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Ontological Flip Teaching: a Flip Teaching model based on knowledge management

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Abstract Training models are designed for students to acquire knowledge at the individual level. Yet that knowledge is not usually applied later to increase organisational knowledge, as represented by the didactic resources available on a subject, nor to improve the effectiveness of the subject itself. In industrial, economic and production areas, knowledge is considered a part of an organisation's value. This takes into account the knowledge that is acquired by individuals while doing their work, which can both help improve the work of their peers and increase the overall knowledge available within the organisation. In this work, the student of an educational organisation is considered a person who is able to share the knowledge they have acquired on a given subject so that other students can improve their learning. This work proposes the integration of the classic Flip Teaching model that usually involves students/trainees viewing lectures outside of class time while class time is dedicated to practical exercises, with a knowledge spiral that involves ontological and time dimensions. This integration allows to convert individual knowledge into organisational knowledge through the resources that are created by students over the continuous editions of a training course. A quasi-experimental method proves that the new model, called Ontological Flip Teaching, increases the effectiveness and efficiency of the classic Flip Teaching model in the acquisition of the teamwork competence. The results are based on the students' opinion about workload and time spent to develop both models, the final grades and the student–student interactions.

Keywords Cooperative learning; Flipped Classroom;Flip Teaching; Knowledge management; Knowledge spirals

1 Introduction

The master class is the most significant component of traditional and formal teaching. It represents the main activity of educational paradigms that are focused on teaching (teachers). It is developed in a specific place (classroom) and at a specific time (class time), and requires the physical presence of both faculty and students.

New models and training methods have emerged, however, due to the need to include other aspects in educational processes. These include informal training [18, 19, 21], the active participation of students, technology, which is now ubiquitous and can provide learning at any time and in any place, and the use of knowledge management (hereinafter, "KM") as an organising tool.

Alongside active methodologies like those mentioned above—which involve learning innovation and allow for the simultaneous integration of various methodologies—a series of other methodologies have emerged that are centred on students taking leadership of their own learning. These include problem-based learning, project-based learning, teamwork and game-based learning [7, 17, 34, 42].

One of those models is called Flip Teaching (hereinafter, "FT"). FT originally proposed an exchange of the two traditional learning tasks: the master class lesson, taught in school, and the homework, done at home. The locations of these two tasks were flipped, so they became "lesson at home" and "homework in class".

This model—introduced in 2000 by Lage, Platt and Treglia under the name *Inverted Classroom* [27] and by Baker under the name *Classroom Flip* [3]—was retrieved in 2007 by Bergmann and Sans. The two authors are often considered the pioneers of the model, which they call the *Flipped Classroom* [4].

Various works have reviewed the FT model [5, 22, 26, 32]. Fortanet et al. [16] introduce the concept of bringing cooperative learning together with the FT model through student teamwork. Angelini [2] says that the integration of inverted classwork and cooperative learning contributes to the development of learning competencies (search, choice of material, organisation, understanding of concepts, adaptation and application of knowledge to other contexts). It also leads to improved intellectual, communication and interaction skills; interpersonal and intrapersonal skills; abilities in terms of personal organisation; time and resource management; professional development skills; and personal and social commitment [29].

Cooperative learning is effective if the guidelines outlined by Johnson et al. [24] are followed. These include that group participants should constantly interact by sharing information and resources, reinforcing knowledge, inter alia. The authors also emphasise that the group should carry out activities to promote reflection on the process and evaluation of work.

Regarding the benefits of peer cooperation in learning, a previous research [39] presents an example of scaffolding during the development of an engineering course, in which students are supported by teachers and other students. The authors' proposal describes the benefits of using shared knowledge repositories, the contents of which are created by students. The key idea is the transfer of knowledge produced by students into organisational knowledge, through a KM system called the Collaborative Academic Resources Finder (BRACO, for its acronym in Spanish) [12]. At the same time, certain quantitative measurement instruments provide insight into students' perceptions about the use of this knowledge. They also measure BRACO's impact on student learning outcomes when students promote, organise and use the resources generated by fellow students.

