Online learning mediated by social teaching platforms: an experience from a flipped undergraduate physics course in renewable energies

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Abstract

Active learning strategies and information technology-based pedagogies are perceived as beneficial and their use and development in academic courses is fast increasing. Faculties can use them to design courses that are challenging and fresher, creative, and meaningful for students, to meet students' needs and to promote the learning of contents in a social environment, fostering cooperation and the exchange of ideas among peers. Among the active learning strategies recently developed, the peer-instruction and the flipped classroom are prominent in this field. It has been shown that these practices help students in their understanding of contents and consequently in reaching better results in final exam scores. The Covid-19 pandemic in 2020 and 2021 has forced classes in many academic institutions to move to remote teaching under emergency conditions and has deprived students of much of their social interactions. We show here an experience on applying online learning mediated by social teaching platforms and flipped classroom concepts to an undergraduate course on renewable energies provided amid the Covid-19 pandemic at the Physics Department of the University of Cagliari (Italy) in 2020. The constraints of forced distance learning have been turned into an opportunity to test an alternate course format in a complete online environment. An analysis on students' feedback about our learning method has been performed by a post-diagnostic satisfaction questionnaire, indicating an overall positive effects of active learning strategies in the students' learning experience. The analysis of their achievements during the course provides confirmation for the positive outcome and shows that the flipped classroom architecture is as robust as the traditional methods when facing the constraints of remote learning.

Keywords

Online learning; Distance learning; Flip teaching; Information technology-based pedagogies; Social platforms; Renewable energies

1. Introduction

In the last decade, online teaching has gained more and more attention in higher education (Lederman, 2013; Mitchell, 2014). In the era of social media, where not only people's lives but also contents offered by schools and institutions are moving online, accountability of resources, the need of developing critical and creative thinking, the request of social and cooperative skills have encouraged faculties in considering the ways they organize curricula and lectures to meet the needs of learners (see Karim et al., 2020 and references therein).

In the traditional education system, the role of the instructor is central, since the learning process chiefly involves frontal lectures, and the instructor is the one who imparts knowledge onto the student. Frontal lectures are necessary to teach students in situation where they hold no prior knowledge in a particular field. However, such setup has demonstrated shortcomings that could be impacting students' education, their ability to retain, analyze, and apply knowledge and the development of skills important for their careers outside of academia (Hattie, 2008; Marks et al., 2014; Schwerdt & Wuppermann, 2011). Some of the noted limitations include the small amount of teacher-student interaction, the rigid pace of the lecture, and the fact that lectures only take advantage of one information delivery method (Goodwin, 2013; Toto & Nguyen, 2009). On the contrary, modern educational systems put students at the center of the learning process and, in this context, the instructor is not only a lecturer, but also the coach who provides students with assistance and guidelines to explore contents independently or within a group (Gilboy et al., 2015; King, 1993; Suhre et al., 2019). This would allow students to develop professional competences and skills requested also by their future employments even out of the academic. Even if frontal instruction continues to be predominant in higher education, the increased capabilities of web-based and collaborative instruction technologies have raised expectations for the effectiveness of online learning (Means et al., 2013; Mothibi, 2015). Concerning digital natives, it has been show that the latter feel comfortable with interactive technologies (Tapscott, 2010; Zax, 2009) which, in turns, do not seem to be a detractor for them in learning (DeNoyelles et al., 2015; Vestal, 2016). Interactive content also leads to statistically significant learning gains compared to static content (A. D. Edgcomb et al., 2015; A. D. Edgcomb & Vahid, 2014; A. Edgcomb & Vahid, 2015).

Such web-based educational strategies have been implemented in new pedagogies such as the "blended education" (Bernard et al., 2014; Shachar & Neumann, 2010), which aims at combining traditional teaching methods, as frontal, face-to-face (F2F) lectures, with distance, web-based, education classroom. The blended education method mixes together synchronous and asynchronous learning activities where students learn at different times by means of both frontal and distance activities (Faulconer et al., 2018; Martin et al., 2017). Blended education is also well supported by information and communications technology which provide the basic tools to design and support distance education models (Ardid et al., 2015; Gómez-Tejedor et al., 2020). Online learning strategies have been implemented also in physics and their positive effects on students' academic performances are widely documented in literature (Broadbent & Poon, 2015; Embacher & Primetshofer, 2008; Gütl et al., 2011; Hill et al., 2015; Luksic et al., 2007), also in comparison to results in traditional learning (Demirci, 2010; Sulaiman, 2013; Vo et al., 2017). A large body of literature points out that students may obtain better results when online learning strategies are used in combination with active learning ones (Martin et al., 2017; Means et al., 2009; Mothibi, 2015; Nguyen, 2015).

Active learning strategies are those pedagogical methods that include interactive components during lecture where students learn more by doing (Liberatore, 2017). This method is based on the idea of generative learning (Osborne & Wittrock, 1983), in which learning activities are designed to promote cognitive rather than behavioral processes. Such learning activities require students to link together pieces of knowledge previously acquired in order to create meaning in a given context and to apply them to different contexts, thinking critically (S. C. Lee et al., 2019). Active learning improves student – teacher interactions, gives opportunities for real-time feedback, and increases student engagement (Liberatore, 2017; Miller et al., 2018). This is at the base of the social constructive theory of learning with technology (Brown & Campione, 1996), where successful learning requires continuous conversation between learners as well as between instructors and learners.

