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The *flipped classroom* model potential in online learning: an assessment focused on pedagogical interactions

O potencial do modelo *flipped classroom* no ensino online: uma avaliação centrada nas interações pedagógicas

El potencial del modelo *aula invertida* en la educación en línea: una evaluación enfocada en las interacciones pedagógicas

翻转课堂模式在在线教育中的潜力：以教学互动为重点的评估

Потенциал модели «перевернутого класса» в онлайн-образовании: оценка, сосредоточенная на педагогическом взаимодействии

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Resumo

Este texto avalia uma proposta educativa, alicerçada nos princípios da *Flipped Classroom*, implementada no ensino online, durante o confinamento causado pela Covid-19. A proposta foi implementada numa turma do ensino secundário português e conjuga aulas assíncronas (ASS) com síncronas (AS). Para caracterizar o ambiente de aprendizagem criado pela proposta e compreender a sua influência na participação e envolvimentos dos alunos usaram-se métodos mistos, tendo sido recolhidos dados quantitativos e qualitativos. A análise integrada dos dados revela que a proposta criou um ambiente de aprendizagem adequado, organizado e suportado por uma robusta presença social do professor. O design das ASS potenciou as interações *aluno-conteúdo* conduzindo a altas taxas de compromisso com as tarefas, o que assegurou uma preparação eficiente da ASS. A divisão das AS em episódios de aprendizagem permitiu compreender a influência do design dos episódios nos padrões de interação desenvolvidos. As abordagens dinâmicas e interativas das AS permitiram desenvolver os conteúdos iniciados nas ASS. Apesar do design de alguns episódios ter permitido alavancar o número de *interações aluno-aluno*, também condicionou a construção colaborativa de conhecimentos baseada em processos de investigação e pesquisa.

Palavras-chave: *Flipped Classroom*, Ensino online, Análise multimodal do discurso, Interações.

Resumen

Este texto evalúa una propuesta educativa, basada en los principios del Flipped Classroom, implementados en la educación en línea, durante el encierro provocado por Covid-19. La propuesta se implementó en una clase de secundaria portuguesa y combina clases asincrónicas (ASS) con clases sincrónicas (AS). Para caracterizar el ambiente de aprendizaje creado por la propuesta y comprender su influencia en la participación e implicación de los estudiantes, se utilizaron métodos mixtos, recogiéndose datos cuantitativos y cualitativos. El análisis integrado de los datos revela que la propuesta creó un ambiente de aprendizaje adecuado, organizado y apoyado por una fuerte presencia social del docente. El diseño de la SSA mejoró las interacciones entre los estudiantes y el contenido, lo que condujo a altas tasas de compromiso con las tareas, lo que aseguró una preparación eficiente de la SSA. La división de EA en episodios de aprendizaje nos permitió comprender la influencia del diseño de episodios en los patrones de interacción desarrollados. Los enfoques dinámicos e interactivos de la SA permitieron el desarrollo de contenidos iniciados en la SA. Si bien el diseño de algunos episodios permitió apalancar el número de interacciones alumno-alumno, también condicionó la construcción colaborativa de conocimiento a partir de la investigación y los procesos de investigación.

Palabras Clave: Aula invertida, Aprender en línea, Análisis del discurso multimodal, Interacciones pedagógicas.

Abstract

This work evaluates an educational proposal, based on the *Flipped Classroom* principles, implemented in online learning during the lockdown caused by Covid-19 pandemic. The proposal was implemented in a Portuguese secondary school class and combines asynchronous classes (ASC) with synchronous classes (SC). We collected data using quantitative and qualitative methods, to characterise the learning environment, and its influence on the students' engagement. The integrated analysis of the data reveals that the proposal created an adequate learning environment, organised, and supported by a robust social presence of the teacher. The design of the ASC enhanced *student-content* interactions leading to high rates of commitment to the tasks, which ensured an efficient preparation of the ASC. The SC division into learning episodes allowed us to understand the influence of episode design on the interaction patterns developed. The dynamic and interactive approaches of SC allowed the development of subject contents initiated in ASC. Despite the design of some episodes it has allowed measurable improvements in the number of *student-student* interactions it has also conditioned the collaborative construction of knowledge based on research processes.

Keywords: *Flipped Classroom*; Online learning; Multimodal discourse analysis; Pedagogical interactions.

概要

本研究评估了一项基于翻转课堂，在新冠疫情隔离期间的在线学习中实施的教学提案。该提案已在葡萄牙中学班级实施，并将非同步班级（ASC）与同步班级（SC）相结合。我们使用定量和定性方法收集数据，描述学习环境及其对学生参与的影响。对数据的综合分析表明，该提案创造了一个适当的学习环境，并得到了教师强大的社会影响力的组织和支持。ASC 的设计增强了学生与内容的互动，从而提高了对任务的完成率，从而确保了 ASC 的高效准备工作。SC 划分的学习阶段使我们能够了解阶段设计对交互模式的影响。SC 的动态和交互方法允许推进在 ASC 中发起的主题内容。尽管设计了一些插曲，但它使学生间的互动有了相当的改进，它还为基于研究过程的知识协作构建提供了条件。

关键词: 翻转课堂; 在线学习;多模态话语分析;教学互动。

Аннотация

В данной работе оценивается образовательное предложение, основанное на принципах Flipped Classroom, реализованное в онлайн-обучении во время локдауна, вызванного пандемией COVID-19. Предложение было реализовано в классе португальской средней школы и сочетает асинхронные занятия (АСЗ) с синхронными занятиями (СЗ). Мы собрали данные, используя количественные и качественные методы, чтобы охарактеризовать учебную среду и ее влияние на вовлеченность учащихся. Комплексный анализ данных показал, что предложение создало адекватную среду обучения, организованную и поддерживаемую активным социальным присутствием преподавателя. Дизайн АСЗ улучшил взаимодействие ученика с содержанием, что привело к высокому уровню приверженности к выполнению заданий, что обеспечило эффективную подготовку АЗ. Разделение СЗ на учебные эпизоды позволило нам понять влияние дизайна эпизода на разработанные модели взаимодействия. Динамичные и интерактивные подходы СЗ позволили развить предметное содержание, инициированное в АСЗ. Несмотря на дизайн некоторых эпизодов, он позволил измеримо улучшить количество взаимодействий между студентами, а также обусловил совместное конструирование знаний на основе исследовательских процессов.

