Adapting a Micro-Flip Teaching with E-Learning Resources in Aerospace Engineering Mathematics During COVID-19 Pandemic

J. A. Moraño-Fernandez, S. Moll-Lopez, L. M. Sanchez-Ruiz, E. Vega-Fleitas, S. Lopez-Alfonso, and M. Puchalt-Lopez

Abstract In this paper, a micro-flip teaching methodology is adapted to a distant learning environment due to the COVID-19 pandemic. An e-learning resource, known as Polimedias, has been used to cover the main ideas of numerical and functional series in the subject of Mathematics I of the Aerospace Engineering Degree at the Technical University of Valencia. These methodologies, the micro flip-teaching and its adaptation, have led to a significant improvement in the grades and in the understanding of the subject. Students have shown a very positive opinion on the different strategies employed before and during the pandemic. The elaboration and usage of polimedias have been proven to be a very flexible tool that adapts perfectly to the new post-COVID-19 learning process.

Keywords Blended learning · Collaborative work · Flip-teaching · Mathematics · Online teaching · Polimedias
1 Introduction

In recent months, the global pandemic of COVID-19 has brought about a complete break with the traditional teaching method, changing the interaction between teacher and student, and its effects will probably continue for some years. Teaching worldwide has had to reinvent itself and adapt to an educational system based on distance learning. However, in recent years and thanks to the latest advances in educational research, many universities and educational centers had been adapting to a more student-centered teaching methodologies, such as the Flip-Teaching (FT) or Blended-Learning (BL) methodologies. These methodological adaptations prior to the COVID-19 pandemic have been able to soften and attenuate the effects of adaptation to distance learning methodologies. The resources needed to continue teaching during the global confinement have been based on the resources for autonomous learning, already employed, for example, in flip-teaching methodologies. Technical University of Valencia (Universitat Politècnica de València, UPV) has been making a strong effort to implement flip-teaching methodologies during the last years. Due to that effort, some results have been obtained [1, 2], and an extension and adaptation of these results are introduced in this paper.

New technologies have been the key in the pre-COVID-19 era, and the fundamental communicative vehicle during the pandemic, developing new ways of communication and transmission of knowledge. Students have an immense amount of information on the network, accessible from anywhere at any time. This ease of resources has allowed teachers to implement new learning methodologies inside and outside the classroom, increasing the students’ active role in the learning process. Indeed, teaching is becoming more than a mere transmission of information, since the information is almost everywhere: teaching should focus on learning how to learn. It is a priority to discern the useful information, to manage big quantities of data, and to promote a critical spirit for the assessment of the information. In a statement to the World Economic Forum, Paul Kruchoski mentioned that the university will need to focus on learning to learn [3]. Learning is becoming a lifelong process and with today’s pace of change, everyone needs the tools to learn throughout life. This process of learning to learn is based on the aforementioned active role of the students and in a more flexible pace adaptable to the individual needs of the learners.

Among the student-centered forms of transmission of knowledge, it is worth mentioning Massive Open Online Courses (MOOCs). These courses have emerged in recent years and have attracted the attention of both students and teachers. Unlike traditional face-to-face education, MOOCs have a few temporal and spatial limitations: students can access the course at any time and in any place, as long as they have access to the Internet [4]. Platforms like EdX, Coursera, and Udacity bring together a huge collection of MOOCs from many prestigious universities. MOOCs can be considered one of the most important steps in the direction of online autonomous learning. Nevertheless, their impersonal nature can be considered as an important drawback.
In a smaller scale, UPV has been developing POLIMEDIA, consisting of a system for the creation of multimedia contents and with the aim to support face-to-face teaching. POLIMEDIA ranges from the preparation of the teaching material to the distribution of these materials through different media channels (TV, Internet, CD, etc.). POLIMEDIA is a resource integrated in the educational PoliformaT platform (Sakai), employed at the UPV. This teaching material consists mainly, but not limited to, of the production of short videos (polimedias) with different options of edition and with a duration of no approximately 10 min, in which a concept or an idea is explained. The elaboration of polimedias has been proven to be a very flexible tool that adapts perfectly to the new teaching methodologies such as FT or BL. These methodologies allow establishing a link between activities outside and inside the classroom [5].

Among the new methodologies employed nowadays promoting an active learning process, we find blended methodologies defined as the combination of traditional and interactive modes of classroom instruction with learning technologies [6]. Other researchers define blended learning as a combination of face-to-face and online learning instruction with the objective of complementing each other [7]. These methodologies combine parts of the traditional, online, and flipped modes. Except for the traditional mode, technology is strongly related with the online education and with the flipped methodologies. Literature on e-learning and flip-teaching is growing hugely, emphasizing student learning effectiveness [8].