From the point of view of KM, and under conditions of traditional teaching (assuming that several people are simultaneously learning in the same place), knowledge is created when people exchange it. The great problem of the master class is the lack of an exchange of tacit knowledge (belonging to the individual student), because the flow is unidirectional. Knowledge, therefore, is transferred only from one person (teacher) to many people (students). This is called *weak socialisation*; that is, conditions exist for the exchange of tacit knowledge among people, but the flow is unidirectional rather than multidirectional [38].

Relating the terminology of KM to FT, research shows that, in learning situations with weak socialisation (unidirectional flow of knowledge), greater efficacy and learning efficiency are obtained if learning is done through an interiorisation phase. That is, teachers transform their tacit knowledge into explicit knowledge (that is produced externally to the individual). This may be done, for example, through a video that allows students access to knowledge at any time and place, and from any technological platform. This is the FT activity called the "home lesson".

FT models also propose that—since the activities of weak socialisation have now been taken out of the classroom—teachers (experts) and students (apprentices) should take advantage of their spatial and temporal coincidence, encouraging the active participation of students for a true socialisation experience, or knowledge exchange. In this sense, a great variety of educational activities are carried out in the classroom (solving doubts that emerged while watching the videos, solving problems, debating ideas, etc.). These are based on different methodologies, as mentioned above. These FT activities are called "homework in class". From the point of view of KM, this model works only with two phases: interiorisation (lesson at home) and socialisation (homework in class).

Based on the above, this paper proposes a new FT model, incorporating the rest of the phases that Nonaka and Takeuchi [30] define for KM, i.e. exteriorisation and combination. This is achieved by including a third activity called a "link", which acts as a link between the activities at home and in the classroom. In the "link", students must carry out work from the video and complementary material of the teacher (combination), and they must generate a result (exteriorisation).

From the point of view of knowledge generation, knowledge in FT is generated and/or selected by teachers (didactic resources for the interiorisation phase—lesson at home). The main contribution of this new model, called *Ontological Flip Teaching* (hereinafter, "OFT"), is the inclusion of knowledge generated by students from previous editions of the academic course. This knowledge is freely used by students of the new course in the interiorisation activities (lesson at home) and in combination and exteriorisation (link activity). In temporal terms, this work includes the variable “time” in an FT model and the transference of knowledge by students from previous courses to later ones.

This fact contrasts with previous works in the literature, which present variants of the initial concept of FT, integrating activities such as problem-based learning [41], challenge-based learning [13], cooperative learning [2, 16, 41] or the adaptive learning rhythm [36]. Yet, most of the research work has focused on developing the model, applying it to experiences in concrete academic subjects during different academic years in a separate way.

The objective of this work is to study the impact of the OFT on the workload and learning outcomes of students. A quasi-experimental method will allow to answer the research questions, which ask whether the use of videos—produced by students of previous course editions—entails extra work for students, facilitates their performance of a certain task and/or improves their learning results.

The following section presents the proposed conceptual model, including the KM model that will be integrated into the FT model. The research questions, study variables, measuring instruments and research context will then be introduced. The paper will end with a discussion of the results, conclusions and proposed future lines of research.

2 Conceptual model

The present section begins with a description of the KM model (made up of the epistemological, ontological and time dimensions) that will be integrated with the FT model. The second subsection includes the three modules that make up the proposed OFT model, namely Module 1 (M1: interiorisation), Module 2 (M2: combination, exteriorisation) and Module 3 (M3: socialisation). They are based on the phases of the epistemological dimension of Nonaka and Takeuchi [30].

2.1 Knowledge management model

One of the first and most widespread models of KM is that specified by Nonaka and Takeuchi [30], in their theory of organisational knowledge creation. This model is appropriate to our work, since the training process can be considered organisational learning. For example, a university represents an organisation which, in turn, is composed of departments (subjects) and individuals (faculty and students). This model of KM is based on two dimensions that are described below: the epistemological dimension and the ontological dimensions [9, 10].

