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A Learning Analytics Tool for the Support of the Flipped Classroom

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Abstract

Nowadays, there are quite a few experiences of the use of the flipped classroom in engineering education due to their advantages in comparison with the traditional methodology. The possibility of promoting students' active learning under the flipped classroom can lead to improvements in the learning outcomes. Nonetheless, there are several issues that arise when using the flipped classroom (such as the students' need of preparing the face-to-face lesson) that must be addressed. In order to take advantage of the whole potential of the flipped classroom, we propose the application of learning analytics to improve the flipped classroom. In particular, we define a methodology that proposes a set of recommended actions to be done to enhance a specific type of flipped classroom through learning analytics. Moreover, we present a learning analytics tool designed and implemented specifically for this methodology. This tool allows teachers to obtain relevant information needed to improve their flipped classroom experiences. The information is provided using several visualizations that are analyzed and explained in detail. We illustrate the use of the tool with students from engineering courses.

Keywords: Flipped Classroom*;* Learning Analytics*;* Active Learning; Methodology; Interventions

1. Introduction

Although the use of active learning methodologies in Engineering Education is not a new topic, its popularity has increased worldwide in recent years. Methodologies (which are not exclusive among them) like project-based learning [1], problem-based learning [2], or the Flipped Classroom (FC) [3] are used more and more nowadays. This increasing interest in active methodologies is partly because of the development of technological tools such as MOOC (Massive Open Online Courses) platforms which allow implementing new learning methodologies, and partly because of the shift from the teacher-centered learning to the student-centered learning, which is currently happening in many educational institutions.

In this work, we focus on the FC methodology. The FC tries to promote students' active learning activities done in the face-to-face lessons [3]. To achieve this objective, teachers can provide instructional resources (like videos, readings, etc.) before the face-to-face lessons in order to present the concepts which students are going to need in these lessons. During each face-to-face lesson, students can do active learning activities, like group-solving problems or debates between students, oriented to encourage the active participation of these students. Apart from that, the FC can be implemented using different approaches; in particular, we group the types of flipped classroom models defined in [4] into four types: flipped classroom focused on exercises, flipped classroom focused on groups, flipped classroom focused on experimental activities, and flipped classroom in which students create the academic resources. In a previous work [5] we use this classification to define four scenarios for the application of learning analytics (LA) and the FC. In particular, in this work we focus on the first scenario, i.e. the flipped classroom focused on exercises where students do active learning exercises during the face-to-face lesson (for example, one student do an exercise in the blackboard and their classmates give their feedback).

Like other learning methodologies, the FC has advantages and drawbacks. One of the most important advantages of the FC is the increase of the students' engagement, in terms of the three components of

engagement: behavioral, emotional and cognitive [6]. For instance, in comparison with the traditional model, in a flipped classroom context the students' engagement is improved because they watch more the videos before the face-to-face lesson [7] [8], because they access more to the e-learning platform which contains academic resources [9], and because they attend more the face-to-face lesson [10]. Nonetheless, the FC has important drawbacks, such as the students' requirement of preparing the class [11] [12], or the students' difficulty to obtain immediate answers to their questions when watching the videos [3]. In spite of this, advantages usually outweigh the disadvantages, and for this reason the FC has obtained positive results in many studies [12] [13], although there are some studies that have shown negative effects [14]. For example, one of the greatest problems of the FC is that students should access the instructional resources before the face-to-face lesson, since if they do not access these resources, the model loss most of its benefits (students cannot do appropriately the in-class active learning activities if they do not prepare the instructional resources previously) [15]. We think that most FC's drawbacks might be avoided using learning analytics from the analysis of raw data that are gathered from most of the e-learning platforms, such as Moodle [16], or Open edX [17]. In this direction, LA can give a suitable solution for this issue. In this work, we understand LA as defined in the 1st Conference of LA "Learning Analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs." [18]. Therefore, the idea is to analyze the students' data and their contexts, in order to be able to improve the FC. In addition, teachers can have a specific plan for their students in terms of the previous preparation of the lesson which has to be monitored (e.g. teachers can aim to make students curious about some parts of the lesson's video in order to promote the students' focus on these specific parts of the video), and this can be done using LA techniques.

Although there are specific recommendations of using LA for the FC, as far as we know, there is not any concrete methodology in the literature that defines specifically how to improve the FC using LA techniques. In order to allow teachers, from all the educational levels and backgrounds (from high school

history courses, to engineering courses at university) to use the FC and, in addition, to benefit from all the potential advantages provided by the FC, it is necessary to define the specific actions that teachers should do using the available information about students and their learning context.. In this direction, this work contributes with a methodology to improve the FC focused on exercises through LA. We also present a learning analytics tool specifically designed and implemented to use this methodology, which allows teachers to visualize some information for enhancing the FC. For example, it allows teachers to analyze the students' preparation of the face-to-face lessons (i.e. if they access to the preparatory videos and exercises where the concepts used in that lesson are explained) which is one of the most relevant problems of the FC [19]. In this way, teachers are able to alert students, before the face-to-face lesson, about the need of preparing that lesson. Moreover, we present the visualizations used by the tool, and analyze the criteria used to choose each of these visualizations.

The remainder of the work is organized as follows. Section 2 introduces the related work about LA and the FC. The third section defines the proposed methodology. Section 4 presents our learning analytics tool. The fifth section discusses an example of results associated with the methodology. Finally, the last section shows the conclusions and the future work.

2. Related Work

The FC is a methodology that aims to use active learning activities during the face-to-face lessons (such as group activities or debates between students) instead of having traditional teaching. To achieve this, teachers provide a set of academic resources, before the face-to-face lesson, which explain the topics that students will cover in this lesson. Students have to study previously the topics covered in these resources (videos, online exercises, readings, etc.), in order to prepare the lesson. Thus, students can take advantage of accessing lesson's topics out of the class, since they can learn these topics at their own pace, accessing whenever they want and during all the needed time [3].

In the last years, the FC has been used with different types of students, from K-12 to undergraduate students [20] [21] [22]. This is not surprising, due to the positive effects shown in several studies such as the following:

- Good learning outcomes and indicators [23].
- Improve students' perceptions about their learning (students believe that they have learned more with the FC than with the traditional class) [24].
- Improvement of the students' feelings about the class; in other words, students prefer the FC more than the traditional class [24].

However, this does not mean that the FC is always better than the traditional class. In many works, there is a portion of students (usually, a small number of students in comparison with the whole group) that do not like the FC and they prefer the traditional class [25]. There are also works where the FC does not provide better learning outcomes than the traditional class [3].

Considering the issues related to the FC, it is not surprising that several works try to enhance different aspects of it. For example, there are works that adapt the face-to-face lesson using learning design [26] [27], other works add new activities between the preparation activities and the face-to-face lessons [28], and other works provide new tools to follow the flipped methodology, from web platforms to mobile Apps [29]. Furthermore, there are works that try to address one of the FC's most relevant issues: the need of preparing the face-to-face-lesson. When there is a need of previous visualization of the preparatory videos, exercises are also included as a motivational measure. This is done using two different approaches: (1) students have to do formative or summative exercises after watching the videos [30] [31] [32]; (2) students have to do exercises while they are watching the videos (i.e. the exercises are embedded on the video or on the video's visualization panel) [13] [33] [34]. Moreover, there are also other alternatives to try to encourage students to prepare the class, such as asking them to bring to class questions about the

videos [3] [35], or giving extra scores, during the face-to-face lesson, to the students who show that they have prepared the lesson [32]. Other measures might be added to motivate students to make their preparatory activities such as gamification or the own use of learning analytics. For instance, gamification techniques (such as giving badges) based on the preparatory activities can encourage their correct completion [29] [36]. Learning analytics techniques (such as giving dashboards and compare their own performance with respect to others) can also motivate students to complete the activities [5] [20]. Therefore, learning analytics could also be used for motivating students in this phase of the FC and not only to make actions on the face-to-face lessons.