Reconsidering the role of teachers promoting active learning strategies represents the base of the "flipped classroom" (FC), also known as "inverted classroom" (Lage et al., 2000). In this method, students' performances in learning are "flipped" with respect to traditional education. Indeed, while in the latter the teacher explains concepts during class and the students study them at home, in the FC model students prepare the class content on their own at home, while during class they work together and discuss matters as a group (Gómez-Tejedor et al., 2020). In FC, many active learning strategies are used, e.g., students read before they come to class, allowing teachers and lecturers to focus on students' reflections on topics covered during the class encouraging discussions and critical thinking. FC activities are in general organized in three steps (Gilboy et al., 2015): before class, during class (F2F) and after class. Before class, students have access to the material (textbooks, videos, online lectures and so on) and have a first contact with the contents of the course in preparation for the in-class activities. Then, students face up with higher level learning such as applications, analysis, discussions, and synthesis of the contents discussing with the lecturer in a F2F situation. Finally, after class they study, elaborate, and summarize their knowledge with assessments and final exams. One of the main promising features of flipped classrooms resides in the out-of-class activities, which allow students to engage with and reflect on the parts of the instructional material they find more challenging (Gómez-Tejedor et al., 2020; Howitt & Pegrum, 2015; Jaster, 2017). The advantage of allowing students to read the material in advance is twofold: on one hand, it has been shown that students learn better if they face up with the material in advance (Karim et al., 2020). On the other hand, students can send feedback to the instructor which can be used to create a proper "time for telling" (Schwartz & Bransford, 1998) during F2F activities. Positive effects of FC span over many areas of learning (Dobson, 2008; Johnson & Kiviniemi, 2009; Marcell, 2008; Narloch et al., 2006), especially concerning Science Technology and Mathematics (STEM) and physics (Asiksoy & Özdamli, 2016; Deslauriers et al., 2011; Şengel, 2016). In the last decade, FC has been further implemented in online learning with the use of no in-class lectures. Instructors ask students to engage with short lecture videos and concept questions associated with each video outside of the class and using the entire class time for active engagement (Karim et al., 2020). Beside the potential benefits of the FC methodology, some criticism appears concerning two main issues: lecturers face up with considerable work to create and coordinate learning materials and activities, especially with high quality flipped videos; there can be some resistance by students in doing the required work at home and come prepared to class to participate in planned activities (Herreid & Schiller, 2013; Milman, 2014). In the latter case, it has also been suggested (Tomas et al., 2019) that posting videos online may not offer sufficient scaffolding for some students, as they are unable to ask questions to clarify their ideas in real time, and similarly, teachers cannot pose questions to check for understanding as learning is taking place (Howitt & Pegrum, 2015).

The creation of social environments with a high degree of interactivity is also considered a good practice in online learning and teaching. Social interactions and the exchange of knowledge between teachers or lecturers and between students are well implemented in online discussion forums. These platforms facilitate distance learning and interactions (Miller et al., 2018). Indeed, their asynchronous nature allows students to learn with their own rhythm and gives freedom in organizing their time to study (Nguyen, 2015). Social platforms for education foster student engagement in learning, allowing for discussions with instructors and between learners at any time, realizing a major advantage over other forms of communication (Miller et al., 2016; Nandi et al., 2009). This, in turn, helps in gaining confidence during lectures and when interacting with colleagues and instructors. Other advantages of online discussion forums include greater student participation and enhanced academic performances. Moreover, some studies indicates that students participate more in online discussions than in the traditional classroom (Durham, 1990; Miller et al., 2016, 2018; Smith et al., 2000). Other studies indicate that online discussion forums allow them to increase the exchange of ideas and improve their ability to make connections between concepts among diverse contexts (Miller et al., 2018, and refs therein). One important feature of online forums is that participants have access to course materials in advance. This leads to a series of advantages for students such as to be better able to follow F2F teaching and to ask more meaningful questions during classes, as well as to perform better on exams (Deslauriers et al., 2011; Dobson, 2008; Johnson & Kiviniemi, 2009; Marcell, 2008; Narloch et al., 2006; Schwartz & Bransford, 1998).

Collaborative annotation systems have recently been developed and used in education as social learning communities. Online annotation systems are computer-mediated communication tools that allow groups of people to collaboratively read and annotate material online. The social platform “Perusall” is one of them. Perusall is an online, social platform designed by Eric Mazur from Harvard University (Crouch & Mazur, 2001; Lasry et al., 2008) to promote high pre-class reading compliance, engagement and conceptual understanding (Miller et al., 2016). The instructor creates an online course on Perusall, uploading electronic files as materials (video, textbooks, notes), and then generates reading assignments. Students annotate the assigned reading by posting (or replying to) comments or questions in a chat-like fashion. The platform automatically assigns scores to students’ annotations as an indicator of the quality of each student’s involvement in collective reading assignments. A report (the so-called “confusion report”) can be automatically generated to have an overview of the content of students’ annotations. Teachers can read and analyze these reports to delve deeper into specific content that needs further clarification during lectures. Perusall allows teacher to encourage students self-drive and learning outside the classroom before face-to-face meetings with teachers in the classroom (Teo et al., 2014).