2.1.1 Epistemological dimension

The epistemological dimension is mainly based on the creation of knowledge by the organisation, as opposed to the creation of individual knowledge [30]. Individuals usually produce knowledge of two types: tacit and explicit [33]. Tacit knowledge refers, for example, to the experience of a person, while explicit knowledge may refer to an article written by another author. Knowledge is produced through the following four phases, which interact in the form of a spiral (see Fig. 1):

1. *Exteriorisation* In this phase, tacit knowledge is converted into explicit knowledge. For example, in writing this article the knowledge that is in the “head of the authors” (tacit) becomes knowledge included in the (explicit) publication;
2. *Interiorisation* This is the reverse phase to exteriorisation. Here, explicit knowledge becomes tacit knowledge. Reading this article (explicit knowledge) will increase the reader’s own (tacit) knowledge;
3. *Socialisation* During this phase, tacit knowledge is shared among people (note that the flow is multidirectional). It occurs when a group is talking, debating or working on a specific topic;
4. *Combination* The “combination” of explicit knowledge produces new knowledge. This is very similar to the process used by the authors of this work, to create a state-of-the-art approach that brings KM and FT together to form a new model OFT.

The set of these four phases can be represented as a spiral where tacit knowledge and explicit knowledge interact, as Fig. 2 shows.

2.1.2 Ontological dimension

The ontological dimension raises the idea that the knowledge created by the individuals of the organisation must be transformed into a collective or organisational knowledge.

In the educational sector, individuals are both students and teachers. Therefore, according to the ontological dimension, the knowledge acquired by students must be transformed into organisational knowledge—or, in other words, knowledge that becomes part of the organisation’s overall didactic resources on a subject. Nonaka and Takeuchi [30] propose four phases for the ontological dimension, in their theory of creation of organisational knowledge: *conceptualisation, crystallisation, justification* and *knowledge networking.*

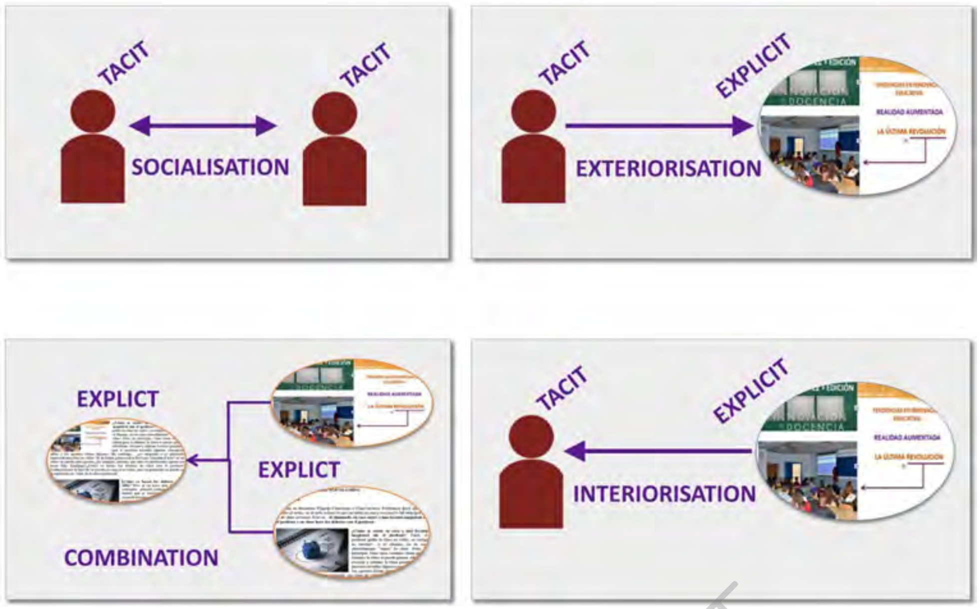
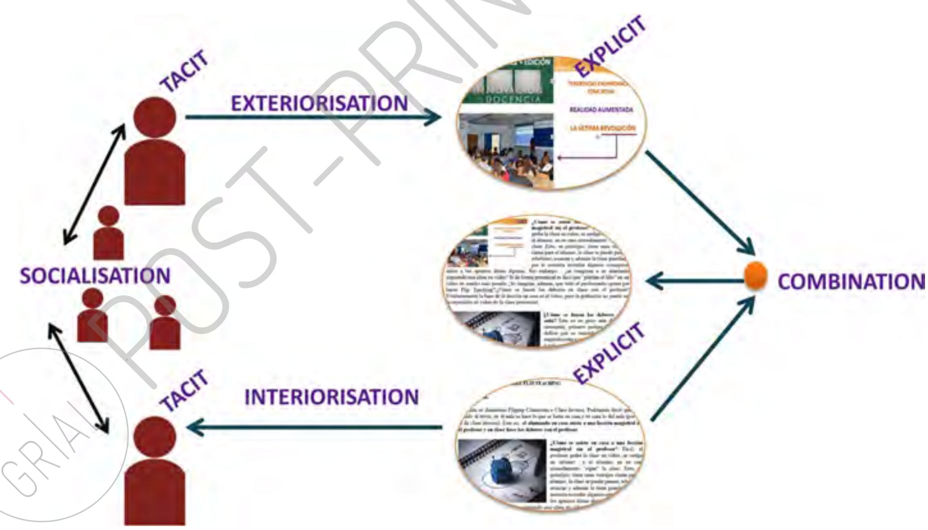