Among all the available student data that are used in LA, we choose those related to the exercises and videos, because they provide useful information to adapt the face-to-face lesson to the students' needs and because they are common in FC environments [5] [20]. In addition, this kind of information can be gathered, analyzed, and visualized by LA tools to help teachers to follow the FC [20] [29]. The choice of these students' data, indicators and visualizations for our work has been made analyzing different previous works focused on different aspects of LA. First, there are different LA works that use low level indicators and correspondent visualizations related to videos such as the ones implemented in "ANALYSE" [37] for tracking the number of different and repeated visualizations for each portion of video, or the ones of "CourseVis" [38] to show the student performance on exercises. Moreover, some works analyze the interactions between students and videos (in the context of a real FC course) by means of different LA indicators associated with the videos (e.g. the total number of views or the views by day or week) [39]. There are also works which compare the behaviors of high achieving students and low achieving students, in terms of their videos' visualization patterns, using LA indicators such as the students' frequency of access to the videos [40]. There are other higher level LA indicators that try to give insights about the learning process such as those related to action research for academic purposes [41] or such as the efficiency or the constancy that give information about how much a student learn by unit of time or if the student learns in a constant way during the different days [42]. In addition, some works have analyzed

how to define LA metrics (indicators) focused on measuring the effectiveness of students in terms of their interaction with educational resources (e.g. videos or exercises) using low level data such as the videos' completeness percentage or the number of correct exercises [43].

In terms of the use of LA and the FC, we point out some preliminary works that deal with this joint use. There are works that explore the use of LA in a FC environment [20] which show some examples of LA visualizations which can be used to obtain useful information in the FC context, and some guidelines about the use of that information for the FC (this tool has not been designed from scratch for the FC, but it has been developed to provide teachers with academic information). Moreover, our previous work introduced the combination of LA and the FC [5] through a theoretical framework and several examples of possible applications. There are also works that focus on post-course analysis related to the students' result in e-learning courses such as MOOCs which use the FC as their learning model [23]. In fact, the motivations of this work are precisely based on these previous works [5] [20] [23]. However, these previous works do not define a methodology that explains in detail how to take advantage of LA in a FC (e.g. what specific actions teachers should do), and they do not design and implement a specific tool to support the FC using LA, which are precisely the main contributions of this work.

3. A Proposed Methodology for Improving FC using LA

We define a methodology focused on the enhancement of the FC using LA. Our methodology allows teachers to adapt the face-to-face lesson to the students' learning needs defining a set of actions done before, and during, that face-to-face session.

3.1. Indicators Related to Videos and Exercises

We have used some of the indicators defined in [5] as our starting point, but we have modified slightly some of them. In particular, the selected indicators are classified into two types: (1) indicators that are related to just one student; and (2) indicators associated with a group of students.

We have chosen as a temporal milestone each week of the course, since the considered courses are scheduled through this temporal division (typically the course is split into 14 weeks). However, the indicators can be obtained for any other temporal division different from one week. Next, the selected indicators are presented.

The indicators related to the data of just one student and just one video, or just one exercise, are as follows:

- Percentage of visualization of a video. How many seconds out of the total of the video the student has watched (it does not take into account if a second has been watched more than once, only if the second has been watched at least one time).
- Number of times that each second of a video has been watched by one student (in this case, the indicator takes into account all the times that the student watches that second).

Next, we give details about the indicators associated with several students (e.g. with the whole class).

- Percentage of the videos of the week which have been watched by the students. We consider that a video has been watched if the percentage of visualization of this video exceeds a threshold (this threshold can be defined by the teacher). In this case, the indicator uses the data associated with all the videos of a specific week of the course.
- Number of times that an exercise has been solved satisfactorily by the students. If students do not try again the exercise when they have already done it (which is frequent in most cases), this indicator is the same as the number of students that have solved an exercise correctly.
- Number of times that an exercise has been attempted by the students.

- Percentage of the exercises of the week which have been attempted by the students. As before, the indicator uses the data of all the exercises of a course's week.
- Quality of the resolution of the exercise. This indicator is associated with just one exercise and will be explained next.
- Utility of the videos from the perspective of the percentage of visualization. In this case, this indicator uses the data of one, and only one, video and its value can be either "true" or "false". This indicator will be explained next.
- Utility of the videos from the perspective of the seconds watched. This indicator also uses the data of one specific video. The value can be "true", "false", or an "intermediate value" (the indicator will also be explained next).

The indicator "Quality of the resolution of the exercise" analyzes the students' effort needed to solve the exercise correctly. It is defined as the quotient between the number of times that the students have solved correctly an exercise and the number of times that they have attempted the exercise. The possible values of this indicator are included in the set [0, 1], where a value of "0" means that the exercise has never been solved it correctly. Values close to zero indicate that the student has attempted the exercise much more than they have solved it correctly, while values close to one show that the student has solved correctly the exercise the majority of times that have attempted it, and a value of "1" indicates that the students have solved correctly the exercise all the times that they have tried it.

Regarding the indicator "Utility of the videos from the perspective of the percentage of visualization", it aims to measure if the video might be useful for students. To achieve this, we use two parameters defined by the teacher. On the one hand, we use the parameter "percentage of students", which defines the minimum number of students that are needed to consider that the video has not been watched enough (e.g. if the teacher indicates that this parameter has a value of five percent, at least the five percent of the students have to watch less than a certain percentage of the video to consider that the video is not useful).

On the other hand, we use the parameter “percentage of watching”, which defines the video’s minimum percentage of visualization to consider that this video has been watched (e.g. if the teacher defines this parameter with a value of 54%, then, at least a certain number of students have to watch less than the 54% of the video to consider that the video is not useful). In this way, teachers can know whether students are using the videos to try to learn the concepts, because it allows them to detect if a number of students of the class watch the video less than a specific threshold.

With regard to the indicator “Utility of the videos from the perspective of the seconds watched”, we focus on the number of times that each second of the video has been watched. We want to detect large number of views associated with the videos’ seconds (considering all the views of the students). In particular, we consider that the number of views related to a video’s second is large if an indicator defined as the quotient between the “total watches of the second” and the “amount of students that have watched the second” is greater than a threshold defined as the quotient between “minimum amount of watches among all students” and “maximum amount of watches among all students” plus one. We define the situation in which the video’s second has a large number of views as an “alert”; in other words, we say that there is an "alert” with one specific second, when that second has been watched a large number of times. If the video has a huge number of alerts, then we label that video as “not useful” video; otherwise, we label the video as “useful”. Nonetheless, we are aware that there could be situations in which a large number of visualizations associated with a video’s second is associated with a video conveying appropriately the concepts (for example, if a part of the video explains a practical example, it would have a large amount of views). For this reason, we use the term “alert” and we write between quotes the word “useful”. Therefore, in order to consider this, we provide teachers with the information about the specific seconds of the videos with a large amount of views, and teachers have to determine whether if they are real problems or just interesting parts of the video. Moreover, in order to define an additional case between “there is an alert with one second” and “there is no an alert”, we define an additional case called “the second could have an alert”, when it is not clear that the number of views associated is large (when the indicator’s value is close

to the threshold's value). In order to know whether the video is "useful" or not, teachers have to define the percentage of the seconds of the video which have, or could have, an "alert". This percentage is used as a reference to determine the "utility" of the video. The idea is that if the video contains a certain amount of seconds with an "alert" (i.e. seconds that are more watched than expected), or with possible "alerts", then the video might not be "useful".

3.2 Definition of Rules and Interventions

In this section, we focus on the definition of some specific actions that teachers can do in a FC using the information provided by the previous LA indicators. Our methodology is intended to tailor to most of learning contexts; however, it is fundamental that teachers take into account their own learning context. For instance, one teacher can produce a segment of a video aimed to be interesting for students or in order to promote the students' self-reflection, so that this segment should have associated a number of views larger than the other segments. In order to not define this pattern as a problem (in a lot of cases, when students watches one segment over and over again is because they are not understanding the concepts explained in this segment), the present methodology defines this pattern as an "alert". It is up to the teacher to decide if the "alert" is what it was intended, or it is a problem that should be addressed.