In traditional educational models, learning can be divided into two phases: transmission and assimilation [9, 10]. The transmission phase consists mainly of conference-based teaching in which students play passive roles [11]. In the assimilation phase, students apply the new information acquired in their assignments, laboratory practices, or in-group activities [12]. In this second phase, teachers can be present (laboratory practices) or absent (tasks outside the classroom).

The FT methodology reverses the two main activities of the traditional model: lessons are taught outside the classroom through and the exercises or assignments are solved in class with individual or cooperative activities [8], changing the classroom into a meeting and debate point [13]. The interaction inside the classroom can happen in different ways: the most common models include problem-solving, cooperative resolution, cooperative tests, quizzes with gamification elements, and teacher-student interaction based on problems. This interaction teacher-students-content allows establishing the so-called interactive triangle [14].

A great effort is required to apply some new methodologies in the classroom [15, 16]. It has been calculated that approximately two years are needed to consolidate and stabilize a complete educational methodology, such as FT or BL. For the implementation of a new methodology, a slower and more progressive strategy is recommended. For example, to use gradually different stages, and measuring the impact of each one on the students’ learning process would be a wise approach. These small steps or processes add the word micro as a prefix, when they are referred, as in the micro flip-teaching methodology. The total effort of introducing a new methodology is therefore normally divided in several steps, helping the teachers to achieve satisfactory results, and softening the adaptation to new forms of learning.
Nevertheless, the latest situation with the COVID-19 pandemic has changed the rules about adapting new methodologies. Suddenly, the learning and teaching process has become completely online. Activities inside the classroom have lost their meaning and new ways to interact with the students have arisen. Platforms as TEAMS, ZOOM, SKYPE, PoliformaT have become the meeting point for teachers and students alike, in which to share teaching material, solve doubts, and collaborate with each other to reach the desirable knowledge. The main problem that universities and educational centers have faced has been the short period of time for changing from one traditional teaching mode into a new online distant teaching. This barrier has been softened when FT methodologies were playing an important role before the pandemic situation.

In this paper, the authors present the initial micro-flip-teaching methodology and the adaptation to an online distant methodology or online FT where the inside-the-classroom part has been changed for an outside-the-classroom mode.

2 Polimedias in Micro-FT Before COVID-19

One of the simplest applications of polimedias, apart from supporting face-to-face mode, is to facilitate learning outside the classroom. In this study, a Micro-Flip Teaching (MFT) method was employed: the main characteristic of this model is that it was not necessary to apply it to the whole subject, but to the main ideas that the teacher wanted to highlight. For its application, we used polimedias as the main tool (see Fig. 1). The MFT model was tested with a positive impact on learning process, obtaining a significant improvement in the grades of the students. The polimedia-MFT model that was initially applied consisted of three stages: Outside the Classroom (OC), Linking Activity (LA), and Inside the Classroom (IC) (see Fig. 2).

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**Fig. 1** Polimedias: consisting mainly of short videos of approximately 10 min, these videos are designed to support face-to-face learning. In the picture, an image the presentation of a polimedia about series can be seen.
2.1 Outside the Classroom

This phase involved all the activities that took place outside the classroom. It was at this stage where polimedias were used with the aim of transmitting a significant part of knowledge to the student without the teacher being present. As mentioned before, the polimedias have an estimated duration of 10 min, to maximize the attention and predisposition. In addition, each video is accompanied by additional material that allows them to evaluate the acquisition of knowledge and skills.

2.2 Linking Activities

It consisted of the activities that were used to establish a connection between the activities inside and outside the classroom. These activities consisted of the realization of a work or a questionnaire in which the students applied the concepts explained in the polimedia. These activities were also completed through the platform for automatic evaluation. This provided immediate feedback to the student, allowing them to assess their progresses. The duration of this activity was thirty minutes maximum.

2.3 Inside the Classroom

Depending on the responses of the students to the questionnaires, the teacher was able to know the deficiencies and the degree of skill attained by the students prior to meet them at the classroom. This information was used to design the activities of this stage. Activity in the classroom could be structured in different ways:
- The results of the linking activity could be used as a teaching resource. A brief discussion could be established on the results obtained, whether they are correct or erroneous.
- The teacher tries to clarify the concepts that the students have not been able to assimilate.
- A test solved in groups, as an strategy to promote collaborative work, can be carried out, in which the learning resources generated up to that moment are used.

The teacher chooses the form that best suits the dynamics of the group or the degree of assimilation of the concepts.