Fig. 1 Nonaka's knowledge phases

Fig. 2 Interaction among the epistemological phases



In previous studies, carried out in educational contexts, these phases have been transformed into the following: *conceptualisation*, *consolidation*, *distribution* and *combination* [10]. The conceptualisation, consolidation and distribution phases have been carried out in previous research work, proving that it is possible to generate organisational knowledge to be transformed into a didactic resource [40]. The combination phase is included in the FT model proposed in this work.

2.1.3 Time dimension

It is not possible to integrate the two dimensions without accounting for a third one, i.e. time. The whole process occurs in spirals that develop over time. As the time goes by, more spirals are produced and, consequently, both organisational knowledge and individual knowledge grow. The new model, OFT, is explained below.

2.2 Proposed conceptual model (OFT model)

Most formal educative models are designed so that knowledge is created within the individual. These models do not usually consider all phases of the epistemological dimension (they only consider interiorisation) and do not take into account any phases of the ontological dimension.

This article proposes that the FT model is perfectly transformable and embedded within the three dimensions of the organisational knowledge creation model, namely the epistemological, the ontological and the time dimensions.

As mentioned, the FT model is usually based on two main activities, "lesson at home" through explicit knowledge (videos in most of the cases) and "homework in class" through educational activities in the classroom. From the point of view of KM, this model works only with two phases, interiorisation and socialisation, as shown in Fig. 3a. The socialisation phase requires the exchange of knowledge, yet students come to that exchange with only a low level of acquired knowledge, under the revised Bloom model composed by remembering, understanding, applying, analysing, evaluating and creating [28], since the student has only internalised the new knowledge through a video (students acquire the first two Bloom's levels, in the best case).

The OFT model incorporates all the phases defined by Nonaka and Takeuchi [30] in the epistemological dimension for KM: interiorisation, socialisation, exteriorisation and combination (Fig. 3b). The main novelty of this new model is the inclusion of a link activity, in which students carry out academic work based on the teacher's video and the complementary material. Carrying out academic work requires a high cognitive level of the revised Bloom taxonomy [28] and, from the point of view of KM, this activity is associated with the combination of explicit knowledge and exteriorisation. The inclusion of the combination and exteriorisation phases to the FT model (which does not usually contain them) solves deficiencies that have been tested and validated in a previous work [8], who propose an enriched FT model called *Micro-Flip Teaching* [20].

The phases of the ontological dimension are also included in the proposed OFT model. They are: *conceptualisation* (the common view of knowledge is obtained from the academic work that students must carry out, as well as the concepts necessary to do so); *consolidation* (students create videos with the results of the training action and how to do it. They also add a file with those results); *distribution* (academic resources can be classified and facilitated in a KM system that allows students to search the knowledge provided by students of previous courses); *combination* (students of the subsequent courses seek, identify and apply the knowledge provided by students of previous courses).

The FT models (even the Micro-FT) usually act in a flat dimension (2D). Namely, they only act during the development of the subject. From the point of view of KM, this is equivalent to the action of one cycle and one phase of knowledge: "creation". However, the creation of knowledge in organisations obeys spirals of knowledge. Spirals are 3D models, where the variable time is taken into account (hence the inclusion of the time dimension), as is the enrichment of knowledge from its use. Figure 4 represents what happens in two consecutive academic courses, where each course corresponds to a plane. In plane 1, students acquired knowledge during the *link activity* (LA-x). This knowledge was then conceptualised by the students themselves and was made available for students from other courses too (F1 and F2 flows). Both flows represent the knowledge (videos, reports), created by students during an academic (year "x") in the link activity, is used by other students of the next academic (year "x + 1") during the link activity (F1 flow) and during the lesson at home stage.