Research has shown that the use of a collaborative annotation systems together with active learning strategies can enhance student learning in many instructional settings in physics classes and in various types and levels of student populations. Cooperative problem solving with peers have been widely used in physics, enlightening their positive influences in helping students to develop effective problem-solving strategies and a coherent knowledge of physics (Heller et al., 1992; Heller & Hollabaugh, 1992). Indeed, many studies have shown that students prefer the diverse set of resources on the Internet compared to a single, text-heavy textbook and online annotation systems increase student learning across many different educational settings (C. S. Lee et al., 2013; Stelzer et al., 2009). The social nature of Perusall offers a wide range of activities which that provides both students and instructors with constant feedback on how students are engaging with the reading assignments.

In this paper, we report an experience on the implementation of the FC method in an undergraduate course in renewable energies mediated by social platforms. The organization of such courses in universities responds to an increasing interest on this topic among students, and to meet industry requests of specialized workers (Marks et al., 2014; Tomas et al., 2019; Yasnin et al., 2017). To make courses more appealing and to present the most up-to-date renewable energy issues, lecturers started to implement a series of information technology-based innovations in learning (Ebers Broughel et al., 2017). They capture students’ curiosity and further encourage them to better understand, interpret, be competent, and build creativity in physics. The synergies among these innovative teaching practices may advance teaching and learning (Kassens-noor, 2016).

In 2012, the Physics Department of University of Cagliari (Italy) instituted a course on renewable energies for undergraduate students. The course has been provided with a combination of face-to-face lectures and the implementation of different active learning strategies during the years. The arrival of the Sars-Cov II pandemic in 2020 (World Health Organization, 2020), forced many universities to teach their educational programs without physical presence, leading to an increment of online resources for lecturers and learners. The Physics Department of University of Cagliari has not been exempted from these changes and the pandemic has demanded a scrutiny activity about student learning and online teaching. For this reason, at the beginning of 2020, the Renewable Energies course has been redesigned and organized with online activities only. To foster students' engagement in this new learning environment, traditional frontal lectures alone have left room for new modern methodologies and learning instruments such as the FC. Moreover, a large use of social platforms as Perusall (see *Perusall Website*) or Moodle (see *Moodle Website*) has been done to promote students' interactivity during lectures. In experiencing this new learning strategy, we addressed a research question about the inquiry of possible learning gains in students. While the course design is meant for a small class size, we were interested in understanding the impact of innovative teaching strategies in enhancing students' engagement and learning. This research follows the line of previous papers in the field (Supraptono & Prasetiyanto, 2019; Tomas et al., 2019).

2. Methods

2.1 Participants

The sample consists of 24 students, 19 of them actively participating to the course. Concerning gender, 11 students were males, eight females. Among the 19 students actively participating to the 2020 course, only 13 participated to the satisfaction questionnaire, whereas all of them solved the proposed exercises. 10 students are in between 18 and 22 years old, while three are in between 23 and 27 years old. All students attended the course online. An informed consent to participate in the study has been obtained from participants. Students gave their informed consent to publish the results of the study.

2.2 Course description and organization

The course "Renewable Energies" ("Energie Rinnovabili" in Italian) has been provided at the Physics Department of the University of Cagliari, Italy, between March and June 2020 during the lock down caused by the Covid-19 pandemic. For this reason, the course has been designed and organized in an online environment making a large use of Perusall and other online learning platforms such as Microsoft (MS) Teams and Moodle. The course was optional for third-year students in the undergraduate curriculum in physics.

The course syllabus comprised 11 topics spanning from renewable energies to energy efficiency in transportation and buildings: 1- Introduction to the energy problem ("Introduzione alla questione energetica"); 2 – Fossil Fuels and CO_2 ("Combustibili fossili e CO_2"); 3 – Wind Energy ("Energia eolica"); 4 – Hydroelectricity, Waves and Tides ("Energia idroelettrica, onde e maree"); 5 – Geothermal energy ("Geotermia"); 6 – Biomasses ("Biomasse"); 7 – Solar thermal and thermodynamic technology ("Energia solare termica e termodinamica"); 8 – Solar cells ("Celle solari"); 9 – Cars, trains and bicycles ("Automobili, treni e biciclette"); 10 – Planes and Ships ("Aerei e Navi"); 11 – Buildings ("Edifici").

For each subject, the reading material (free textbooks and notes) is uploaded in advance on the Perusall platform. Other kind of material such as video-lectures and related slideshows and exercises for students on each subject have been collected through the Moodle platform which has served as a repository. Finally, student-teacher interaction has occurred by means of MS Teams. Student activities and course materials for each subject have been organized in three sequential steps, spread over two weeks, as follows:

1. Step 1: Students critical read of written assignments through Perusall platform. One-week time is allotted to complete the assignment. After week 1, a 45-minute video-lecture on the topic is made available on the Moodle webpage.
2. Step 2: During week 2, after listening to the video-lecture, students solve the exercises of a written assignment on a given subject. Then, they submit their handwritten and scanned solution on the Moodle website within the week.
3. Step 3: At the end of week 2, a live exercise session of about 1 hour takes place on MS Teams, during which students take turns on offering their solution to the exercises and results are critically discussed with the instructor.