In order to explain in detail the methodology, first we separate the use of videos' indicators from the use of the indicators related to the exercises, and, after that, we analyze the joint use of the two types of information. Moreover, taking each of the course's weeks as a temporal reference, we differentiate between resources of the same week and resources of different weeks.

Use of Videos' Information

In this section, we present how to use the indicators related to the student's interactions with the videos, in order to improve the FC. We analyze the actions that can be done by teachers using: the percentage of

visualization of the videos (Table 1), the number of times that each second of the video has been watched (Table 2), the utility of the videos from the perspective of the percentage of visualization (Table 3) and the utility of the videos from the perspective of the intervals watched (Table 4). It is important to remember that we use the week as a time milestone only as an example; any other time interval can be used easily through the definitions of these indicators.

TABLE 1 Percentage of Visualization of the Videos - Interventions

Considered videos	Intervention
Videos of the week	If a video has a low percentage of visualization in comparison with the rest of the week's videos, teachers can consider changing the format of the video, or changing some of its parts, or, as a last resort, changing the whole video, because there are several students which are not watching this video as much as the other weeks' videos. Moreover, if some students have associated a low percentage of visualization in comparison with their mates, the teacher can alert them, before the face-to-face lesson, to inform them that it is necessary to watch the video in order to prepare the face-to-face lesson. In addition, if there is a remarkable number of students whose video's percentage of visualization is low (it is up to the teacher to decide that percentage), the teacher might make a further explanation of the concepts pointed out in that video, during the face-to-face lesson. This explanation should be usually done at the beginning of the lesson, before the active learning activities.
Videos of different weeks	If teachers detect a week whose videos have a low percentage of visualization in comparison with the other weeks, they can ask students about this fact. If the decrease of the students' engagement is caused exclusively by an internal factor of the course (i.e., the decrease has not been caused by other factors like the workload

	related to other courses), teachers can consider to change something about that week of the FC. For instance, they can decrease the week's workload reducing the number of videos or preparatory assignments for the FC in order to provide students with more time to watch the rest of the videos and understand them. Teachers can also modify the videos to be more interesting for the students, etc. Furthermore, teachers can use the evolution of the percentage of visualization of the videos of different weeks, as an indicator of the students' involvement with the FC throughout the semester. For example, if students have associated a steady percentage of visualization along the semester, teachers can infer that they are investing the same amount of time during the semester, but, if there are huge fluctuations it is possible that some factors have affected the students' work (factors that teachers can know asking their students). To sum up, this type of information allows understanding better the results provided by the actual structure of the FC course.

TABLE 2 Number of Times that Each Second of the Video Has Been Watched - Interventions

Considered videos	Intervention
Videos of the week	If the number of views associated with a specific time interval of the video is high, there is a possible anomaly in this interval. Teachers should check if this part of the video is intended to interest students or to increase their reflection about the explained topics (the topics that students are going to work on during the face-to-face lesson). If the interval of the video is not intended to be different from the rest of the video, then it could be possible that students do not understand the concepts associated with that interval, so that it might be needed to change that interval, or to explain in detail the concepts related to this part of the video at the beginning of the

	face-to-face lesson of the FC (before the active learning activities). Moreover, it is also possible to analyze individual student patterns, in order to alert teachers about specific students which are struggling with the concepts shown in the video, so that the teacher can help them to understand the concepts (e.g. providing them with additional resources).

TABLE 3 Utility of the Videos from the Perspective of the Percentage of Visualization - Interventions

Considered videos	Intervention
Videos of different weeks	Teachers can specify a reference percentage of visualization used to decide whether a video is useful or not. Through an overview of all the videos of the course, teachers can see easily which videos are problematic for the students (i.e. the videos that students do not watch before the lesson) and which are useful for them (i.e. the videos watched by the students before the lesson). In this way, teachers can modify the structure of the FC course; for instance, they can reorganize the videos in order to alternate the most watched videos with the least watched ones, they can also consider if it is worth replacing the preparatory videos of a face-to-face lesson with preparatory readings for example, or they can allow students to see the videos at the start of the face-to-face lesson in order to answer their questions about the videos. The main advantage of this indicator is related to the fact that it allows teachers to get a straightforward overview of the whole course's videos, so that it helps them making decisions about the changes needed to take advantage of the FC.

TABLE 4 Utility of the Videos from the Perspective of the Intervals Watched - Interventions

Considered videos	Intervention
Videos of different weeks	This indicator allows teachers to obtain a summary of the course's videos, but now from the point of view of the patterns related to the visualizations of the time intervals of the videos. Teachers can see if the videos have a lot of possible alerts, and check if this pattern is the intended one; or the other way, if there are something wrong in the video which produces a large number of repetitions of specific intervals of the videos. In this way, teachers can see if the preparatory videos are working as intended, if they should modify or change any videos (and how many of them), or if they have to explain something at the beginning of the face-to-face lesson.

Use of Exercise's Information

In this section, we analyze how to use the indicators associated with the exercises that can be used to enhance the FC. Particularly, we show the interventions related to the use of: the number of times that an exercise has been attempted (Table 5), the number of times that an exercise has been solved satisfactorily (Table 6) and the quality of the resolution of the exercise (Table 7).

TABLE 5 Number of Times that an Exercise Has Been Attempted - Interventions

Considered exercises	Intervention
Exercises of the week	If the exercise has not a number of attempts sufficiently high (this number depends on the teacher's criteria), then the exercise is not working as expected. In this case, there are several actions that teachers can do. Before the face-to-face lesson, teachers have to ask to students whether if there is any problem related to the

	exercise's format or content. If teachers receive feedback commenting that there are problems, teachers can prepare an activity to do at the beginning of the face-to-face lesson in order to cover the content associated with the exercise. After that, teachers might change the format of the exercise to avoid these problems in the future. If students do not provide any feedback, teachers have to remember them that it is vital preparing the face-to-face lesson doing the exercises.
Exercises of different weeks	Through an overview of the mean number of attempts associated with every set of week's exercises, teachers can know how students have prepared the different FC lessons. This is particularly important when evaluating the results of the course (why these results have been obtained), since this information allows teachers to know if their students have prepared the concepts associated with each week doing the corresponding exercises. Moreover, teachers can also obtain more information about the students' workload analyzing whether the exercises have been done or not (in particular, it would be necessary to ask students if there is any problem related to the exercises' format or content, in order to know if they do not do the exercises' because of the time required or because the characteristics of the exercise); consequently, this information allows teachers to better balance this workload along the course.

TABLE 6 Number of Times that an Exercise Has Been Solved Satisfactorily - Interventions

Considered exercises	Intervention
Exercises of the week	If the exercise is solved correctly a large number of times (as in previous cases, this number depends on the teacher's criteria), then teachers can reduce the number of active learning activities related to the exercise's concepts that are done during the face-to-face lesson, since students have learned these concepts.

	In this way, the FC lesson is adapted to the students' learning paces and achievements, since it is possible to focus on the most difficult concepts for students. Conversely, if the exercise is not solved correctly an enough number of times, then teachers have to ask students about the exercise's format or content in order to enhance the exercise in future courses. Moreover, teachers have to spend more time of the lesson doing activities related to the exercise's concepts in order to address the gap in the students' knowledge associated with the problematic exercise.
Exercises of different weeks	Analyzing the way in which students have solved the exercises related to different weeks, it is possible to infer how well they have learned the concepts. In particular, if the students are able to solve correctly the major part of the week's exercises, then there is not any need to change the structure of this part of the FC course. However, if there are problems with the exercises, it might be worthwhile to change that structure (we focus on this kind of changes in the following section, the one related to the joint use of the videos' and exercises' information).