Those students can use these didactic resources to perform the activity at home (AH-x + 1) and the realisation of the link activity (LA-x + 1).

The three modules that make up the new OFT model—Module 1 (M1: interiorisation), Module 2 (M2: combination, exteriorisation) and Module 3 (M3: socialisation)—are explained below. Figure 5 shows the relations among

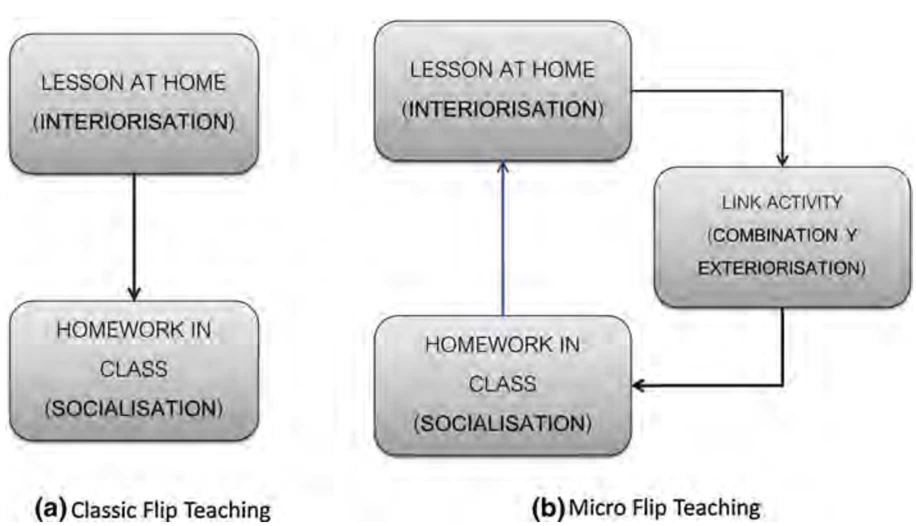


Fig. 3 "Classic Flip Teaching" and "Micro-Flip Teaching"