While each topic takes two-week time to complete, one new topic is introduced every week, so that the final assignment of one topic is done during the same week as the preparatory reading for the next one. In total, 11 online meetings (11 hours, one for each topic) have been allocated for the discussion time.

At the end of the semester, each student is additionally required to discuss a short presentation (10-15 minutes) on a topic of choice related to the curse syllabus. Results and calculations presented by students are discussed in front of the class in a MS Team session. Final scores are attributed with the following algorithm: comments on the assigned material on Perusall (10%), solution of exercises (30%), final presentation (60%).

2.3 Learning strategies

Activities during the course were organized according to active learning strategies and a large use of FC method has been done throughout the course. We used a revised version of “standard” FC steps, “before class – F2F – after class”, with after class and F2F steps reversed. Step by step assessments and exams have been performed before the F2F discussion time. On the one hand, the choice to reverse standard FC steps allowed the lecturer to obtain a complete picture of student level of learning and assessments lecture by lecture, preventing possible misunderstandings or solving intermediate (conceptual) doubts, also about the exercises. On the other hand, students could reinforce higher level learning not only about the content of lectures, but also on the step-by-step assessments requested by the course and on their general understanding.

F2F step has been organized as a discussion time using MS Teams. Students shared with lecturer and their peers both conceptual doubts and their results and methodologies adopted to solve exercises. The lecturer acted as facilitator guiding the discussion through the contents of the lecture. Questions raised by students in Perusall comments have been addressed by the lecturer in F2F time. This choice is basically due to the online nature of meetings so to leave students free to interact without any external intervention. In this picture, final exams become part of both F2F and after class activities, since presentations are performed on MS Teams classmates having the possibility to follow their peers’ exams.

As indicated in the previous subsection, the Perusall platform has been used in “before-class” activities (step 1). Lectures are based on the open-source textbook “Sustainable Energy – without the hot air” by David McKay (McKay, 2008) with suitable integrations provided by the lecturer. Every week students were asked to insert at least 4 comments on Perusall material to attest their understanding and foster their learning through interaction with peers. Students feedback on written material has been used to prepare video-lectures. They are scripted so to condense what is normally presented in a two-hour frontal class.

2.4 Measures

We developed a questionnaire to investigate how the FC methodology affected students' satisfaction concerning online learning. Participants responded using a 4-point Likert type scale (from 1=completely disagree to 4=completely agree) to 18 questions divided in four different sections. In section 1, we investigated with five items how Perusall platform influenced student's critical reading, student-student, and student-lecturer interaction. In section 2, students answered to three questions (one of which is a fixed-alternative question) on the use of video lectures during the course. The aim of this section was twofold: on one hand, we wanted to investigate how students perceived the lack of in-class interaction in favor of online teaching; on the other hand, we collected interesting details on how students make use of recorded video lectures as part of their learning process. In section 3, we asked 6 questions regarding the exercises we proposed and how they have been discussed in the MS Teams virtual class along the lines of the FC methodology we used. Finally, in section 4, students evaluated the course and its pedagogical aspects and answered to a fixed-alternative question about online didactics. The average time to fill the questionnaire was 7 min 44 sec. We include the English translation of the questionnaire in the Appendix. The questionnaire was written in Italian and imported in Microsoft Forms. The lecturer distributed it as a link via email to students at the end of the course (June 2020). Students' participation was voluntary with no positive or negative inducements. Answers were collected in the June – September 2020 period (from the end of lectures to a few days before the start of the new academic year).

Concerning the exercises presented to students, typically, they are context-rich problems involving very simple calculations but requiring critical assumptions on values and formulae to use in calculations, much like Fermi problems (see the supplementary material for a complete list of them). The use and potential of Fermi problems in the STEM disciplines has been proved in detail to support the development of important competences and skills as creativity and innovation, critical thinking, problem solving, decision making, learning to learn (Ärlebäck & Albarracín, 2019). Week after week, the input of assigned exercises becomes less specific, and more assumptions are required. The lecturer rated the exercises during the course and before the first exam session (June).

The same sets of exercises have been proposed to students (n = 15; males = 8, females = 7) in 2019, when the course had been taught in a traditional way (frontal lectures) with a limited use of active learning strategies. The Perusall platform has been used to provide reading material in advance to students, but a complete implementation of the FC as explained in the previous section has not been made. Moreover, the lecturer, the program, the course organization, and the time allocated to students to solve the exercises have not changed passing from frontal lectures only to the online FC class. An informed consent to participate in the study has been obtained also in this case. Students gave their informed consent to publish the results of the study.