Ключевые слова: Перевернутый класс; онлайн-обучение; мультимодальный дискурс-анализ; педагогическое взаимодействие.

Introduction

The pandemic caused by Covid-19 has forced schools and teachers to take emergency measures, so during the critical period, teaching-learning activities moved into the digital world as the most appropriate and safest option.

The new model implemented, which needed to be remote, was only possible using digital technologies but, because it lacked planning and adequate teacher training, it was dubbed emergency remote teaching (Bozkurt & Sharma, 2020).

The versatility of the digital environment allows the planning of proposals that result from the combination or adaptation of pedagogical models to improve the effectiveness of online learning. One of these models is *Flipped Classroom* (FC). Some flipped learning practices are considered to empower online learning because they foster the teaching presence in this environment (Marshall & Kostka, 2020). It helps students to become engaged and motivated by enhancing their interactions in synchronous encounters (Tang et al., 2020), which are the basis of collaborative learning.

In Portugal, from April 14th, 2020, until the end of the third term (June 26th, 2020), high school teachers and students used for the first time virtual environments to replace face-to-face teaching. This was an unprecedented opportunity to explore this learning environment at secondary school level.

In this context, the study aims to evaluate a pedagogical proposal implemented in online learning, during the pandemic, based on assumptions of interaction and collaborative learning, as advocated by the FC model. More specifically, we intended to investigate whether the implemented proposal enhances pedagogical interactions between students and teacher and promotes students' autonomy and accountability for their learning. The following research questions (RQ) guided this study:

RQ1: What are the main characteristics of the learning environment induced by the implemented pedagogical proposal?

RQ2: How did the design of the activities proposed in the different sessions influence the students' involvement/participation in the activities?

The investigation of pedagogical interactions developed in virtual environments requires combining quantitative approaches with qualitative analyses to the content of these interactions to understand better the variables that guide the knowledge construction process (Coutinho, 2013). In this regard, multimodal discourse analysis is an asset as it enables the capture and analysis of all communication channels to better describe the issue under study (Bower & Hedberg, 2010). Being supported by an ecological analysis ensures a more contextualised understanding of the variables and their relationships in this new educational ecosystem.

The knowledge produced within this study should improve the implemented proposal and contribute with some insights to many of the questions raised to online education as a future educational trend and learning model of the next decade (Wong, 2020).

Theoretical framework

Online learning

The transition to digitalisation has allowed teachers and students to continue the teaching-learning process, given the flexibility of learning times and places (Zhang & Cheng, 2012) that this medium provides. However, the sense of remoteness and disconnection from the online environment can contribute to students' disinterest, demotivation, and increased dropout rates (Aragon & Johnson, 2008).

In online education, teacher-student interactions are the most crucial factor contributing to student satisfaction and improved learning outcomes (Moore, 2002). These can occur through synchronous (videoconferencing and chat rooms) and asynchronous (email and discussion forums) tools. Environments that promote better educational outcomes combine both tools (Owens, Hardcastle, & Richardson, 2009).

In this study, online learning is defined as a teaching and learning process in a virtual environment using asynchronous and synchronous communication tools. This option lies in the need for the teacher to design an environment which encourages social interaction, supports demanding academic principles and fosters students' self-regulated learning skills (Muirhead, 2005). It is, therefore, a matter of adjusting the course components to meet the individual needs of the students, this aspect which Moore (1993), in *Transactional Distance Theory*, calls *structure*, considers crucial to the quality of online learning. Along with *structure*, opportunities for *dialogue* and the degree of *learner autonomy* are the variables that order teacher-student relationships when they are apart in space/time (Moore & Kearsley, 2007). Combining these variables allows for the development of differentiated pedagogical approaches that enable interaction to minimise the psychological and communicational gap (*transactional distance*) in distance interaction (Moore & Kearsley, 2007).

Thus, *dialogue*-based, and less structured pedagogical proposals (more flexible in design and implementation) decrease the *transactional distance*, as opportunities for dialogue lead to modifications in the *structure* to meet the learners' needs, learning styles, and rhythms. In these cases, students' good sense of transactional proximity is more relevant to the learning process than the geographical distance between student and teacher (Tori, 2010). This makes online learning pedagogically promising as it, due to being learner-centred, encourages deeper learning (Grieve, Kemp, Norris, & Padgett, 2017).

Flipped Classroom

The *Flipped Classroom* model reverses the traditional way activities are proposed to students and integrates technologies to enable more dynamic and interactive learning. Thus, before class, students receive direct individual instruction, mediated by internet-connected devices, through video lessons and, in the classroom, interactive group learning activities may take place (Bishop & Verleger, 2013).

This inversion of activities theoretically entails a series of pedagogical benefits. It centres learning on the students being held responsible for exploring the materials to prepare themselves for the face-to-face lesson (McLaughlin et al., 2014). Students learn at their own pace, as the features of video lessons (pause, repeat or advance) allow them to control their learning (Ribeirinha & Silva, 2020). It enhances the change of learning habits, as early autonomous study can positively affect the ability to self-regulate learning (Lai & Hwang, 2016). However, the main advantage of FC is the increased time available, in the classroom, for activities and interactions (Van Alten, Phielix, Janssen, & Kester, 2019; DeLozier & Rhodes, 2017). It provides more opportunities to interact with their peers and the teacher, practice and apply knowledge, and develop collaborative learning (DeLozier & Rhodes, 2017).

The division of online learning into synchronous and asynchronous classes creates two distinct learning moments that can mirror the FC model (Marshall & Kostka, 2020). An example of this is the SOFLA (Synchronous Online Flipped Learning Approach) model that aligns FC principles with online learning to ensure a visible and robust teaching presence that motivates students during online learning classes (Marshall & Kostka, 2020).

Studies on the application of FC in online learning reveal that it produces positive effects on learning, concentration and academic achievement when compared to other online learning methods (Tang et al., 2020). They also show that collaborative FC instructional design increases students' engagement and social presence in the course (Wu, Hsieh, & Yang, 2017). Wong (2020) highlights the difficulty for students to maintain attention levels in synchronous sessions. Stöhr, Demazière and Adawi (2020) indicate that while there is no statistically significant difference in average student performance when compared to face-to-face teaching, the FC approach in online learning leads to significantly larger spread - a polarisation - in students' outcomes.

