theoretical classes	2
Debates	1
Dynamics and games	1
Increase in-class hours	1
You don't need to change anything	4
Insert more Videos	1

4. In what way do you think you learn better? (In this question, students could give more than one suggestion)	
Student suggestions	**Number of answers**
Listening to the teacher speak	15
Reading or studying alone in the book	8
Watching video lessons	6
Making summaries	9
Doing activities with teacher guidance	12
5. Do you prefer lectures or classes where students solve exercises and do practical activities?	
44% answered that they prefer expository classes and 56% classes where they solve exercises and do practical activities.	
6. Do you think that the bimonthly assessment was fair and in accordance with the contents studied?	
Yes - 94% and No - 4%	
7. What is your degree of difficulty in learning the content of Genetics?	
Little difficulty	0%
Medium difficulty	64%
Much difficulty	36%
8. What was your average study time during the survey?	
0 to 1 hour	84%
1 to 2 hours	16%
2 to 4 hours	0%
More than 4 hours	0%

FC also responded to a questionnaire to collect opinions on the methodology and on possible changes in study habits during the research period, as shown in table 5.

Table 5. Questionnaire answers by the Flipped Classroom (FC).

1. Give a score from zero to 10 to the following points about the development of the Biology subject during the application of the "Flipped Classroom" method in the last five weeks.	
Point addressed	**Grade averages**
Methodology	5.18
Video classes	5.56
Reading and research sources	6.26
Classroom activities	6.53
Communication with the teacher	5.88
Personal motivation	4.44
Group on WhatsApp	5.97
2. How long did you study the subject per week outside the classroom?	
0 to 1 hour	56%
1 to 2 hours	35%
2 to 4 hours	9%
More than 4 hours	0%
3. Do you consider that the methodology helped in your organization of studies and in studying more?	
Yes (a lot)	3%
A little bit	44%
No	53%
4. Do you prefer lectures or classes where students solve exercises and do practical activities?	
76% responded that they preferred lectures, and 24% preferred classes where they solve exercises and do practical activities.	
5. Do you think that the bimonthly assessment was fair and in accordance with the contents studied?	
Yes - 74% and No - 26%	
6. What is your degree of difficulty in learning the content of Genetics?	
Little difficulty	29%
Medium difficulty	53%
Much difficulty	18%

7. Give your opinion about the "Flipped Classroom" methodology, the advantages and disadvantages you observed, criticism, praise, or suggestions. (In this question, students could give more than one suggestion).

Advantages / Compliments	Number of answers
Encourage study at home	4
Practical activities in the classroom	4
Generates autonomy	4
Knowledge before class	3
A different way of learning	2
Group activities	1
More interaction with content	1
More time to do activities	1
Inspiring	1
Disadvantages	**Number of answers**
Working after school hours	11
Lack of time	5
learning difficulty	4
Lack of discipline to study at home	3
Teacher/student distance	3
Difficulty learning alone	2
Questions when studying	2
Tired to study	2
Lack of custom with the methodology	1
Lack of concentration in video lessons	1
Present oral work to the class	1
Live far from school	1
Class lack of seriousness	1

DISCUSSION

Some students from both research groups had problems of infrequency and unpunctuality, which hampered their participation in lectures and/or classroom activities. This was the reality for some students until the end of the study period. In addition to this problem, a small portion of the students in both classes remained alien and unmotivated and did not show positive results.

This was not reflected in students who already had the habit of studying at home or in those who showed interest in trying the new methodology. All of them followed the script of previous studies and had good use in doing exercises and practical activities. Similar results were observed by Ramirez and Suárez (2017), who applied the flipped class method in their research in High School Physics, in which most students were satisfied with the methodology. Table 3 shows that even starting from similar results in the initial assessment, the FC significantly improved its grades in the final evaluation after applying the didactic sequences in both classes.

The results presented in Graph 1 demonstrate that the traditional methodology did not contribute to the improvement of TC results during the study period. In the traditional methodology, the student listens to the content transmitted by the teacher, usually without questioning. This posture of the teacher as a center, a figure of authority in the classroom, and the student as a repeater of concepts refers to banking education, a technicist criticized by Paulo Freire (Barros, 2019). It is up to the teacher to bring meaning to the lecture, bringing it from the field of repetition to the field of reflection. The traditional way of teaching does not have to be banking. It needs to be meaningful and engaging. Unfortunately, teachers do not receive instruction and training to develop methods that make lectures more effective teaching tools.