2.5 Analyses

We firstly carried out a descriptive analysis of the questionnaire to investigate how students experienced the FC. Secondly, we analyzed students' achievements during the FC course. Exercises are divided in 10 different sets with 1 to 3 exercises each covering all the course topics. They are graded on a 1 to 10 scale to have an indication on students learning and understanding rather than evaluate their level of knowledge on a particular topic. The analysis focuses on the mean vote distribution per exercise for both years. We calculate the total mean vote as the ratio between the sum of mean vote per exercise and the total number of exercises. This has been done to obtain an overall indication on the effects of the introduction of FC methodology. Since in the last two years, the same sets of exercises have been proposed to students, we made a comparison between grades on the exercises of courses with (2020) and without (2019) the introduction of FC pedagogy. This measure is useful to understand if the new FC methodology introduced in 2020 has influenced the learning outcomes of the course. To determine whether there are any statistically significant differences between the means vote of the two years, we carried out a multivariate analysis of variance (MANOVA). All analyses were performed with the SPSS (ver. 26.0) software.

3. Results

3.1 Students' satisfaction

Concerning the items related to the influence of the Perusall platform on student's performances during the course (see Fig. 1a), all students affirmed that the time left to read the material on the platform was excellent. Concerning interactions, it should be noted that only two students were completely satisfied respectively about the use of Perusall to foster the out-of-class interaction between students and to the interaction with the lecturer before the class. Anyway, most of the students are at least satisfied with both kind of interactions. The mains values for section 1 are showed in Table 1. Students' opinions on the use of video lecture are shown in Fig. 1b. Concerning the time left by the teacher to watch video lectures, students appeared to be completely satisfied. The same result appeared for the usefulness of video lectures to understand the content of the course (see Table 1 for the section 2 means).

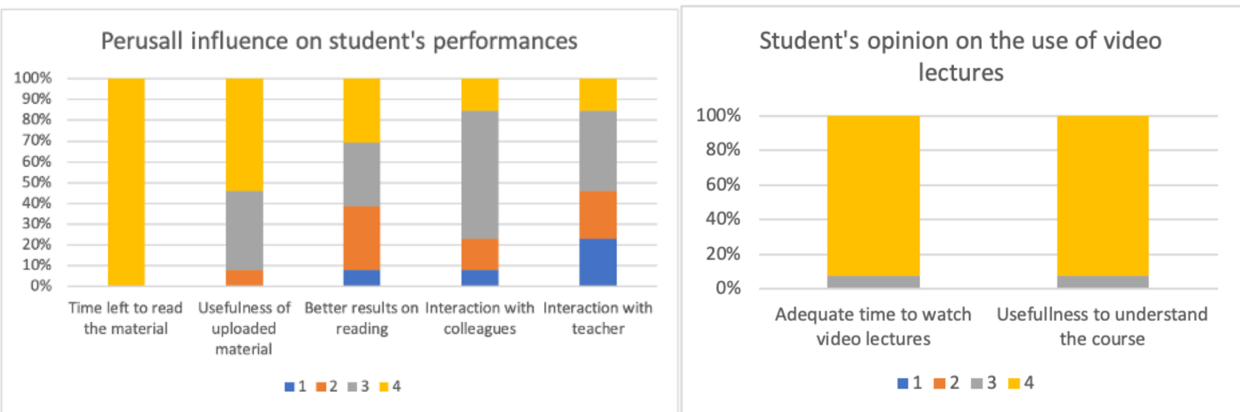

Fig 1a, 1b. Student's response at the section 1 and 2 of the engagement questionnaire. In x-axis a schematic list of questions. Students could answer by using a 1 (completely disagree) to 4 (completely agree) ranking scale (on the bottom of the chart).

Fig. 2 shows student's reports on watching video lectures during the course as a function of the number of answers per item (fixed-alternative question). Results on students' feedback about the exercises and the virtual discussion during lectures are shown in Fig. 3a. It should be noted that the time left to solve exercises and to discuss the exercises in the virtual class as well as the utility of the exercises to understand the content of the course and to improve students' critical thinking capabilities were perceived as completely adequate by almost all students. Moreover, students preferred group correction activities than individual correction of exercises (see Table 1 for the section 3 means).

In the last section of the questionnaire, we collected students' perception about the use of FC as pedagogical method in physics (see Fig 3b). Most of the students (n=9) rated the FC method as very adequate. The use of FC method for distance learning had been voted by 3 students as very adequate, by 4 students as adequate and by 1 student as very inadequate. Most of the students thought that the FC method could also be applied to other courses in physics (n= 9), while for 4 of them it could not be used in other courses. Only 2 students would have preferred to attend the course in a frontal way, whereas 11 of them were satisfied with the methodology used. Concerning the possibility to attend a FC in a frontal way, 8 students completely disagreed with this item, while 5 of them agreed (see Table 1 for the means).