### 3 Changing to Online FT Methodology During COVID-19 Pandemic

As mentioned in the introduction, COVID-19 pandemic has change education around the world. Internet has become the linking way to stay in contact and to keep teaching/learning, despite the distance. One of the advantages of the polymedia-MFT methodology was its easiness to adapt to this new situation. The confinement has forced this MFT methodology into becoming a online FT methodology. Face-to-face sessions have been changed by online meetings through PoliformaT or TEAMS. Accessing internet has not been an important issue, since all the students were capable to be in contact or reach a connection point at least for the time needed to download the information or to contact with the teacher. All the Polimedias about series has been used as a part of the online FT methodology, combined with support sessions and solving-problem meetings. Students have been able to access these videos, and use them as a teaching resource. The content of these videos has been used in the online face-to-face classes, in which the students could show the skills attained from these videos to solve problems or answer some questionnaires. The polimedia online FT model that has been applied these last months consists of three stages: FT Activities (FTAs), Linking Activities (LAs), and Online Sessions (OS) (see Fig. 3).

#### 3.1 FT Activities

It is at this stage where polimedias and videos are used with the aim of transmitting the knowledge to the student without the teacher being online at the same moment. The polimedias have now an estimated duration of 10–20 mins, to maximize the attention and predisposition. As a main difference with the MFT methodology, the number and duration of the videos have increased. In addition, each video is accompanied by additional material that allows them to evaluate the acquisition of knowledge and skills, such as solved exercises and tests.
3.2 Linking Activities

It consists of the activities that are used to establish a connection between the FT activities and OS. These activities consisted of the realization of tests or questionnaires about the concepts explained in the polimeditas. These activities can be completed through the platform for automatic evaluation, providing the students immediate feedback. The duration of this activity is about thirty minutes.

3.3 Online Sessions

As in the face-to-face sessions, the responses of the students to the questionnaires and tests provide important information about the level of understanding to the teacher. Online sessions were schedule via TEAMS, in order to complement the learning process. Taking into account the responses of the students, the teacher is able to design activities for the online sessions in a way that favors learning or assimilation of the concepts seen in the FT phase. Online live activities can be structured in different ways:

- The results of the linking activity can be used as a teaching resource.
- The teacher tries to clarify the concepts that the students have not been able to assimilate.
- A group test is carried out in which the learning resources generated up to that moment are used.

Apart from these stages, in order to clarify the concepts, several doubts-sessions have been made. As a natural evolution, starting from online individual tutorship, students started to gather in small groups (4 or 5 people) and meet with the teacher before or after the linking activities in order to clarify doubts, and in many cases to ask for more exercises and test. These groups appearing naturally are the ones chosen by the students themselves to help each other during the learning process. Taking advantage of this work-in-groups processes, several group-exercises have been proposed, promoting collaborative work.
4 Application of the POLIMEDIA-MFT METHODOLOGY

Mathematics I is a compulsory annual subject with 12 ETCS, of which 75% corresponds to Theory/Problems (TP) sessions and the remaining 25% to laboratory practices (LP), taking place the first year of the Aerospace Engineering Degree at the School of Design Engineering (ETSID) of the UPV. Students are divided into the ARA group (High Academic Performance), with teaching in English, and NARA group with teaching in Spanish. Both groups, regardless of the names, have the same program, assignments, and exams.

Nevertheless, the polimedia-(micro/online) FT methodology was applied only to the students of the ARA group in two stages: during the academic years 2018/2019 (before the COVID-19 pandemic) and 2019/2020 (during the pandemic). From the pandemic, much more material has been created, but the results presented here correspond to the chapter of numerical and functional series, since for the students from 2018/2019 this was the only material provided.

The students of the non-ARA group were able to access the same resources but the methodology was not applied. For the academic year 2018/2019, there were 124 students, 50 belonging to ARA group and 74 belonging to NARA. 32 students answered the survey about the polimedia-MFT methodology. For the academic year 2019/2020, there were 118, 46 from the ARA group and 72 from the NARA group. 35 students were able to answer the survey.

5 Results and Opinions

For the academic year 2018/2019, students were assessed about series. A simple two-factor ANOVA test has been conducted to analyze the differences among group means in the sample. Since the P-value is less than 0.05, there is a statistically significant difference between the mean of Series grades when we consider the factor ARA/NARA with a level of significance of 5% (Table 1). Furthermore, the average of grades in ARA group is significantly greater than the average of grades in NARA group (Table 2).

| Table 1 | ANOVA for series grades |
|---------|-------------------------|
| Source  | Between groups | Intra groups | Total (Correlation) |
| Sum of squares | 31.0834 | 485.756 | 516.84 |
| Degrees of freedom | 1 | 122 | 123 |
| Average square | 31.0834 | 3.98161 |
| F-value | 7.81 |
| P-value | 0.006 |
Table 2  Summary: series grades

|        | ARA | NARA | Total |
|--------|-----|------|-------|
| Size   | 50  | 74   | 124   |
| Average| 7.78| 6.76 | 7.16  |
| Std. Deviation | 1.71 | 2.16  | 2.05  |
| Variation Coef. | 22.03% | 32.03% | 28.60% |
| Minimum | 2.87 | 0.99 | 0.99 |
| Maximum | 10  | 10   | 10    |
| Range  | 7.13| 9.01 | 9.01  |