Fig. 4 New "Ontological Flip Teaching" model

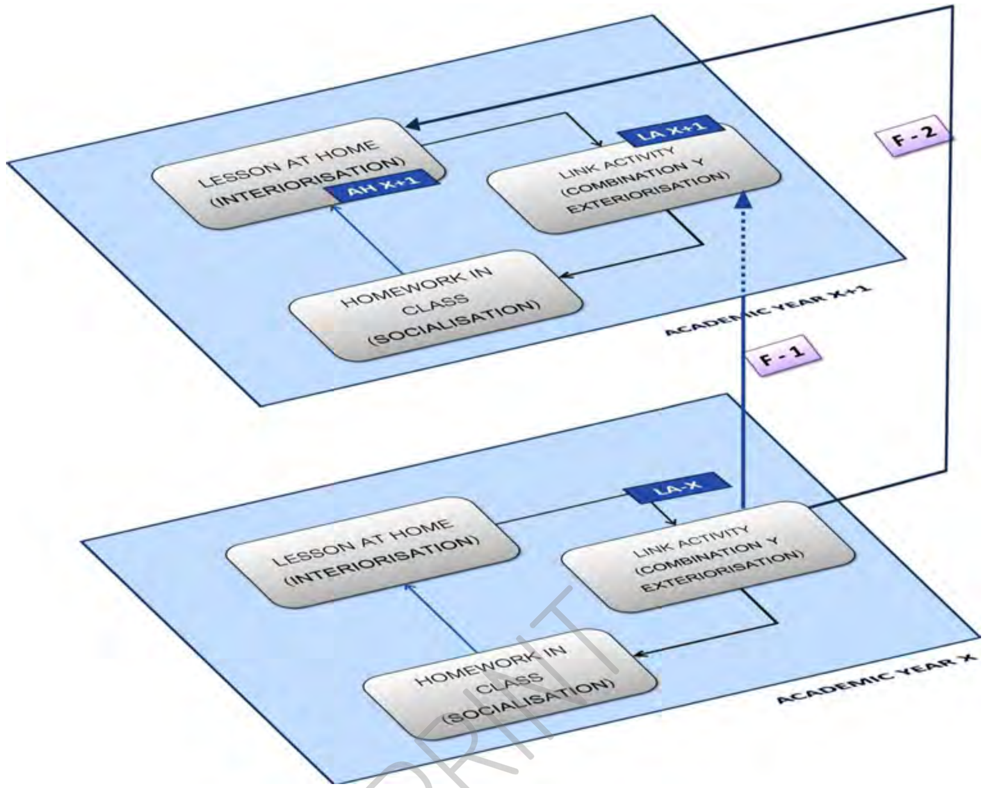
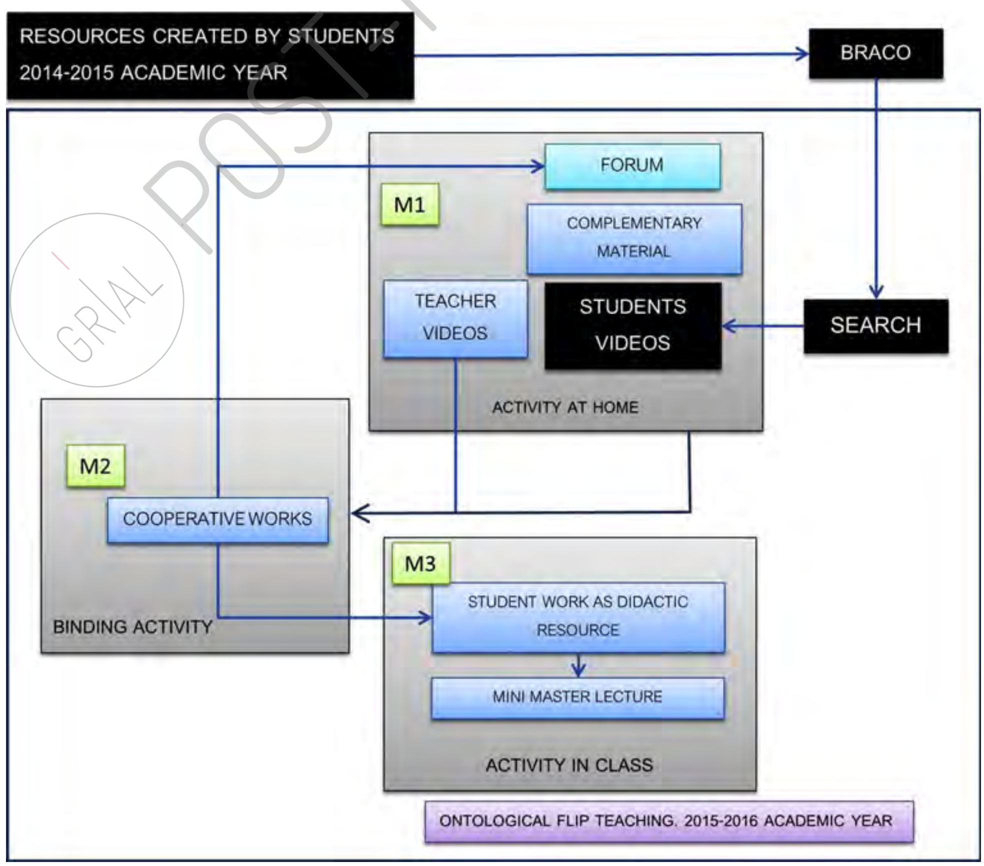


Fig. 5 Modules of the OFT model



the modules during each session of OFT model. It also shows (with the black background) the new modules that allow us to integrate the experience of the students of previous courses, for the phases of interiorisation, combination and exteriorisation.

2.2.1 Module 1 (M1) Interiorisation phase: "Lesson at home"

This module includes, first, the use of videos made by the teacher, which contain theoretical aspects developed in the master lessons. The characteristics of those videos are described in the following:

(1) They are concrete. For example, the videos are a maximum of 10 min long, since Biggs and Tang [6] argue that "the attention of students is typically maintained for about 10 to 15 min, after which learning drops off rapidly";
(2) Their content approach itself, since the most important concepts should be highlighted to fit them into the 10 min of the video. For this reason, the video for the "lesson at home" (M1) should be made by staff who have more capacity to synthesise the main parts of the considered topic [8].