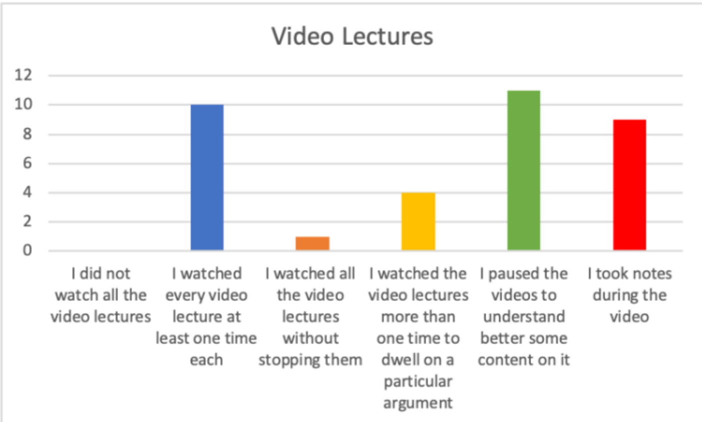

Fig 2. Student's reports on watching video lectures during the course. In y-axis, the number of answers per item (x-axis).

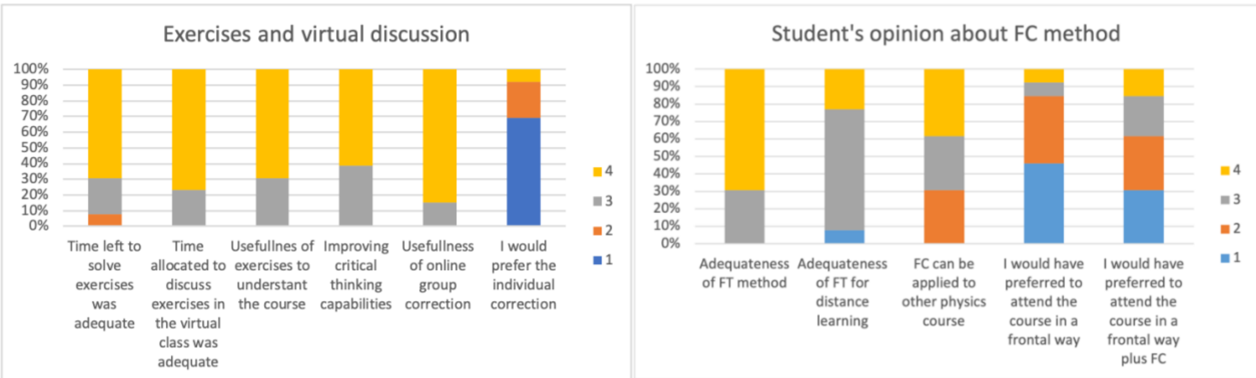

Fig 3a,3b. Student's response at the section 3 and 4 of the engagement questionnaire. In x-axis a schematic list of questions. Students could answer by using a 1 (completely disagree) to 4 (completely agree) ranking scale (on the right of the chart).

Finally, Fig. 4 shows students' feedback on how much the various phases of the course have been important in their learning process (fixed-alternative question). Most of them (n=9) estimated that the critical reading on Perusall had not been important, 4 estimated it as having a good influence on them. Video lectures had been estimated as not important in the learning process by 3 students, and important by 10 of them. Exercises had been estimated as not influent by 9 students, and as influent by 4 of them. The online group correction activity has been estimated as not important by 6 students, and as influent by 7 of them.

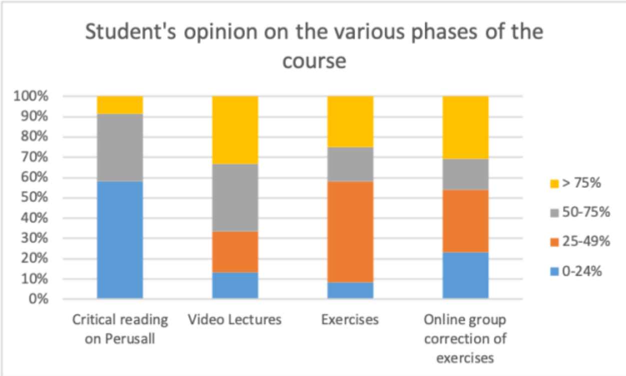

Fig 4. Students weighed how much (in percentage) the various phases of our pedagogy have been important in their learning process. They could choose among 4 different intervals, from 0-24% to >75%.

Table 1. Descriptive statistics for the satisfaction questionnaire

	Mean	S.D.
Section 1: Perusall influence on student's performance		
Time left to read the material	4.00	0.00
Usefulness of uploaded material	3.46	0.66
Better results on reading	2.85	0.99
Interaction with colleagues	2.85	0.80
Interaction with teacher	2.46	1.05
Section 2: Student's opinion on the use of video lectures		
adequate time to watch video lectures	3.92	0.28
usefulness to understand the course	3.92	0.28
Section 3: Exercises and virtual discussion		
Time left to solve exercise was adequate	3.62	0.65
Time allocated to discuss exercises in virtual class was adequate	3.69	0.48
Usefulness of exercises to understand the course	3.62	0.51
Improving critical thinking capabilities	3.77	0.44
Usefulness of online group correction	3.85	0.38
I would prefer the individual correction	1.46	0.88
Section 4: Student's opinion about FC method		
Adequateness of FC method	3.69	0.48
Adequateness of FC distance learning	1.77	0.93
FC can be applied to other physics course	2.23	1.09
I would have preferred to attend the course in a frontal way	3.08	0.76
I would have preferred to attend the course in a frontal way plus FC	3.08	0.86

3.1 Students' achievement

Concerning the analysis of the mean votes per exercise, data are shown in Table 2 in the appendix. Figure 5 shows the total distribution of votes among the 10 exercises in 2020 and 2019.