TABLE 7 - Quality of the Resolution of the Exercise - Interventions

Considered exercises	Intervention
Exercises of the week	If the quality of the resolution is closed to zero, then students have not understood the concepts asked in the exercise because they have attempted the exercise much more than they have solved it correctly. Therefore, if teachers have not designed the exercise to be difficult or challenging for their students (in this case, the value of this indicator has to be close to zero), then the teacher can adapt the FC lesson doing one or both of these options at the beginning of

	the lesson: (1) they can explain the concepts associated with that exercise, or (2) they can do other types of exercise related to those concepts. To the contrary, if the quality of the resolution is almost one, then the activities done during the FC lesson related to the exercise's concepts can be skipped, since students have already understood these concepts. In this way, teachers can focus the class on other activities related to more difficult topics.
Exercises of different weeks	In this case we focus on how the students have solved the exercises. If the mean quality of resolution of the week's exercises is high (close to one), then they are not having problems at all to solve those exercises. However, if the mean quality of resolution of the exercises of the week is low (close to zero), students are having problems with the exercises. Through this information, teachers can decide if their theoretical conception of the week (e.g. if the week has to be challenging for students, or it has to be 'easy' to understand for them) meets the real situation of the learning process.

Joint Use of the Video's and Exercise's Information

In this section, we analyze how teachers can combine the video's information and the information related to the exercises in order to improve the FC. We focus on two possible sets of indicators that provide teachers with the information needed for that enhancement.

Use of the Percentage of Visualization of a Video, the Number of Times that an Exercise Has Been Attempted, and the Quality of the Resolution of the Exercise

These three indicators allow teachers to know easily if students are following the FC methodology, or if they are struggling with any part of it. The idea is to provide teachers with visualizations which show these indicators together, so that they have all the information that they need at a glance. For instance, comparing the percentage of visualization of a video with any of the exercises related to it (with the exercise's number of attempts and with the quality of its resolution), it is possible to know: (1) if students watch the preparatory video for the lesson, (2) if they try the associated preparatory exercise, and (3) how well students solve the exercise.

In this way, these joint visualizations allow teachers to improve individually each part of the preparatory process (the videos or the exercises). Moreover, they provide teachers with useful information related to the students' knowledge about the concepts prepared through the videos and exercises, and this allows teachers to adapt the face-to-face lesson to the students' needs (this adaptation can be implemented through different actions, from doing activities focused on the most difficult concepts of the preparatory videos or exercises, to skipping activities whose associated concepts students have already understood).

It is also possible to compare the videos to the associated exercises in order to discover if any of these elements of the pair "video – exercise" are causing problems (or both, or no one). One possibility is to analyze if a video with a low percentage of visualization has associated an exercise (or several exercises) with a quality of the resolution's value close to zero. In this case, the exercise might not be an issue but instead, the video might be causing the problem, since most times students are not able to solve correctly the exercises related to the video; so that teachers have to focus their efforts to improve the video instead of enhancing the exercise. Conversely, if the video's percentage of visualization is not low (using the teacher's criteria), but the exercise has a low quality of resolution, then the problem might be in the exercise and not in the video.

Use of the Utility of the Videos from the Perspective of the Seconds Watched, and the Quality of the Resolution of the Exercise

The joint use of these two indicators aims to allow teachers to detect several patterns related to the students' interactions with the videos and exercises, and compare whether those patterns fit with the intended effects of those videos and exercises The idea is to analyze the video's intervals with alerts in order to know the most watched concepts, and analyze the student's quality of resolution related to the exercises where those concepts are asked. Specifically, the most useful patterns for teachers that can be detected are the following.

1. When the video's intervals aim to be interesting or challenging for students, we have in these intervals an "alert" from the perspective of the seconds watched, and a quality of the resolution's value close to zero (challenging interval) or close to one (interesting interval) in the exercises related to the concepts of those intervals.
2. When the exercises aim to go further in comparison with the concepts explained in the videos, the video should not have many alerts, but the quality of resolution of the exercise should have a value close to zero.
3. If the video and exercise are focused on explaining clearly the concepts to the students, we should not have alerts in the video, and the quality of resolution value of the exercise should be close to one.

Therefore, teachers can analyze whether videos and exercises generate the intended effects on students and, if not, they can know which one (the video or the exercise) is the cause of the students' problems. In addition, as in the previous joint use of video's information and exercise's information, we are able to adapt the FC to the students' needs, since we obtain information about the concepts that are either most difficult for students or most understandable for them, and this allows teachers to do active learning activities during the face-to-face lesson which best fit to students' needs.

4. The Tool to Support the Methodology

In this section, we present the design and implementation of our learning analytics tool that supports the methodology specified previously. Moreover, we illustrate some of the visualizations related to the indicators defined in the methodology that allow teachers to adapt the FC to the students' needs.

4.1 Design and Implementation of the Tool

Our tool extends the utilities provided by an existing e-learning tool named "GEL". "GEL" is a web platform focuses on supporting SPOCs (Small Private Online Course [44]) providing teachers and students with facilities to share resources (videos, exercises, PDFs, and so on) and to access to them. Moreover, "GEL" gathers data related to students' interactions with the resources and provides teachers with several visualizations associated with that data (for example, when students access to the platform or how many exercises students have done). Apart from that, a mobile platform has been developed to support the FC in the "GEL" environment, making easier the use of this methodology for both teachers and students [29]. For these reasons, "GEL" is a suitable base to develop our tool.

We extended "GEL" because of the following reasons:

- "GEL" is focused on the students' access control and on sharing academic resources, but it is not focused on the combination of LA with the FC.
- Some indicators defined in our methodology do not have visualizations in "GEL", so that it is necessary to implement these visualizations in order to be able to follow the methodology.

These are the reasons that promote the development of a new tool that allows us to implement the methodology. This new tool is implemented as an extension of "GEL" in order to take advantage of its functionalities, like the gathering of the student data (which is needed to generate the visualizations about

the indicators), or the sharing of academic resources between teachers and students through a common interface.

4.2 Visualizations

The visualizations of our tool are generated automatically, so that teachers do not have to do anything to obtain these visualizations. Teachers only have to access to the e-learning platform which supports the tool. The main purpose of this section is to present the criteria used to choose specific visualizations instead of others, and to show some examples of these visualizations in the context of our methodology.

Three main criteria were used to design and implement the visualizations.

1. The types of visualizations (i.e. bar charts, graph charts, etc.) that are used in our tool have been analyzed in other works with positive results [20] [42].
2. The visualizations must be understandable for teachers without knowledge about data, LA, technology, or any other type of knowledge different from the teaching process itself. This will allow any kind of teacher to use our tool independently of their computer skills, from teachers with a high technological background to teachers focus exclusively on humanities studies.
3. In order to be concise, the visualization has to show the minimum amount of data bringing the most possible information, so that, it only has to show the specific information that allows teachers to follow the methodology