Methodology

Research Procedures

The present study applied a mixed-methods approach to the empirical research process, e.g., it combined quantitative and qualitative research approaches, concepts and techniques (Johnson & Onwuegbuzie, 2004).

This methodological option assumes that the interaction between methods provides better analytical possibilities (Creswell & Plano Clark, 2013), offering a more robust answer to the initial question. However, it is recommended that themes or issues be shared between the different techniques, thus ensuring the unity of the research design and increasing the level of their integration (Yin, 2006).

The strategy of *concurrent triangulation* was adopted (Creswell & Plano Clark, 2013). That is, quantitative and qualitative data were collected simultaneously and subsequently compared to determine convergences, differences, and combinations. Analytical integration was the final stage of the process, whereby quantitative and qualitative results were integrated to produce coherent and mutually supportive information.

Participants and study context

The research took place in a 10th-year class, in a Portuguese secondary school, in Physics and Chemistry (PC), between 30/04/2020 and 2/06/2020.

The class consisted of 22 students, 10 students are female, and 12 are male. The average age was 15.05. The average result in PC in the previous term was 62%. All the students have internet-enabled devices at home and spend, on average, more than three hours online per day.

The consent to conduct the research was granted by all participants through the informed, clarified, and free consent document for participation in research studies.

Before the school closure, due to the pandemic, in this class, the FC model was being implemented and consisted of the online lesson held individually by the student at home and the face-to-face lesson held in school, at the subject time. For the online class, we used the *Edmodo* e-learning platform, where the programme contents were made available in the form of didactic videos accompanied by the monitoring quiz. In the face-to-face class, the teacher and students first discussed the online class: the contents of the video, any misunderstandings, and the answers to the quiz. Subsequently, the students were proposed activities that interspersed individual and group work, from the resolution of exercises in the adopted textbook, exploration of simulations and problem-solving.

With the closure of the schools, the teacher attempted to maintain the teaching-learning dynamic, that is, to implement in online learning, a proposal that would meet the FC principles. This proposal also had two components, asynchronous classes (ASC), where students, individually, explored the materials provided by the teacher and synchronous classes (SC), where, in groups, they discussed and expanded the contents explored asynchronously.

Design of the implemented proposal

Before implementing the proposal, we provided the students with a timeline with the regular schedule and tasks for the various ASC and SC. Each week, the students had two ASCs and two SCs interspersed. The duration of the SC was 90 minutes (defined by the school directorate).

For ASCs, a set of materials was made available on the *Edmodo* platform, on average, 36 hours before the SC. These materials focused on one curricular content and included a set of slides, a didactic video (average duration of 1.5 minutes), a quiz (with 5 questions), the pages of the textbook and the list of exercises that could be solved. Students had to explore these materials, make notes, answer the quiz and post a question on the platform addressed to a classmate about the explored content.

The SCs took place on the *Zoom* platform, with all students. Everyone discussed and extended the learning resulting from the exploration made during the ASC. We structured SCs by learning episodes. The first few minutes were devoted to welcome, informal dialogue and monitoring of the tasks set out in the ASC. In the next episode, we created two virtual rooms, and the students were divided randomly, in equal numbers into these two rooms (half of the students stayed with the subject teacher, the other half with the researcher, also a subject teacher). There they discussed the contents of ASC, the aspects that had raised the most doubts and analysed the answers from the quiz. In the third episode, students were randomly assigned to six virtual rooms (with 3 or 4 students) to work, in groups, on a set of activities that included problem-solving, exploring simulations, and analysing experimental results.

Collecting and processing data

To answer the research questions, we collected data from various sources: records from the *Edmodo* platform, statements produced on the *Zoom* platform, students' perceptions collected through a questionnaire and the researcher's reflections.

Edmodo platform data

The analysis of ASC used the percentage of students who completed the quiz, together with the respective average score and the number/type of interaction between students and teacher. To these data we applied descriptive statistics.

Learning Environment Questionnaire

The learning environment featured by complex interactions between material, organisational, functional and social parameters is one of the most important factors in students' personal and academic development (Moos, 1979). To explore the students' perceptions of the psycho-social aspects of the learning environment, we used a questionnaire. It was structured on the basis of two classroom learning environment research instruments, with ample evidence supporting their psychometric properties and cross-cultural validity (Charalampous & Kokkinos, 2017): The *College and University Classroom Environment Inventory* (CUCEI) (Fraser, Treagust, & Dennis, 1986) and the *What is Happening in this Classroom* (WIHIC) (Fraser, McRobbie, & Fisher, 1996).

These two instruments were translated into Portuguese and adapted to the online context. Thus, from the WIHIC questionnaire, seven scales (teacher support, involvement, student cohesiveness, cooperation, investigation, task orientation and equity) combined with three scales from the CUCEI (innovation, satisfaction and individualisation) were used. This resulted in a questionnaire with ten scales, each composed of five items (statements), with five possible levels of response: Almost never (1), Seldom (2), Sometimes (3), Often (4) and Almost Always (5). Table 1 exemplifies the items of one of the scales used in the questionnaire.

Table 1

Questionnaire scale

Involvement	1	2	3	4	5
I have the opportunity to express my opinion during classes (both synchronous and asynchronous)					
My ideas are used during the discussions/debates					
I ask the teacher questions during classes (both synchronous and asynchronous)					
I am asked to talk about how I solved a given problem					
I try to accomplish my tasks					

To ensure the validity of the questionnaire, we consulted experts in the field of Educational Technology, whose comments were incorporated into the final version. The reliability of the data obtained was estimated by calculating Cronbach's alpha coefficient for each scale of the questionnaire.

A Multimodal analysis of the discourses produced on the Zoom platform

The discourse analysis followed, with slight modifications, the approach proposed by Bower and Hedberg (2010). The authors propose a multimodal discourse analysis in web conferencing environments (webc), that integrates three elements: the mediation instruments (web conferencing), the participants (teachers and students) and the object of study of the lesson (curriculum-based tasks).

The discourse coding scheme, developed by the authors, makes it possible to ascertain whether the discourse is related to the mediating *technology*, to coordination *activities* between people or *curriculum content*. The discourse coding takes place in two stages: first, the learning episodes developed in the webc are categorised, and then the discourse that occurs in each learning episode is categorised.