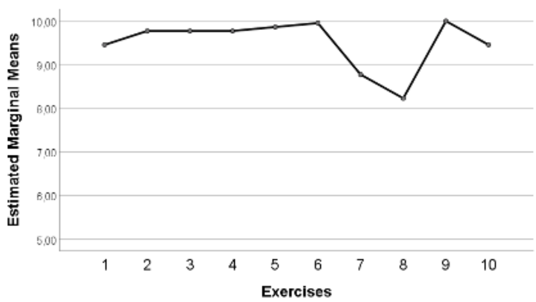

Fig. 5 The sum of the distributions of mean votes in 2020 and 2019

The distribution of votes in 2020 and 2019 is shown in Fig. 6a and b. In 2019, the total mean vote has been 9.41 ± 0.16, whereas in 2020, 9.52 ± 0.21.

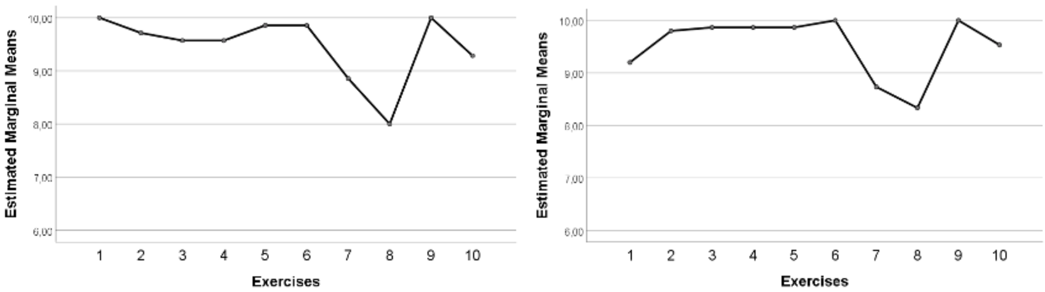

Fig. 6a,6b. The distribution of mean votes in 2019 (on the left) and in 2020 (on the right)

The results of the MANOVA did not show a significant multivariate difference between 2020 and 2019 mean votes (Wilks' Lambda= .41, F = 1.90, p >.05). Only for the first exercise, a univariate significant difference appeared between the two samples (F = 7.27, p < .05); in particular, students obtained a higher vote in 2019 than in 2020.

4. Discussion

We have studied the effects of introducing active learning strategies and the FC model into a physics course on renewable energies for bachelor students at the Physics Department of University of Cagliari, Italy. Lectures have been provided during the Covid-19 pandemic and students attended frontal lectures only. The peculiarity of the situation has demanded a scrutiny activity about student learning and online teaching, leading to a robust implementation of active and social learning strategies to circumvent the lack of in-class student-student and student-lecturer interaction. For this reason, online learning has been mediated using social platforms such as Perusall.

The main changes brought about the standard FC methodology were that we used a revised version of "standard" FC steps, "before class – F2F – after class", with after class and F2F steps reversed. Step by step assessments and exams have been performed before the F2F discussion time. The choice to reverse standard FC steps has been done to allow the lecturer to obtain a complete picture of student level of learning and assessments lecture by lecture, preventing possible misunderstandings or solving intermediate (conceptual) doubts, also about the exercises. Moreover, in this way, students could reinforce higher level learning not only about the content of lectures, but also on the step-by-step assessments and on their general understanding as requested by the course. We stress the fact that the F2F step has been organized in a complete online environment, by means of MS Teams. The lecturer acted as facilitator guiding the discussion through the contents of the course. Questions raised by students in Perusall comments have been addressed by the lecturer in F2F time. In this picture, final exams become part of both F2F and after class activities, since presentations are performed on MS Teams classmates having the possibility to follow their peers' exams.

We performed an analysis on student satisfaction about the active learning strategy and the use of social platforms by a post-diagnostic questionnaire. What emerges is that most of the students are satisfied with the learning design and methods used during the course. On average, more than half of the class evaluated as positive the experience in using the Perusall platform. Almost two thirds of the class found that Perusall helped them to get better results in reading the material. Moreover, the use of a social platform to improve the student-student interaction has been evaluated as positive by most of the students. This aspect assumes a particular relevance because interactions could influence students' engagement, motivation and satisfaction in attending lectures (Bolliger, 2004; Garrido et al., 2019; Gilboy et al., 2015; Kortemeyer, 2016). Although social interactions play an important role in education, literature shows that the process of learning in online environments sometimes suffers from a lack of interaction between peers and between the class and the lecturer (Burnett, 2001; Derakhshandeh & Esmaeili, 2020) that should be overcome with suitable actions implemented by lecturers. Video lectures have been considered very useful to understand the contents of the course by all the students. That student appreciated the organization of the course is reinforced from the fact that the class also appreciated the time left to watch videos and to solve the exercises. Let us stress the fact that the course has been organized during the lock down period caused by Covid-19 pandemic, thus video lectures and texts on Perusall have been the only material available for students to learn the content of the course. Students used the possibility to watch more than one time the content of the lectures and this has been evaluated as an advantage in the learning process.