In addition, students have a forum through which to ask questions, although they may be answered by the faculty or other students. Likewise, complementary material is usually available and contains Web references to expand the concepts exposed in the video. The description of the task to be performed by students—which is based on applying the concepts exposed in the teacher's video—is included in this supplementary material.

The main contribution of this work is based on integrating the "lesson at home", of the classic FT models, with knowledge generated by students from previous courses, to help current students carry out the same activity. This generated knowledge consists of a document with the results of the work done by students of previous academic courses, as well as a video describing how the results have been achieved. Namely, the video refers to "what and how it has been done".

All the knowledge contributed by the different students (grouped into work teams) is added to a KM system. The system's search engine facilitates students' access and identification of the most appropriate knowledge for each situation. For example, students can search for the type of activity that they must perform. This search will show all the available knowledge that describes what has been done, and how, for that particular activity. The KM system is called BRACO. Other research has shown its ease of use and efficiency, in terms of finding the knowledge necessary to perform a specific activity [13, 39].

2.2.2 Module 2 (M2) combination and exteriorisation phases: "Link activity"

The main objective of M2 is to create a link between the activity carried out at home (M1) and the activity carried out within the classroom (M3). The main objective is for students (either individually or in groups) to perform a task that, on the one hand, is an application of what has been done in M1 and, on the other hand, provides results that will be later used as a didactic resource to promote socialisation in the classroom activity (M3).

This task requires a combination of explicit knowledge (video) and complementary material. From all this knowledge, students must create a combined work from the didactic material available in M1.

At the same time, students should make explicit their own results. Under this model, it does not particularly matter whether the result is wrong or right, or even its quality level. The most important thing is that students perform the processes of combination and exteriorisation (M2). With the experience acquired in previous modules, teachers and students will work on those results, in M3, through different learning actions based on the quality of those results.

In this module, the students can also access the forum, available in M1. It is important to clarify any theoretical concepts before (or during) the combination and exteriorisation processes of M2.

2.2.3 Module 3 (M3) socialisation activity: "Homework in class"

In other FT models, socialisation is used to solve doubts and even to spark debate about the videos available in M1. In the proposed model, students must apply the concepts exposed in the videos, through the completion of a task. Therefore, resolving doubts and engaging in debates are emphasised earlier, in M1 and, most of all, in M2. This is because it is only when students try to apply new knowledge that they usually discover their doubts and shortcomings, related to the considered knowledge.

The main activity of M3 is socialisation, namely knowledge exchange during a face-to-face session (spatial and temporal matching). All participants in the action are recognised as having knowledge: teachers are at the expert level, and students contribute the knowledge they have acquired through the tasks of M1 and M2 (interiorisation, combination and exteriorisation). The acquisition of knowledge by the students is essential for a true exchange of knowledge. For this reason, M2 is of strategic importance.

To carry out the socialisation activity, the results of the work carried out during M2 are used. For example, during the classroom session a student (or a group), whose results are wrong, work on those results with their partners. Said students communicate their explicit knowledge, while other students may ask, make corrections, debate or propose changes. Teachers have the role of facilitator–moderator in the exchange of knowledge among the students. Further, as Angelini [1] says, a good facilitator must know how to guide students towards a social conscience, a critical analysis of the reality that arises and a social commitment. The socialisation process is carried out from a basis of tasks with different types of results, to enrich the debate and improve students' learning.

Teachers, based on the knowledge generated in the classroom, add new knowledge. They may do this, for example, by focusing on the reasons for certain mistakes in the results, by providing concepts that have not been applied or by pointing out the failures in the process. These actions are similar in the case of a job well done: teachers may explain the reason why it is correct, the adequacy of the applied concepts, etc.

In this module (M3), there is continuous alternation between socialisation (knowledge exchange, when the students expose and debate the results of the tasks) with weak socialisation (when teachers explain why the tasks are well or badly done and provide new knowledge). For that reason, to clarify the model, socialisation is represented by two different activities called "Student work as didactic resource" and "Mini master lecture".