In the first phase, we categorised episodes according to the following parameters:

- *Technology,* discourse regarding the tools available on the webc platform. The technology has two categories associated with it:
  - when only the teacher has access to most of the technological tools of the webc (Presentation).
  - when all of those involved have access to the webc tools for collaborative construction of knowledge (collaboration).
- *Interaction,* discourse regarding the coordination of interactions between people in a learning episode. This type of interaction has associated three categories of e-learning activity design:
  - teacher-centred activities: when there is the transmission of large amounts of information from the teacher to the students.
  - teacher-led activities: when short segments of information are transmitted, which may be examples or demonstrations, interspersed with activities carried out by the students. There is interaction and feedback.
  - student-centred activities: students carry out goal-directed tasks, and the discursive flow between students enables the construction of formal concepts through collaborative learning. The teacher adopts a mediating role.
- *Content*, curriculum-based discourse related to the learning of specific content in a learning domain. We categorised the content according to:
  - factual knowledge: knowledge of elementary and discrete information, such as terminologies, details, and elements.
  - procedural knowledge: knowledge associated with the skills to carry out a specific process, perform a particular technique or execute algorithms.
  - conceptual knowledge: knowledge in more complex and organised ways, includes knowledge of theories, principles, and models.

Subsequently, the discourse occurring in each learning episode is categorised. In discourse segmentation, the authors advise the use of the *sentence* as the unit of analysis because it is less exposed to the problems of segmentation and subsequent coding, which may affect the validity of the process (Bower & Hedberg, 2010). Categorisation of discourse is done based on the *subject* matter and the *nature of the interaction*. Categorisation based on *subject* matter enables one to determine whether the discourse is more related to the type of tasks inherent in the curriculum (*content*), to coordination between people in interaction (*activity*) or webc (*technology*). There is the possibility of combining the three categories, resulting in categorisation with nine categories: content (C), technology (T), activity (A), activity-technology (A-T), activity-content (A-C), technology-content (T-C), activity-content-technology (A-T-C), tasks sentiments/attitudes and unclassifiable.

We can also categorize the discourse according to the *nature of the interaction* into "question" and "statement". As "statements" are categorized phrases that do not elicit any response, whereas "question" elicits a response. The "question" or "statement" can be initiated independently or responsively. Thus, regarding the *nature of the interaction*, eight categories of discourse coding resulted: independent question (IQ), independent statement (IS), the question in response to an action (QRA), the question in response to a question (QRQ), the question in response to a statement (QRS), a statement in response to an action (SRA), a statement in response to a question (SRQ) and a statement in response to a statement (SRS).

We began the discourse categorisation process with the transcription of verbal and non-verbal discourse (actions), process with inherent discourse segmentation, as we used sentences as units of analysis and subsequently carried out their categorisation. To ensure the reliability of this process, we randomly selected a learning episode to be categorised by another researcher. We calculated the reliability of the coding process through the percentage of concordance, i.e., the number of sentences coded equally concerning the total number of sentences in that episode. We applied statistical tests to the categorised data.

Results

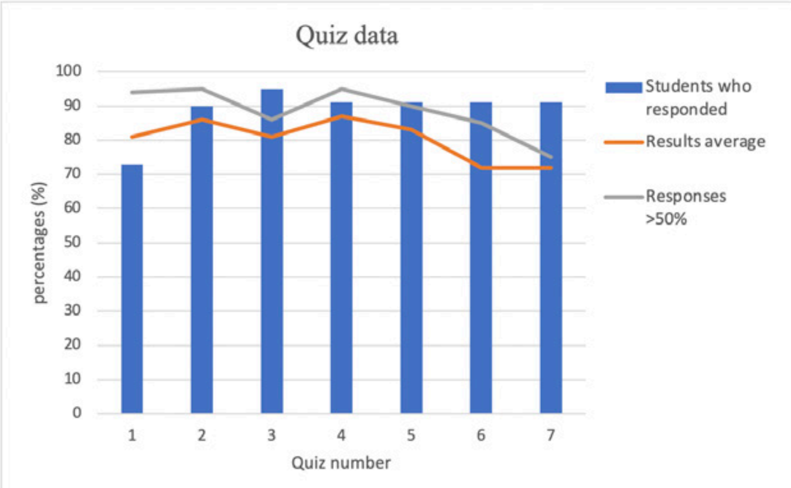
Results concerning the asynchronous class (ASC)

With the data taken from the *Edmodo* platform, it was possible to construct the graph in Figure 1, which combines the percentage of students who took the quiz with the respective average learning outcomes.

Per ASC, on average, 88.9% of students responded to the quiz. The overall average of results obtained in the quiz was 80.3%, and the percentage of students who scored above 50% was 88.5%.

Figure 1

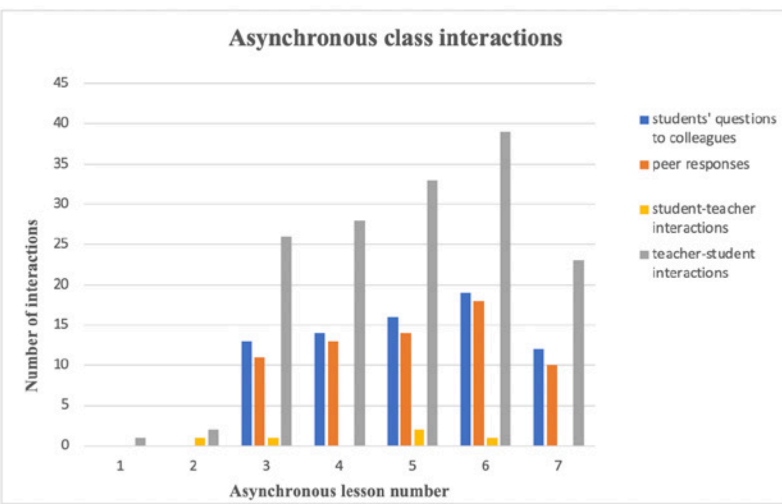
Quiz Data



We asked students to post a question on the platform addressed to a peer. The graph in figure 2 illustrates these interactions. On average, per ASC, students asked 14.8 questions to their peers related to the explored contents and the average response was 13.2. Students interacted on average .7 times with their teacher, and most of these interactions were questions related to curriculum content, while the teacher, on average, made 21.7 interactions with students. Some of the teacher's interactions were responses to students' queries, but most were comments on students' interactions.