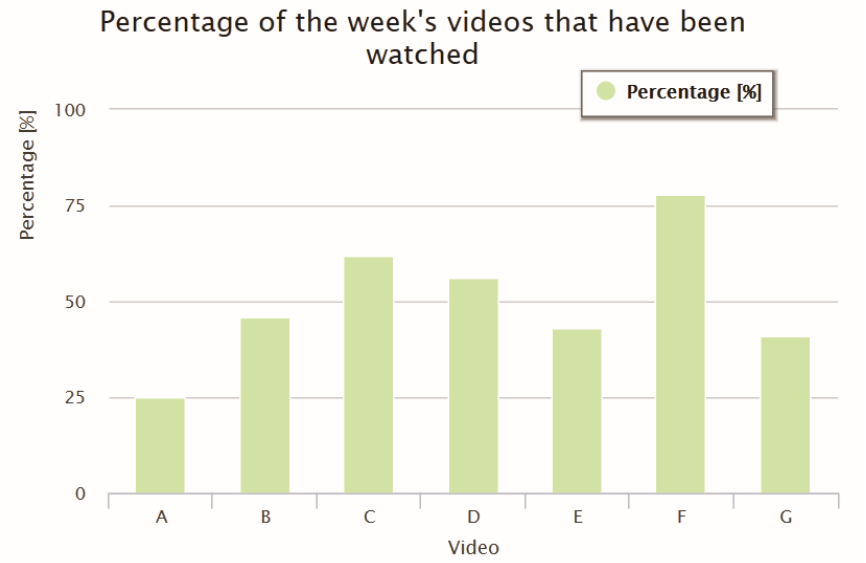
Using the above criteria, we have chosen the visualizations (shown in the following sections) for the indicators used by the methodology. In order to provide insights about the utility of these visualizations in a real scenario, we have used data from real engineering courses to generate those visualizations. We had the data from 3785 students enrolled in 20 engineering courses taught between September 2016 and January 2017. The demographic data related to these students are the following: out of the 3785 students,

2651 are males and 1134 are females, and, from another point of view, 2249 are freshmen (i.e. first-year students) and 1536 are sophomores (i.e. students who are repeating the course). The courses have different sizes in terms of numbers of students, ranging from less than 10 students to 600 students. We tested how the visualizations would be in different courses with positive results.

Videos' Information

Percentage of Visualization of the Videos.

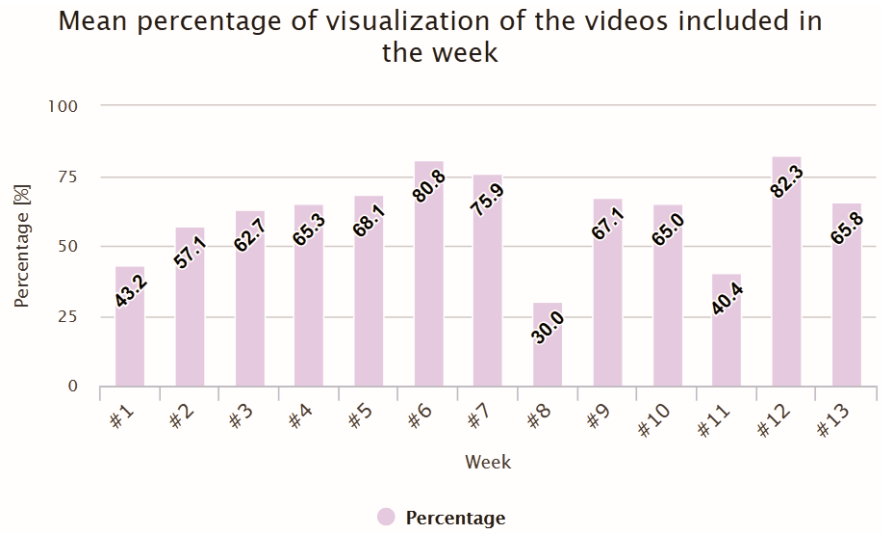
In this case, we use a bar chart to show the percentage of visualization of the videos of one week and the mean percentage of visualizations of the weeks' videos, because it is a simple way to present this type of information. These two visualizations can be seen below (Figure 1 and Figure 2).



<Figure 1 about here>

In this example, students are not watching the week's videos so much, since the percentage of visualization of each video is less than 80% and, in some cases, it is below the 50%. Through this

information, teachers can consider changing something about the videos, such as the format or the duration.

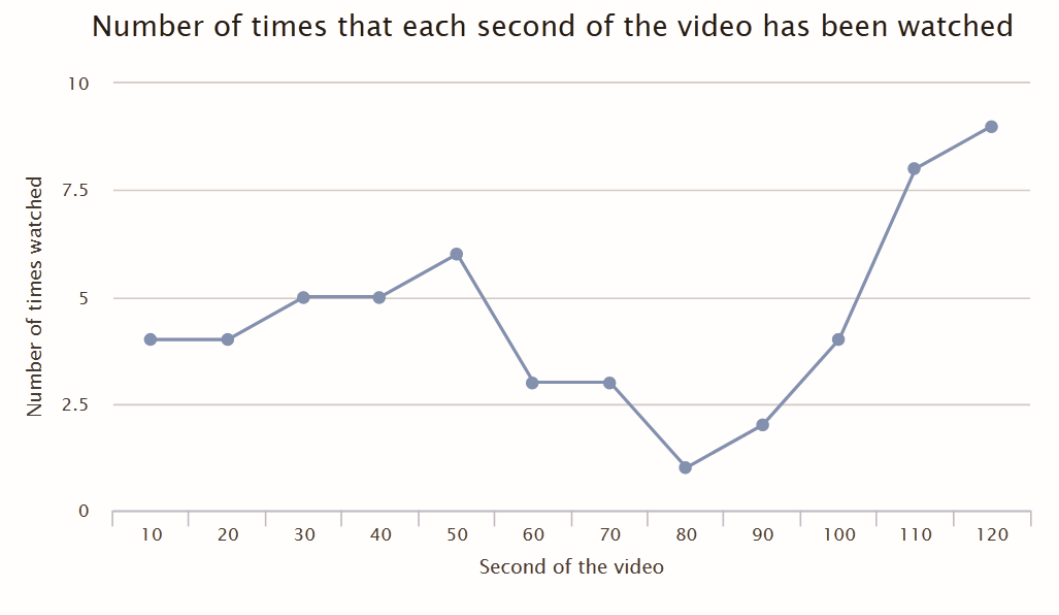


<Figure 2 about here>

We can see a huge decrease in the percentage of visualization of the week's videos for the eighth week (week #8), so that teachers have to find out if this is because an internal factor (e.g. students do not find the videos useful) or because an external factor (e.g. in that week there is a huge workload due to other courses).

Number of Times that Each Second of the Video Has Been Watched.

In order to visualize the number of times that each second of the video has been watched, we choose a line chart since it provides a quick and easy way to understand this information. Figure 3 shows this visualization.



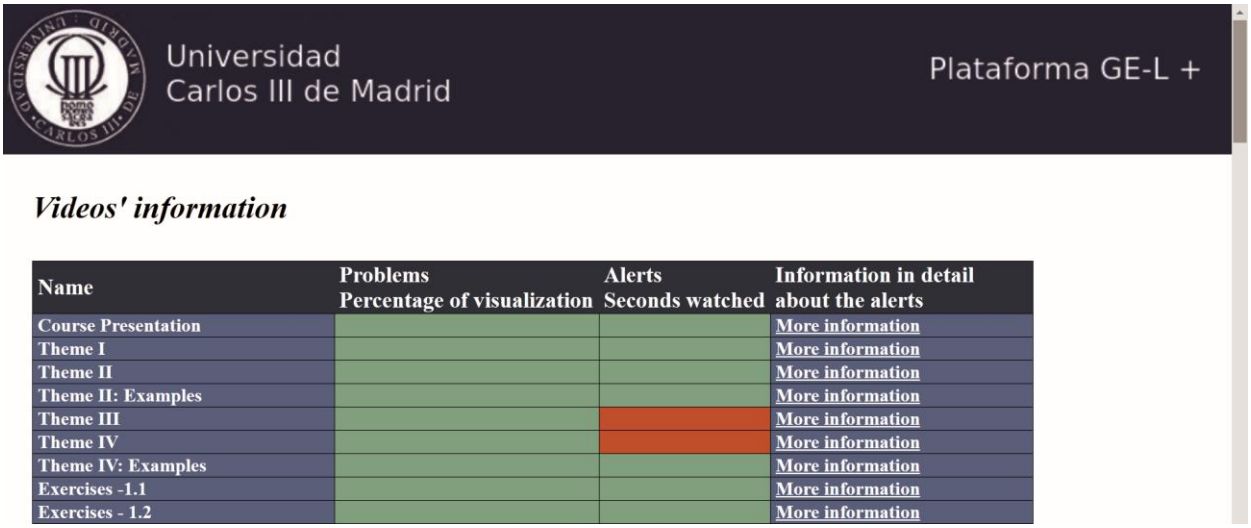
<Figure 3 about here>

In this example, there is a huge increment in the video's visualizations from second 100 to second 120, so that there is an alert that should be checked by the teacher in order to know if the video is working as predicted (e.g. if the video's interval [100, 120] tries to be challenging for students).