Concerning the exercises, most of the students evaluated as positive all the aspects we asked them. They evaluated the exercises as useful to understand the content of the course and to improve their critical thinking capabilities. The F2F phase of the FC has been considered as highly positive, the time allocated to discuss the exercises during the virtual class meeting has been evaluated as very adequate by two thirds of the sample and adequate by the others. Another positive aspect of the F2F phase has been represented by the working group in solving and discussing the exercises during the online meetings.

According to students, the various phases of the proposed learning strategy positively influenced their learning process. If, on the one hand, they affirmed that the use of Perusall has been not so important during the course (it has taken only 0-24% of their time), on the other one, watching video lectures has been considered important for most of them (taking more than the 50% of the time). This confirms what has emerged before, that video lectures are the real way through which students learn contents during the course. Accordingly, the individual work on solving exercises has been considered less important than video lectures, taking less than 50% of the time for two thirds of the class, and vice versa for the group solution activity in the virtual class. A qualitative comparison of the last activities shows that most of the students considered the group correction of the exercise as more important in the learning process than the individual one.

Concerning the students' achievement, the same set of exercises has been proposed to students in both years 2019 and 2020. A multivariate statistical analysis on the distribution of means between the exercises in the two years did not show any significant difference between the twos. Nevertheless, let us note that, at least at the univariate level, the analysis shows a significant difference only in the first exercise (concerning measurements units for energy and conversions), where the 2019 mean vote is higher than the 2020 one, because the topic of the exercise had been addressed directly in the F2F class in 2019, while it has not been mentioned in the recorded video lecture in 2020. We also note that students reported a slightly lower grade in the exercises 8 in both years; the topic of set 8 is power losses in cables transporting electricity generated by solar panels; while students are familiar with Ohm's laws and electric circuits, they struggled with applying the principles to such unknown setting. Even if there are no significant differences between the two years, we note that the means are higher in both cases. As a positive outcome of the introduction of the FC methodology, we note that the latter did not negatively influence the learning during the course, being the votes on the exercises very high in 2020 (in between 8 and 10 over a maximum of 10). This has positively influenced the final grades obtained by students at the end of the course, too, which are mostly piqued towards the higher value (30/30). Let us note that, in the present situation (2022), with most pandemic related restrictions lifted, the class has been offered by keeping the flipped format, but with an in-person F2F discussion session of exercises. In person F2F for such an elective course with a focus on applications and real life is typically a relaxed experience for students, where they often engage in discussions, offer they views on the subject of the class and ask questions when they are not sure. While such environment is very difficult to reproduce in an online setting, we consider a success the fact that, as far as the ability to solve exercises, student's learning outcome has not declined. More data coming from restored in-presence activities will allow us to make a detailed comparison between the online and the F2F student's experience in attending the course. This point is left for future research. Finally, the overall perception of the course by students in 2020 has been very positive, being them very satisfied of the proposed learning strategy.

5. Conclusions

In conclusion, students' feedback indicated the overall positive effects of active learning strategies in learning the contents of the course. Our data goes in the direction of previous studies about the positive effects of social platforms on students' performances in reading (Miller et al., 2016, 2018). Video lectures has been considered very useful to understand the content of the course. Let us stress the fact that the course has been organized during the lock down period caused by Covid-19 pandemic, thus video lectures and texts on Perusall have been the only materials available for students to learn the content of the course. Students have given positive feedback also on the role of group discussions to solve and correct the exercises.

In this paper, we also addressed a research question about the inquiry of possible learning gains in students thanks to this new pedagogy. While the course is designed for a small class size, we were interested in understanding the impact of innovative teaching strategies in enhancing students' engagement and learning. We investigated students' achievements during the course and compared them with the ones obtained in the previous year (2019), where active and online learning strategies were partly used, and the course had been provided in a traditional frontal way. This allowed us to investigate the learning gains of such modern methods with respect to traditional ones in students' assessment by comparing grades on the same exercises during the years. Statistical analysis did not show any significant difference between the two. However, being the distribution of votes very high even in 2020, when the FC has been introduced, the latter had certainly not negatively influenced the learning outcomes of the course, thus its effects had been positive. Putting together this result with the fact that the overall perception of the course by students in 2020 has been very positive, we can conclude that the FC methodology is a valid alternative to traditional face-to-face lectures. We leave a more in-depth analysis of this point for the future when we will be able to collect more data from flipped classes. The good overall results obtained by the implementation of FT method encourages research into the development of suitable active and online learning strategies in physics courses. More data are needed to study the mid- and long-term effects of these methodologies in students' achievements.

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Ethical statement

Informed consent to participate in the study has been obtained from participants. Any identifiable individuals participating at the study have been also aware of intended publication. Informed consent to publish has be obtained from participants of the study. This work was carried out in accordance with the principles outlined in the journal's ethical policy and with the 'Codice etico e di comportamento' of the University of Cagliari.

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