Figure 2

Interactions through the platform



Results of the synchronous class (SC)

Eight classes were held on the *Zoom* platform, each lasting 90 minutes, with an average attendance of 21.5 students. Each class was divided into learning episodes, making a total of 21. Table 2 exemplifies dividing the class into learning episodes and shows the first categorization made in each episode.

Table 2

Division of the lesson on the 14/05/2020 into learning episodes and their categorization

14/05/20		Categorization				
Episode (E)	Task Description	Interface (Technology)	Interaction (activity design)	Task type (Content)	Number of students	Time (min)
E1	Welcome and verification of completion of ASC tasks.	Presentation	Teacher-centred	Checking the completion of summaries (declarative)	22	9:12
E2	Summary of contents covered in ASC	Presentation	Teacher-led	- ASC dialogue (declarative) - Correction of work (procedural)	11	28:50
E3	Distribution of students in groups by virtual rooms to solve a worksheet	Collaboration	Student centred	Group problem solving (conceptual)	4	45:03

Note. Adapted from "A quantitative multimodal discourse analysis of teaching and learning in a web-conferencing environment–the efficacy of student centred learning designs", por M. Bower & J. G. Hedberg, 2010, *Computers & Education*, *54,* 462-478.

We used the same categorisation matrix in the students' and teacher's discourse by the learning episode. The reliability of this process was 80.2%. Tables 3 and 4 show the result of the categorisation of episode 3, on 14/05/20, for the teacher and students, respectively.

Table 3

Categorisation of teacher's discourse

Teacher's discourse (14/05/20) Episode 3 (45:03 minutes)									
	IQ	IS	QRA	QRQ	QRS	SRA	SRQ	SRS	Total
Content (C)	2	1	1		4	2		4	14
Technology (T)									0

Teacher’s discourse (14/05/20) Episode 3 (45:03 minutes)									
Activity (A)	2	2		1	3		1	1	10
A-T		4							4
A-C	10	2	1		6	3		6	28
T-C									0
A-T-C	1				1				2
Sentiments/attitudes		1				2		5	8
Unclassifiable									0
Total	15	10	2	1	14	7	1	16	66

Note. Adapted from “A quantitative multimodal discourse analysis of teaching and learning in a web-conferencing environment–the efficacy of student centred learning designs”, por M. Bower & J. G. Hedberg, 2010, *Computers & Education*, *54,* 462-478.

Table 4

Categorisation of students’ discourse

Students’ discourse (14/05/20) Episode 3 (45:03 minutes)									
	IQ	IS	QRA	QRQ	QRS	SRA	SRQ	SRS	Total
Content (C)							23	6	29
Technology (T)									0
Activity (A)	1						3	4	8
A-T								1	1
A-C		2				1	3	1	7
T-C									0
A-T-C		1					2	11	14
Sentiments/attitudes		1							1
Unclassifiable								1	1
Total	1	4	0	0	0	1	31	24	61

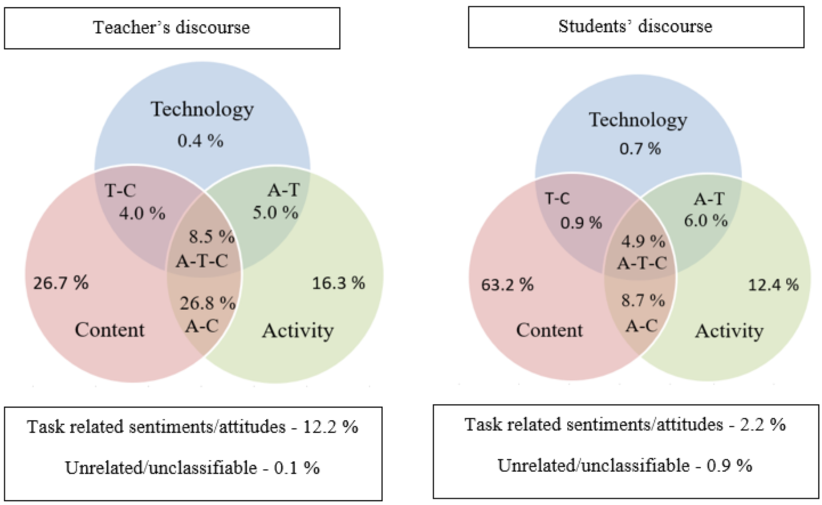
Note. Adapted from “A quantitative multimodal discourse analysis of teaching and learning in a web-conferencing environment–the efficacy of student centred learning designs”, por M. Bower & J. G. Hedberg, 2010, *Computers & Education*, *54,* 462-478.

The categorisation of the 21 learning episodes resulted in 1490 discursive interactions (coded units of analysis) of the teacher and 978 of the students.

We present the percentage distribution of these interactions by *subject* in the graph in Figure 3.

Figure 3

Percentages of units of analysis coded in each category across the 21 learning episodes



Note. Adapted from "A quantitative multimodal discourse analysis of teaching and learning in a web-conferencing environment–the efficacy of student centred learning designs", por M. Bower & J. G. Hedberg, 2010, *Computers & Education*, *54,* 462-478.

A Chi-square tests for homogeneity of the overall proportions of the students' and teacher's discourse, regarding the *subject* was used, which revealed significant differences between the two, X^2 (df =8; N=2468) = 407.19; p< .001. Subsequently, we compared the individual categories using a two-populations proportions equivalence test to determine which categories of teacher and student discourse were significantly different. The results of this comparison are shown in Table 5.