Utility of the Videos from the Perspective of the Percentage of Visualization and Utility of the Videos from the Perspective of the Intervals Watched.

Through this visualization, we aim to show the information in a concise and meaningful way. For this reason, we use two colors to present the utility of the videos from both perspectives: green if there is not any important information about the video's visualization pattern that the teacher should take into account; and red if the video's percentage of visualization is low (in the case of the utility from the perspective of the percentage of visualization), or if it has a considerable amount of alerts (when the utility is from the perspective of the intervals watched). Moreover, we provide teachers with a link to analyze in detail the alerts of the videos from the perspective of the intervals watched (Figure 5 shows the information provided through this link). Apart from that, in order to avoid overwhelming teachers with a lot of

information, we keep simple the interface, so that we only show the name of the video, the utilities from both perspectives, and the link to analyze the alerts of the corresponding video. We can see this visualization in the following figure (Figure 4).



<Figure 4 about here>

This example shows that most videos do not have any problem from the point of view of the percentage of visualization, and they also do not show any alerts except from the video ”Theme III” and “Theme IV”. The teacher can obtain information in detail about those videos (specifically the information about the alerts) if they use the link “More information” in the corresponding case. Therefore, through this link, they can check if the video’s results are the intended one (e.g. if the video tries to be challenging, then there would be alerts shown with a red color in the column “Alerts - Seconds watched”).

Alerts of the Video.

In this case, we want to show teachers the intervals of the video with have a large number of views. Moreover, we provide teachers with a direct link to the interval of the video where the alert is. In this way,

teachers have only to click on the link to know the specific interval which have an alert (or which can have an alert). This visualization is shown in the figure below (Figure 5).

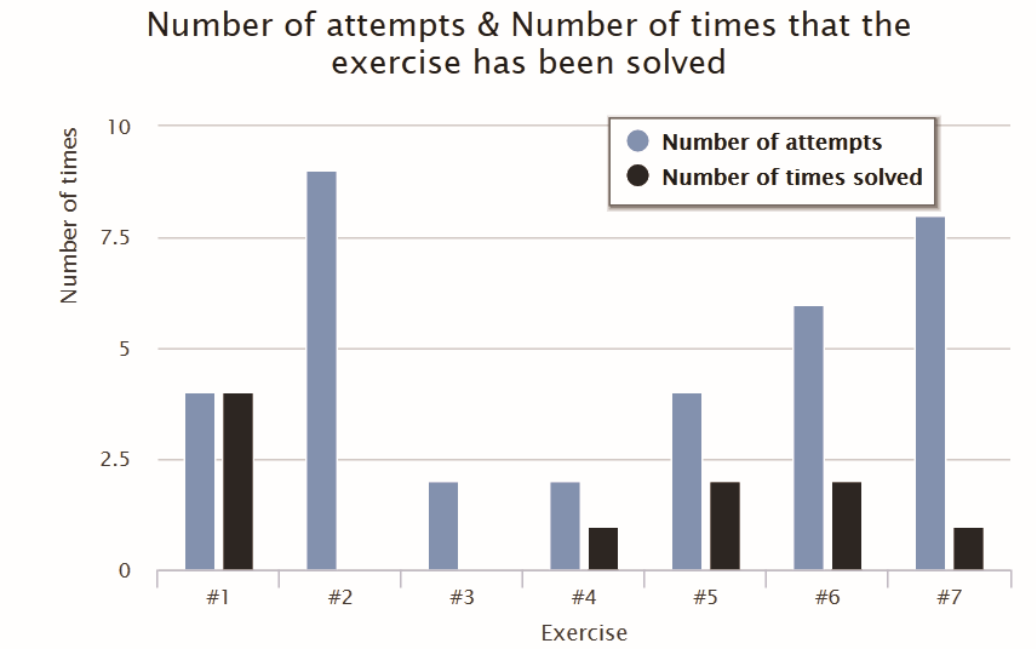
<Figure 5 about here>

In this example, we can see the alerts and possible alerts of a course's video. There are four possible alerts in the intervals shown in Figure 5 which last from the corresponding "Start" time to the corresponding "End" time. Moreover, there is one alert in the interval from [03:52] (three minutes and 52 seconds) to [04:25] (four minutes and 25 seconds). If the teacher clicks on any of the "Type of interval" items (i.e. if they click on the column with the text "Interval with a possible alert" or "Interval with an alert"), the tool plays the video from the "Start" time until the "End" time.

Exercises' Information

Number of Times that an Exercise Has Been Attempted & Number of Times that an Exercise Has Been Solved Satisfactorily

This visualization provides two exercises' indicators at a time because it can be useful to teachers to compare in the same graph the number of attempts of an exercise, and the number of times that this exercise has been solved correctly. This information can be conveyed very easily through a double bar chart as we see in the following figure (Figure 6).

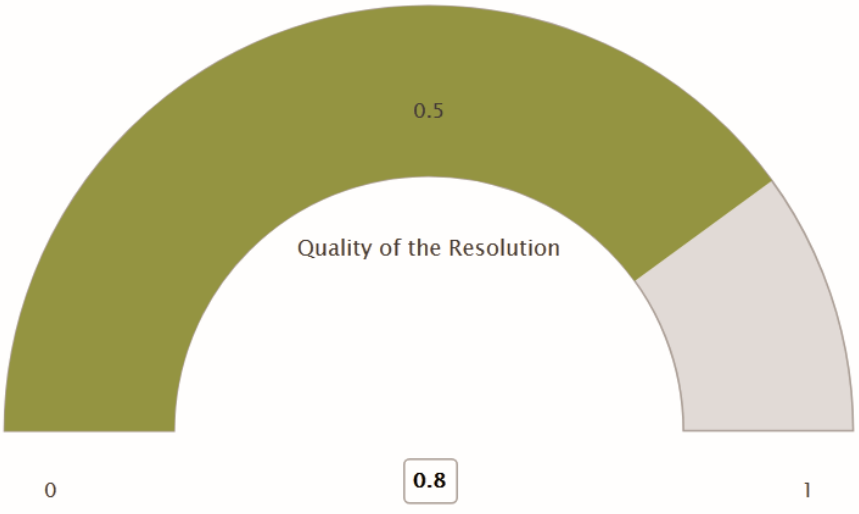


<Figure 6 about here>

In this case, it is possible to see two exercises (exercises #2 and #3) that have been attempted, but that have not been solved correctly any time. Using this information, the teacher can do activities, related to the concepts mentioned in those exercises, during the face-to-face lesson, and they can also explain those concepts just at the beginning of the lesson. Apart from that, the teacher can know that the concepts associated with the first exercise (exercise #1) have been learned by the students, since they have solved correctly the exercise all the times that they have tried it.

Quality of the Resolution of the Exercise

We have to remember that this indicator can have a value included in the interval [0, 1], where most-closed-to-zero values indicate that the exercise has been attempted much more than it has been solved correctly, and a value close to one shows that the exercise has been solved correctly most times. Therefore, it is useful for teachers to only see the value of this indicator and its "position" in the defined interval (in our case the interval [0, 1]). One possibility is to use a gauge graph, because this kind of graph allows teachers to know easily the indicator's value and its relative position between two values such as in our case. Moreover, depending on the value of the indicator, the gauge is shown through different colors that progressive change from red to yellow, and from yellow to green, in order to provide teachers with an easy way to detect if the quality of the resolution has a low value (red colors), a medium value (yellow colors), or a high value (green colors). In particular, the color boundaries divided the gauge into three "parts"; the values in the interval [0, 0.33] are shown using red colors, similarly, the interval [0.34, 0.67] is shown through yellow colors, and, finally, the values included in the interval [0.68, 1] are shown using green colors. The visualization associated with the quality of the resolution of the exercise can be seen below (Figure 7).