However, this situation does not occur in the other exams of the subject (Calculus 1, Calculus 2 and Algebra). A simple two-factor ANOVA for these exams led to the following P-Values: 0.6395 for Algebra, 0.3001 for Calculus 1, and 0.5620 for Calculus 2, clearly indicating a non-statistically significant difference between the means when we consider the factor ARA/NARA.

Similar situation can be found for the academic year 2019/2020, in which the average of the ARA/NARA groups were 6 and 5.3, respectively. A simple two-factor ANOVA indicates that the difference can be considered significant. It should be noted that a decrease has been observed, however, between the means obtained by the MFT and those obtained by the FT. This may be due to different reasons: one of which is that during this year, the exam of the series chapter has been fully integrated with other parts of the subject and the students have distributed their effort in various topics. Furthermore, the assessment, one of the weakest points of the post-COVID-19 era, has been much more demanding in time and form, due to the need for greater control during the online exam. This has caused the students’ grades to decrease slightly compared to those obtained in other years. It is worth mentioning that the proportion of students who have passed the subject has been maintained.

A survey was performed to evaluate the experience with the polimedia-MFT methodology and with the online FT methodology. The survey aimed to collect the degree of acceptance and satisfaction in both cases. The first item that students valued is the perception of utility of the methodologies employed. The results are shown in Table 3.

Table 3  Student opinion about methodology

|                  | Post-COVID-19 (%) | Pre-COVID-19 (%) |
|------------------|-------------------|-----------------|
| No good          | 0                 | 0               |
| Barely good      | 2                 | 1               |
| Quite good       | 48                | 15              |
| Very good        | 50                | 84              |
Table 4  Student opinion about linking activities

|                         | Post-COVID-19 (%) | Pre-COVID-19 (%) |
|-------------------------|-------------------|-----------------|
| No good at all          | 0                 | 0               |
| A little good           | 5                 | 6               |
| Quite good              | 20                | 24              |
| Very good               | 75                | 70              |

Table 5  Student opinion about in/out class activities

|                      | Post-COVID-19 (%) | Pre-COVID-19 (%) |
|----------------------|-------------------|-----------------|
| No good              | 0                 | 0               |
| Barely good          | 8                 | 11              |
| Quite good           | 32                | 41              |
| Very good            | 60                | 48              |

Table 6  Student opinion about polimedias

|                     | Post-COVID-19 (%) | Pre-COVID-19 (%) |
|---------------------|-------------------|-----------------|
| No useful           | 0                 | 0               |
| A little useful      | 4                 | 5               |
| Quite useful         | 42                | 55              |
| Very useful          | 54                | 40              |

As can be seen, there has been a wide acceptance of both methodologies: in the case of MFT, 99% of the students have a positive perception, and the same happens for the online FT methodology, although the proportions are not the same between the items Quite good and Very good. The difference can be ascribed to the large number of changes that have occurred in recent months for the students. With regard to the opinion on the linking activities, students have shown very positive acceptance for both methodologies as shown in Table 4.

The activities in-class have also obtained very good results, despite that for the online FT methodology, in-class was conducted in an online environment. The results are presented in Table 5. Nevertheless, in this case, more disparity of results is observed. This may be due to the different techniques used during the activities.

Finally, the students were asked about the materials used for the activities outside the classroom. Specifically, the polimedias had very good opinions. The results are shown in Table 6.
6 Conclusions

In this study, polimedias have been used to cover the main ideas of numerical and functional series, and as an important part of a micro-flip-teaching methodology evolving to a full online flip-teaching in the subject of Mathematics I of the Aerospace Engineering degree. The MFT methodology in the ARA group led to an improvement in the grades and in the understanding of the subject during the academic year 2018/2019. The same methodology was initially planned to be applied in the academic year 2019/2020, however, COVID-19 pandemic changed the way learning was conducted. Online and distant learning became the only method to reach students and provide knowledge. This situation transformed the MFT methodology into an online FT methodology, based only on online resources. Despite this situation, students have shown a very positive opinion of the different steps both in the MFT and FT methodology. In the out-of-class (or online sessions) stage, polimedia videos have been employed as teaching material with duration between 10 and 20 min, in which a concept or an idea is explained. The elaboration of polimedias has been proven to be a very flexible tool that adapts perfectly to the new teaching methodology and have softened the process of adapting to a distant teaching.

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