Table 5

Tests for homogeneity for teacher and student discourse in the categories of the interaction themes

The subject of interaction	Z value	*P* value
Content	-18.99	< .001*
Technology	- .950	.443
Activity	2.746	.008
A-T	-1.057	.326
A-C	12.41	< .001*

The subject of interaction	Z value	*P* value
T-C	5.248	< .001*
A-T-C	3.603	.001*
Sentiments /attitudes	10.32	< .001*
Unclassifiable	-2.436	.010

Note. * indication of significant result for α < .00556, resulting from adjusting the significance level α= .05/9

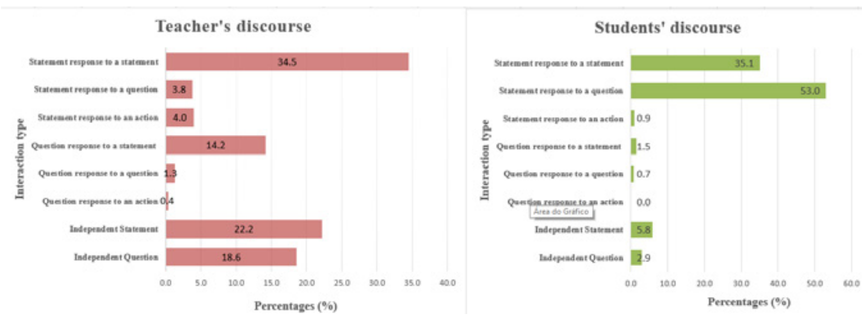
In the *content* category, the students contributed 63.2% of the discourse interactions and the teacher 26.7%. This statistically different result indicates that the students' discourses mainly focused on acquired or in-progress aspects of the curriculum.

Teacher contributions were higher and statistically different in *A-C*, *T-C*, *A-T-C* and *Sentiments and Attitudes*. On the one hand, it shows that teacher discourse was more directed towards the configuration or coordination of the activities and the class and that when the discourse was about the curriculum, it relied on technological tools. The high percentage in the *Sentiments* and *attitudes* category shows that the teacher used an encouraging discourse that valued students' participations.

Figure 4 presents the percentage distribution of discourse interactions based on the *nature of the interaction* presented in the chart.

Figure 4

Discursive contributions of the teacher and students according to the nature of interaction



A Chi-square tests for homogeneity of the overall proportions of the students' and teacher's discourse regarding the *nature of the interaction* was used, which revealed significant differences between both, X^2(df =7; N=2468) = 962.2; p< .001. Subsequently, we compared the individual categories using a two-populations proportions equivalence test to determinate which categories of teacher and student discourse were significantly different. Table 6 shows the results of this comparison.

Table 6

Tests for homogeneity for teacher and student discourse in the categories of the nature of interaction

Nature of the interaction	Z value	*p* value
Independent Question	13.74	< .001*
Independent Statement	12.51	< .001*
Question in response to an action	2.446	.1166
Question in response to a question	1.513	.2585
Question in response to a statement	12.90	< .001*
Statement in response to an action;	5.248	< .001*
Statement in response to a question	-29.44	< .001*
Statement response to a statement	-0.306	.9372

Note. * indication of significant result for α < .0025, resulting from the adjustment of significance level α= .05/8)

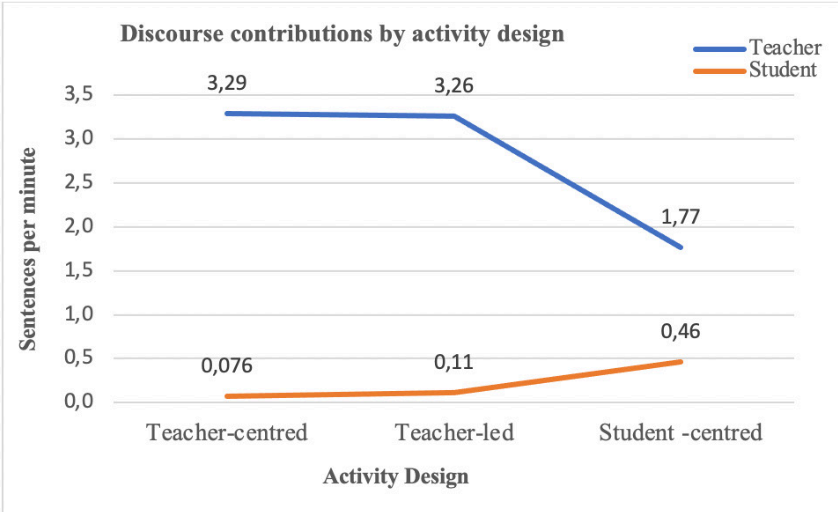
The most frequent and statistically different categories in the teacher's discourse are IQ, QRS, IS and SRA. These categories are directly related to the different roles the teacher was assuming throughout the learning episodes. The high number of IS and SRA happened at an early stage of SC and is associated with a more directive and instructive role of the teacher. On the other hand, when the activity was *teacher-led*, the teacher's questioning was systematic, hence the high IQ and QRS.

The student's discourse presents a high number of SRQ, which evidences a more responsive role, verified not only in *teacher-led* activities but also in *student-centred* ones.

In addition, we analysed the discursive contributions also according to the activity design (Bower & Hedberg, 2010). For this purpose, we selected the learning episodes categorised with the same design and for each episode, the ratio between the total number of interactions spoken by the teacher and the duration of the episode in minutes was calculated. The average of these ratios gives the sentences spoken per minute, by the teacher, for a given activity design. We conducted a similar procedure for the students' discourses. However, their discourse contributions were normalised, when we divided the total number of interactions spoken by the students, by the duration of the episode (in minutes) and by the number of students present in that episode. The average of these ratios gives the sentences spoken per minute and per student for a given activity design. The graph in figure 5 illustrates these contributions for the different activity designs.

Figure 5

Discursive contributions by activity design



Note. Adapted from "A quantitative multimodal discourse analysis of teaching and learning in a web-conferencing environment–the efficacy of student centred learning designs", por M. Bower & J. G. Hedberg, 2010, *Computers & Education*, *54,* 462-478.

We can see that the learning design influences the number of interactions produced in the SC. As expected, as the activities highlighted the role of the students, the number of interactions produced by them increases and, consequently, the number of interactions produced by the teacher decreases.

Overall results (learning environment)

Table 7 presents the different scales of the questionnaire used to assess the psychosocial aspects of the learning environment. For each scale, its internal consistency was estimated through Cronbach's alpha (α). In general, an instrument has adequate reliability when α is at least .70 (Nunnally, 1978). Except for the *satisfaction* scale, all other scales have reliability values equal to or greater than .7. The low mean values of the interscale correlations allow us to assume the discriminant validity of the different scales of the instrument.