<Figure 7 about here>

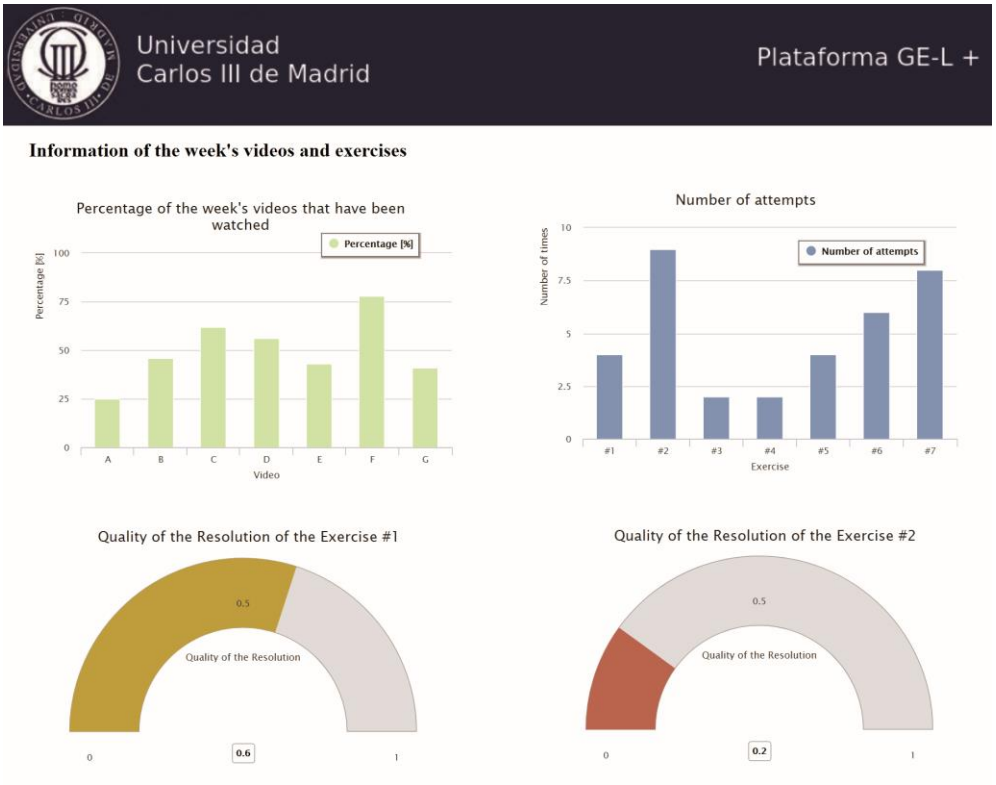
This example shows that the exercise's "Quality of the resolution" indicator has a value of 0.8, which means that the exercise has been solved correctly an important number of times. Therefore, the teacher can infer that the concepts associated with the exercise have been learned appropriately.

Joint Use of the Video's and Exercise's Information.

This section shows two visualizations which combine the video's information and the information related to the exercises (Figure 8 and Figure 9). We have to remark that we consider that the week's videos and exercises include common concepts intertwined, in order to show a possible configuration of our tool. As a result, we show together the indicators associated with the videos and exercises included in the same week of the course, but it would be possible to change this "connection" and show videos and exercises of two different weeks, three weeks, only one pair "video – exercise", and so on.

Percentage of Visualization of a Video & Number of Times that an Exercise Has Been Attempted & Quality of the Resolution of the Exercise

In this case, we present these three indicators to the teachers using the individual visualizations shown previously, but in the same screen in order to provide them with a quick way to analyze all this information at a glance. Moreover, as the indicators have been implemented with the aim of being understandable, teachers should not have any problem to understand this "aggregated" visualization. The "aggregated" visualization is the following (Figure 8).



<Figure 8 about here>

In this example, we can see that students have not watched the videos too much, due to the relative low value of the "percentage of visualization" indicators. Moreover, they have tried the exercises a very few times, less than nine times taking into account all the students of the class. Considering these facts, the teacher has enough information to consider that students have not learned properly the concepts explained through the videos. This fact is corroborated by the low values associated with the qualities of the resolution of the exercises one (exercise #1) and, especially, two (exercise #2).

Utility of the Videos from the Perspective of the Percentage of Visualization & Quality of the Resolution of the Exercise.

Through this visualization, we aim to show the quality of the resolution of the exercises associated with a video and if this value is related to the percentage of visualization of that video. For this reason, we present the videos' utility from the perspective of the percentage of visualization and, next to that utility,

we show the values associated with the quality of the resolution of the exercise which asks for the concepts explained in that video (if there is more than one associated exercise, we show their corresponding quality of resolution). This visualization is shown below (Figure 9).

Videos' and exercises' information

Video's Name	Problems Percentage of Visualization	Related Exercises [QoR]
Course Presentation		Exercise #1: [0.67] Exercise #2: [0.35]
Theme I		Exercise #3: [0.9]
Theme II		Exercise #4: [0.2]
Theme III		Exercise #5: [0.7] Exercise #6: [0.89]
Theme IV		Exercise #7: [0.35]
Theme V		Exercise #8: [0.88]
Theme VI		Exercise #9: [0.6]
Theme VII		Exercise #10: [0.4]
Theme VIII		Exercise #11: [0.73]

<Figure 9 about here>

We can see that the videos with problems related to the percentage of visualization (i.e. videos that are not useful from the perspective of the percentage of visualization) have associated low values of the indicator "Quality of the Resolution of the Exercise". This is not surprising since if students do not watch the video, it is not likely that they can solve the corresponding exercises.

5. Discussion about the Connection with Previous Work

The main purpose of this section is to compare the proposed methodology and the proposed tool with respect to other previous works.

5.1 The Methodology

In the current literature, there are works which analyze the students' preparation of the face-to-face lesson using LA indicators. For instance, students' answers to the preparatory exercises can be used by the teacher to know what topics are most difficult for the students and explain these topics just at the beginning of the face-to-face lesson [34]. Another approach is focused on the analysis of the students' strategies when doing the preparatory activities. In this sense, the analysis of the output of the Linux shell (e.g. the output of the compiler GCC) [26] shows that students only complete summative preparatory exercises, and they do not invest time on the formative preparatory exercises prior to the face-to-face lesson. Furthermore, the students' visualization patterns of the preparatory videos have also been studied to know whether they are preparing the lesson or not [45]. All of these works are focused on just one or two LA indicators within a FC environment; however our methodology uses a broader range of indicators which can be obtained in many FC contexts, so that it is suitable for most of the situations.

Furthermore, the monitoring of the students' learning process within a FC context using LA indicators has also been studied. For instance, the timestamps of the students' accesses to the videos and the duration of these accesses have been analyzed in order to know an appropriate duration of the videos for a FC environment (e.g. [46] recommend that the videos should last between 10 and 15 minutes). There are also works that use LA indicators to compare the students' learning process in different learning environments when using or not a FC approach. For example, the mean number of times that students watch the videos, or the exercises' mean number of attempts can be used to carry out this type of study in MOOCs environments which use the FC such as in [47]. It is also possible to analyze the students' learning process in mobile learning environments which use the FC; for instance [9] monitors the students' learning process in a FC mobile environment using the students' data associated with the amount of time invested in the videos, or whether they like the videos or not. Moreover, some of the works give some recommendations for the FC based on LA indicators such as [20] for the repetition of video intervals. As in the previous case, these types of works only use a small subset of LA indicators for the FC and in case there are recommendations they are very few. Furthermore, some of the works analyze specific learning

environments (e.g. MOOCs or mobile environments), so that it could be difficult to generalize the results to other learning contexts. In comparison, our methodology proposes a broader set of indicators and recommendations for the FC. In addition, it is flexible enough to be used in different learning contexts, since the defined rules and interventions are almost independent of the learning environment.