According to the data presented in Graph 2, the flipped classroom didactic sequence contributed to a significant increase in the students' grades compared to the grades of the first and second assessments. Comparing the results between the traditional and invertive classes in the first evaluation (graph 3) and second evaluation (graph 4), it was possible to observe that the traditional methodology did not contribute at any moment to the improvement of the students' grades. The flipped classroom didactic sequence contributed to a significant increase in students' grades in the second evaluation when compared to the traditional class. These data further reinforce the importance of FCM, demonstrating its effectiveness and applicability in the teaching of Genetics. The same was observed in other studies with different audiences and different areas of knowledge (Salas-Rueda & Ramirez-Ortega, 2021; Calheiros, 2019; Trevelin et al.,

2013). Other studies have also successfully used FCM in other Biology contents in different parts of the world, thus showing the flexibility and adaptability of this method to different teaching realities (Ebrahim & Naji, 2021; Gariou-Papalexiou, el al., 2017; Lo & Hew, 2017). The FCM proved to be an excellent methodology for the teaching/learning process in different areas of knowledge. It is important to prepare classes using videos, audio, images, and animations, with challenging and contextualized activities.

The main role of the teachers in the FCM is to be a mediator and therefore, maintain straight contact with their students, not only during the class but also before, motivating and showing them that the content is not exhausting and that there is more to be discovered and researched. The role of the teacher and the student are totally resignified (Barros, 2019; Schimitz, 2016).

In addition to the significant improvement in grades, other positive aspects of the FCM were observed during the development of the classes, also described by Gariou-Papalexiou, et al. (2017): more active participation of students during classes, more self-confidence during activities, greater social interaction between students, the possibility of using different resources and teaching techniques in the classroom, and more opportunities for communication between teacher and students.

Regarding the questionnaires applied in the present study, after the period of development of the didactic sequences, in the TC students suggested "different" classes with practical activities, debates, and exercises, showing that when adequately applied, active methodologies can be welcomed into the daily life of students in the classroom, even though many students still prefer the traditional teaching method. These findings corroborate those found by Pavanelo and Lima (2017) when using FCM in the discipline called Differential and Integral Calculus I in Engineering courses at ITA (Instituto Tecnológico de Aeronáutica). This work pointed out that, regardless of the difficulties faced during the experience, there is a need for innovative attitudes concerning teaching these subjects in Higher Courses. The FCM directly reflected on the students' attitude and the use of their studies in favor of a better meaning of the contents involved and a higher quality professional training, demonstrating the methodology's success.

Results found by Santos and Leão (2021) and by Oliveira et al. (2020) in studies carried out in public schools showed that students did not have a home study routine. These data, in particular, show that implementing FCM in public schools is challenging. Similar data were observed in the present study, in which the majority of TC students (84%) stated that they studied for an hour or less, and none of them dedicated more than two hours per week, reflecting the difficulty reported by themselves in learning the Basic Genetics content.

On the other hand, 47% of FC students considered that the methodology helped to improve study habits. Of the total number of students, 42% dedicated one to four hours of study per week. For 82% of the students, the FCM added to a study routine resulted in little or medium difficulty in learning the contents taught in the present work. Similar results were demonstrated by Barros, 2019 when stating that the use of FCM as an alternative pedagogical practice to the traditional teaching model is a motivating factor for students who have low academic performance. According to Aquino and Martins, 2021, the use of FCM associated with digital technologies contributes to the formation of critical thinking and student autonomy. In both studies, students reported having dedicated more time to study, using technological tools and feeling important in the process, which led them to be motivated to seek more knowledge and actively participate in building their learning.

The FC also reported some difficulties concerning the methodology, which led to a reduction in initial motivation. The main problems cited were: lack of time to study, working in shifts, tiredness after work/school, lack of study habits, and difficulty learning alone. Some of these difficulties were reported by other authors in studies that applied the FCM in private and public schools, both in basic and higher education (Santos & Leão, 2021; Silva, 2021; Conserva & Costa, 2020; Oliveira et al., 2020; Barros, 2019). On the other hand, the students in the present study cited several benefits of using FCM, including encouragement to study at home, generation of autonomy, more time to carry out activities in the classroom, greater interaction with the content, and carrying out activities group work collaboratively.

CONCLUSION

The FCM used in the present study, associated with technological communication tools, encouraged research and placed the student at the center of the teaching-learning process of Genetics. The FCM proved to be effective in improving learning, and consequently, the grades in this content, considered difficult to understand.

Implementing the FCM for teaching Genetics is feasible and it presents good results. In addition, the didactic sequence developed in this research can be used by other teachers to teachGenetics. It can also be adapted for the teaching of other Biology contents.

The results found in this research were promising. Other studies involving the FCM are necessary to confirm it as an effective didactic-pedagogical tool in teaching-learning with other groups and study contents.

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