Table 7

Results, internal consistency reliability and discriminant validity of questionnaire scales

Scales	Average	Standard deviation	α	Mean correlation with other scales
Teacher support	4.58	.67	.72	.30
Involvement	4.36	.78	.80	.35
Student cohesiveness	4.47	.82	.88	.27

Scales	Average	Standard deviation	α	Mean correlation with other scales
Cooperation	4.46	.73	.83	.29
Investigation	4.25	.78	.91	.40
Task orientation	4.68	.58	.84	.35
Equity	4.69	.58	.83	.28
Innovation	4.53	.70	.81	.34
Individualisation	4.50	.70	.70	.32
Satisfaction	4.46	.82	.62	.17

We can verify that all the scales of the questionnaire have average values higher than 4. However, *equity* (to what extent there is equal treatment of students, including the distribution of praise, questions, and opportunities), and *task orientation* (to what extent compliance with the planned activities is ensured and focus on the lesson content is maintained), stand out as the most valued characteristics of the learning environment. By contrast, the least valued scales were *investigation* (to what extent students mobilise research strategies to solve more complex problems), and *involvement* (to what extent students show attention, interest, and participation).

Discussion

In the ASC, a set of slides, a short video and a quiz were made available, and we asked students to explore these materials and answer the quiz. Except for the first lesson, the percentage of students who answered the quiz was equal to or higher than 90% (figure 1), which demonstrated a high degree of commitment with the task. The quality of the results obtained in the quiz is noteworthy, as the average score was 80.3%, and 88.5% of the students obtained, on average, a score of 50% or higher. Assuming that there is articulation between the materials made available, their exploration will offer better learning conditions (Kenski, 2020) and allow students to control and build information according to their learning styles (Fauzi & Hussain, 2016). These results suggest the complementarity and articulation of the materials provided and respect for the students' learning styles. They show that *student-content* interactions were fruitful, as they allowed students to construct meanings, relate the contents to prior knowledge (Moore, 1989) and then apply them in solving the quizzes. This is aligned with studies showing that asynchronous communication can develop student autonomy and agency, promoting better academic performance (Kent, Laslo, & Rafaeli, 2016).

Students had to post a question addressed to a colleague on the *Edmodo* platform. The analysis of the interactions produced in the ASC (Figure 2), shows that while this strategy was not accounted for in the students' evaluation, no students asked questions on the platform (ASC 1 and 2). The teacher's subsequent indication of the valuation of students' questions and answers, led to an increase in the number of interactions. Besides answering colleagues' questions, some students also presented questions to other colleagues, obtaining an average of 14.8 questions and 13.2 answers per ASC. Therefore, valuing the participation in the proposed activities is one of the factors that increases students' participation, ensuring an efficient preparation of the online class (Kim, Kim, Khera, & Getman, 2014).

By analysing the students' answers posted on the *Edmodo* platform, their careful structuring and scientific rigour stand out, as can be seen in one student's answer to a question of an experimental nature:

> Ju, the selection of multimeter scales should be made with the circuit off to avoid damage or fuse blowing. Since ammeters are very sensitive and are usually protected by fuses, which will blow if the values of the electric current exceed those of the scale. (Student I)

The asynchronous nature of the class offers advantages by extending the time between the question and the answer given by the student, as it allows more time to process the information, thus promoting more reflective answers (Silva & Pereira, 2015). However, it also calls for students' self-regulation skills, which may hinder learning if these skills are not present (Lai & Hwang, 2016). In this sense, it is essential to structure the activities clearly and precisely with support mechanisms for the students, such as the teacher's feedback. By providing adaptive feedback and instructional support appropriate to the different needs of the students, the teacher minimises possible constraints of the approach (Kim et al., 2014).

Figure 2 shows a low number of student/teacher interactions, on average .7 interactions, contrasting with teacher/student interactions, 21.7. Cross-checking these results with those of the questionnaire, we can see that although the scale with the highest score was *equity*, the highest-scoring items of the whole questionnaire were: "Teacher tries hard to help me" (4.90) and "Sessions are organised (both synchronous and asynchronous)" (4.90) belonging to the *teacher support* and *task-orientation* scales, respectively. Therefore, along with the organization (*structure*) of the sessions, the *teacher-student* interactions, which aim to stimulate or maintain students' interest in the content and motivation to learn (Moore, 1989), were perceived by students as those that best characterize the online learning environment. Martin and Bolliger (2018) describe similar results with higher education students by demonstrating that engagement strategies based on *student-teacher* interactions were the most valued by them in online learning. However, a study conducted during emergency online learning with higher education students showed that engagement strategies based on *student-content* interaction, e.g., screen sharing, summaries, and class recordings, were perceived to be the most effective (Abou-Khalil et al., 2021).

Within the scope of this study, the evidence presented reinforces the idea that effective communication is one of the success factors of online learning and that this, being a social activity, is strengthened if carefully nurtured by the teacher (Berge, 2002). Although the success of distance education courses is directly dependent on adequate opportunities for dialogue and well-structured materials (Moore & Kearsley, 2007), in this case, the students' familiarisation with the procedures of the FC model and the recognition of the contribution of the online class exploration (ASC) to Physics learning (Ribeirinha & Silva, 2020), were also decisive.

Concerning the SC, the use of a web conferencing platform, thanks to its communication interfaces, allowed for real-time multidirectional interactions, combining audio, image, and movement, approaching the face-to-face class. However, SC can be more tiring and less varied in terms of sensory stimuli for the student (Dotta & Oliveira, 2014), contributing to students' passivity. Hence, the need to create greater interactivity in the SC through different learning episodes, with distinct designs, and assign different roles to the participants.

Thus, given the pandemic context, the first episode of the SC was welcome. With its *teacher-centred* design, this activity was decisive in creating a friendly, relaxed, and cohesive atmosphere in the group. In the teacher's discourse analysis, the category *Sentiments and attitudes* is frequent (Figure 3), showing that the teacher used an encouraging discourse that valued the students' participation. This positioning highlights the *social presence* of the teacher (Garonce, 2009), whose function is to encourage students to interact and help them develop skills to work in groups, virtually. The questionnaire results reinforce the teacher social presence by indicating that the most-voted scale was *equity*, and within this scale, the item "I am encouraged and motivated in the same way as my colleagues" (4.80).