In conclusion, in all of these works, and as far as we know in the other works shown in the literature, the use of LA within a FC environment depends on the learning context; i.e. the selection of the used LA indicators has been made within the specific context, so that these indicators could not be useful in other contexts. Moreover, in most of these works, only a small set of LA indicators is used, and these indicators are employed to obtain specific context's information. In comparison, our proposal provides a broad range of LA indicators related to both videos and exercises, which can be used in different learning contexts. Moreover, the information that can be obtained through these indicators allows teachers to adapt the face-to-face lesson to the students' needs. Apart from that, the suggestion for teachers' interventions based on the information obtained are almost non-existent in most of these works, there are no guides about what teachers have to look at, and what they have to do with the information that they receive. By contrast, we provide a specific guide of recommendations and interventions based on the obtained LA data, a guide that can help teachers to improve the students' learning process, and this is precisely the main contribution of our proposed methodology.

5.2 The Tool

Nowadays, there is a broad range of available options in terms of LA tools which gather educational data and provide teachers with academic information. Most of these tools, as well as our tool, provide visualizations related to the students' interaction with the academic resources (such as videos or exercises). For instance, there are some tools that provide visualizations about how the students solve the exercises and how they use the hints that help them when doing the exercises [48]. There are also tools

that provide visualizations about the students' performance in the different modules of the course, such as the time invested by the students in the modules or how many students have failed, passed, passed with high grades or have not done the exercises of the module [49]. Moreover, the concepts which are complex for students are also considered in some tools that provide visualizations which show the students' knowledge of these concepts [50]. Videos are also analyzed in some tools, such as in [51] where students can label the videos as "interesting", "important" or "difficult", or in [52] where the tool provides visualizations about the students' visualization patterns (e.g. number of plays, pauses while watching the video, or whether the video has been completely watched or not). Therefore, taking into account this information, we can see that our tool does not offer any new visualization, apart from the two visualizations related to the utility of the videos which are innovate (as far as we know, there is not any other tool that shows this two visualizations).

Nonetheless, this does not mean that our tool does not offer any contribution. In fact, because it has been developed from the beginning to be used in a FC environment, it offers the following contributions:

- Provides the visualizations just in time, i.e. it provides the visualizations when they allow teachers to adapt the face-to-face lesson to the students' needs, so that they are available before the lesson (and, needless to say, after it).
- Obtains automatically the visualizations, teachers do not need to do anything, so that they can focus on adapting the face-to-face lesson.
- It is designed to fit perfectly with the methodology proposed in this work. This implies that the tool provides teachers with information conveyed in time, and that this information is meaningful, i.e. teachers can use the information to know what interventions are more suitable for the corresponding learning context.

6. Conclusions and Future Work

In this work, we define a methodology to improve the FC using LA techniques, providing specific information about the actions to be done to achieve this objective. Furthermore, we present a tool which allows teachers to implement the methodology, since it supports the use of the FC in a broad type of courses and provides teachers with the information needed to implement and follow that methodology. Using the actual literature related to the LA indicators, we have chosen some of them related to the exercises and videos which are appropriate for a FC context, because they allow us to obtain useful information to adapt the face-to-face lesson to the students' needs and, moreover, they are common in FC environments. These indicators and the correspondent visualizations are used in our methodology to provide teachers with the information needed to enhance the FC.

The methodology defines exhaustively several ways to improve the FC using: (1) the videos' information, (2) the information related to the exercises, and (3) the information associated with the videos and the exercises together. Moreover, we differentiate between actions done taking into account the week associated with the video or exercise (in our case, we have chosen the week as a time milestone, but the methodology is flexible enough to allow teachers to choose other period of times), and actions oriented to the entire course along all its weeks.

Furthermore, we designed and implemented a learning analytics tool which uses the methodology in an easy and meaningful way. Our tool extends the functionality of a web platform named "GEL" designed for supporting SPOCs. In particular, the tool provides the information that allows teachers to improve the FC. The key characteristic of our tool, which as far as we know make it different from the rest of available learning analytics tools, is that it has been designed from the beginning to be used in a FC environment where LA techniques are used to improve this active learning methodology. In addition, we have presented the visualizations provided by the tool to provide teachers with meaningful information, and the criteria used to select the specific type of visualization. Not only that, we also show visualizations which

use data from different engineering courses, and this allows us to show the capacities of our tool in real scenarios.

In order to provide all the details about the methodology and the tool, it is essential that we point out some of their limitations. First, although we have tried to provide just the information that teachers need to improve the learning experience, there could be teachers which do not use the methodology or the tool simply because there are too much information for them. In order to overcome this limitation, we must develop and distribute short, simple and understandable guidelines for both the methodology and for the tool. In addition, the methodology and the tool have to be validated in real learning contexts. In spite of the fact that the main focus of this work is to present the methodology and the tool, and that we have validated the process of obtaining visualizations through real courses, it is necessary that we analyze the learning outcomes obtained throughout our methodology and our tool, and the improvements that they provided in comparison with "normal" FC contexts. Moreover, we have to obtain the teachers' and students' opinions about the methodology and the tool (e.g. using surveys or focus groups). Therefore, although this work is the next logical step after the definition of a framework based on the use of LA and the FC [5], it is not the final stage,

Furthermore, there are some interesting possibilities regarding future researches in this area. In particular, a quasi-experimental study to evaluate the usefulness and effectiveness of the proposed methodology would be very useful in order to validate the methodology in a real context. The quantitative assessment would analyze the students' scores and their opinions about the usefulness of the academic resources provided to them. In order to gather these opinions, we might use a form, which will be shown next to the corresponding resource (within the tool); in this way, students only have to indicate their perception about the usefulness of the resource (videos, exercises and so on) writing a score for the resource. Moreover, the results of the students' survey could be compared with the learning analytics indicators to check if the results were similar, which would mean that the learning analytics tools can provide useful information in

an automatic way without need of surveying students. Regarding the qualitative assessment, we could interview both teachers and students about the methodology and about the academic resources used. We would use two qualitative methods to gather this information: (1) focus groups with students and with teachers; and (2) surveys filled by students and teachers. Therefore, this would be a way to evaluate the proposed methodology.

Apart from the evaluation of the methodology, we also point out the importance of an analysis about the different aspects which could affect the learning outcomes. For example, we want to know if the students' results vary if we use a MOOC, SPOC, or face-to-face FC environment, in order to validate if the methodology works regardless of the environment. We also are interested in analyzing if students' demographics affect the learning outcomes because, for instance, young students usually have higher technological skills than older students, and this could affect their grades in contexts with a high use of technology (such as in a FC context). In addition, we think that it would be worthwhile to analyze the learning outcomes provided by the methodology in FC contexts which use frequently group activities, in order to validate if the methodology fits with this type of scenarios, or if there are changes that have to be made.

Finally, to sum up, this work allows us to obtain a detailed insight into the use of LA to improve the FC, defining a specific methodology focused on this objective. Moreover, we design and implement an e-learning tool to implement that methodology, providing teachers with all the information that they need to improve the FC through LA.

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Figure legends

Figure 1: For each video of the week, percentage of visualization

Figure 2: For each week, mean percentage of visualization of the videos included in the week

Figure 3: Number of times that each second of the video has been watched

Figure 4: Videos' utility

Figure 5: Intervals of the video with alerts

Figure 6: Number of attempts and number of times that the exercise has been solved

Figure 7: Quality of the resolution of an exercise

Figure 8: Percentage of visualization of a video, number of times that an exercise has been attempted and quality of the resolution of the exercises

Figure 9: Utility of the videos from the perspective of the percentage of visualization and quality of the resolution of the exercise