In this episode, there was also a control of the activities carried out in the ASC, namely the syntheses which the students had to make (they showed their notes), and the clarification of how the SC would proceed. Therefore, when we analyse the *nature* of the teacher's interactions, a high number of *IS* and *SRA* in this initial phase of the SC is highlighted, associated with a more directive and instructive role.

The second learning episode of the SC had a *teacher-led* design. Here, a discussion was established about the contents covered in the ASC, and possible doubts of the students were clarified. In this phase, the teacher's questions were systematic and specific, thus allowing the participation of all students, hence the high number of *IQ* and *QRS*. In science teaching, questioning is seen as a facilitating tool for learning by promoting the explicitness of students' prior knowledge, involving them in the constructive and reflective processes of active learning, and developing argumentation skills (Loureiro & Neri de Souza, 2009). During emergency online learning, Abou-Khalil et al. (2021) highlighted Q&A activities as the *student-teacher* interaction strategies perceived by students as the most effective and the ones that engaged them the most in online learning.

During this episode, the teacher used technological tools (whiteboard, simulations, spreadsheets, and apps.), which were easily accessible in this context, and by sharing the screen, she demonstrated in real time, the conclusions reached by the students. In this way, the teacher's discursive interactions, when dealing with aspects of the curriculum (*content*), she combined technology tools (*T-C* and *A-T-C*). The use of ICT can provide an unpredictable learning experience, which is not usually available in the face-to-face class and may increase the efficiency of the learning process (Bernard et al., 2004). Although this combination aimed to stimulate students' attention and participation, the questionnaire analysis shows that *involvement* was one of the least-scored scales (4.36), and the item "I ask the teacher questions during synchronous sessions" was the least voted. This agrees with the results of the students' discourse analysis that shows a high number of *SRQ,* which evidences a more responsive role of the student. Moreover, other studies produced in this context reveal the difficulty of synchronous online learning to arouse students' motivation and sustain their attention (Wong, 2020).

With a *student-centred* design, the third learning episode meets the results of studies that indicate the students' need for social connection in an online environment, as a consequence of physical isolation (Mandernach, 2009). Therefore, small groups of students were randomly distributed by virtual rooms, with a task assignment. This activity was responsible for the highest number of interactions per minute per student (Figure

5) and had a percentage increase concerning the previous design of 318%. While the teacher's discursive interactions decreased by 46%, being more directed towards the configuration or coordination of the activities and the students (*A-C*). It highlights the centrality of the learner during these learning episodes.

In these learning episodes, we proposed several tasks that allowed for the (re)construction of knowledge based on research and investigation. The students' discourse analysis shows a high number of *SRQ* based on *content* (Figure 3 and 4), which, during this episode, are primarily in response to questions posed by groupmates. However, when we cross-check these results with those of the questionnaire, the *investigation* scale is the one with the lowest score (4.25), which suggests that, although there were *content*-based interactions, some groups had difficulty to mobilise research strategies to sustain knowledge construction. This fact is also present in the reflections of the researcher, as shown in the following diary entry:

> As I move between rooms, I notice entirely different scenarios. There are rooms in which students enthusiastically discuss the results, the worksheet on the screen is full of formulas, and when they notice my presence, they immediately show me the simulation working. In other classrooms, an immaculate worksheet appears on the screen. When they notice my presence, they tell me that they have finished and have no doubts" .(21/05/2020)

Previous studies report that engagement strategies, based on *student-student* interaction, were perceived by students as the least crucial of the online learning strategies (Martin & Bolliger, 2018; Abou-Khalil et al., 2021). Others point out that collaborative interaction in virtual environments includes short discussion threads, descriptive and superficial knowledge rather than finding deeper explanations for the phenomena under study (Järvelä & Häkkinen, 2002). The benefits of group learning are undoubted. However, they depend on various factors, such as task complexity, previous experience and individual contributions to the group (Gadgil, Nokes-Malach, & Chi, 2012). The randomness in forming groups, the students' unfamiliarity with the procedures and rules of group work in a virtual environment and, above all, the intermittent presence of the teacher (who moved between rooms) seems to have limited the benefits of group learning and engagement with the tasks (Table 7).

A proposal to improve this learning episode could be the formation of groups according to the students' preferences, a more constant presence of the teacher in less autonomous groups and exploration scripts with more oriented tasks.

Conclusions

This study aimed to evaluate a pedagogical proposal, based on the Flipped Classroom model, implemented online during the lockdown caused by Covid-19. The study allowed the conclusion that the implemented proposal presented an organised sequence and with clear objectives. It created a learning environment with a flexible structure to enhance students' interactions with the content, and with the teacher. It highlighted the importance of the teacher's feedback in the students' difficulties, encouragement and support, contributing to the development of their autonomy and accountability for the learning process.

The design presented in the ASC enhanced *student-content* interactions by respecting students' learning styles, leading to high rates of commitment with task completion when adequately encouraged. Thus, ensuring an efficient preparation of the ASC.

In evaluating the SC, the multimodal discourse analysis highlighted interaction patterns consistent with the different learning episodes. The activities were organized and complemented the study initiated in the ASC, as recommended by the FC model, through dynamic and interactive approaches to the contents. However, although times of interaction between students were made possible, the randomness in the formation of working groups, associated with an inconstant presence of the teacher, inhibited the advantages that could result from this interaction. This had implications for the students' involvement with the proposed tasks.

Therefore, we conclude that integrating the FC model in online learning allows teachers to orchestrate activities based on an active pedagogy, capable of raising cognitive conflict to promote appropriate learning supported by intentional and continuous feedback.

Given the characteristics of the study, we should highlight the following limitations. First, the effect of the novelty of SC for secondary school students may have conditioned the results. So, longer research times would have been ideal. In calculating the reliability of the categorisation process, we should have included more learning episodes to cover a broader spectrum of interactions. The results for the third learning episodes may not represent the global pattern of interactions of the class, as the researcher could not be simultaneously in all the virtual classrooms at the same time. Another limitation relates to the impossibility of generalising the empirical results obtained, as they refer to a very particular research context.

Therefore, we recommend a more extended research period for future work to assess whether the positive effects of the proposal persist over time. It would also be essential to compare the effectiveness of the FC model in the online format with the conventional format.

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