3 Research method

This section presents research questions, study variables and measurement instruments, as well as the research context.

3.1 Research questions

The experience that students acquire, when performing a certain academic task, gives them knowledge that can be used as a didactic resource. There are two aspects, however, to consider: the way of transmitting that knowledge and the moment of using it. This requires converting the tacit knowledge of the individuals into explicit and group knowledge (because it is generated by a team).

A simple way to transmit that experience is through a video, recording a brief presentation of what has been achieved (the final product) and another presentation of the process followed to achieve this result. Those experiences (videos made by students) are considered organisational knowledge to be used in upcoming courses. That organisational knowledge can be used in different subjects (if the objective is to acquire a generic competence) or in the same subject (or similar) (if the goal is to develop a specific competence (specific thematic)). In this case, a generic competence is considered, the teamwork competence, and the experience will be applied to a subject different to the subject where the resources have been created.

The aim of this work is to prove that the inclusion of videos made by students of previous courses, as complementary material to the videos made by teaching staff, improves the efficiency of the FT model for students in the current course.

The research questions are the following:

- RQ1: Does the use of videos, created by other students, imply an additional workload?
- RQ2: Does the use of videos, created by other students, reduce complexity in the performance of a given task?
- RQ3: Does the use of videos, created by other students, improve the learning outcomes?

The research will show that the use of audio–visual material created by students from previous courses does not increase the effort, and that it does both facilitate the performance of tasks and contribute to the improvement in learning outcomes.

3.2 Study variables and measuring instrument

A quasi-experimental method is applied, in which an experimental group (hereinafter, "EG") and a control group (hereinafter, "CG") are considered. The quasi-experimental method with a non-equivalent control group is the most appropriate, since the selection was not performed in a random manner [15], and testing the equivalence of both groups is important. In the results section, the homogeneity between the experimental group and the control group was established, based on three types of variables: student profile, perception about teamwork and stimulus received from teachers. The profile of the students who participated in this research has been defined by variables intrinsic to the students: age, gender, grade obtained on the university entrance examination and number of years at university. The second type of variables is based on the perception of students about the importance of teamwork, while the third type is the attention given by the teaching staff to each of the work teams.

All students in the study have a similar perception of the importance of teamwork, which guarantees that the motivation to approach the subject is similar. Finally, an indicator of process has been studied: the stimuli given by teachers. A different perception of those stimuli could alter the research results.

For the measurement of qualitative information (homogeneity of EG and CG, and perception of complexity and time spent during the development of the OFT model), a survey of 27 questions was used as a tool in the EG group [14]. Of these, 4 questions were specific to the use of the BRACO computer tool and were only asked of the EG participants. Of 27 questions in total, 22 questions were common to both groups EG and CG, although only some of these questions were analysed for this research. The questions, not used in this study, are included in a previous work [40].

For the research technique to compare the results of EG and CG, a Wilcoxon nonparametric test was chosen. This is because, after a Shapiro–Wilk analysis, the results of the surveys were shown not to have a normal probability distribution, yielding a p value higher than 0.01. The software used was R-commander version 3.3.2 [35].

The efficiency of the new OFT model is measured by the following variables: time spent and complexity in performing the development of the OFT model, and the final grades of the development.

To measure the quantitative information, the students' scores of EG and CG were used, as was the number of messages exchanged among the students to accomplish the activities. A learning analytics system, the learning management system Moodle, has been used to show the number of messages, type, views, dates of access and averages of the student–student interactions, on the forums where each team's cooperative efforts are carried out. A Web service in Moodle, called "Group Competency", was created. This service includes functions for retrieval information about the platform courses, such as course forums, course teams, threads for a given team into specific forum, particular information from the threads and the users of those threads, number of messages per team, data regarding a post based on its id, users per team, number of views per discussion and views per discussion and user. The whole description is presented in [11].

3.3 Research context

The resources corresponding to the previous experience of the students were generated by 24 working teams in the subject "Computers & Programming" corresponding to the first course of the Energetic Engineering Degree, during the second semester of the 2014–2015 academic year, at the Technical University of Madrid. The quasi-experimental research was carried out in 19 working teams in the subject "Fundamentals of Programming" corresponding to the first course of Biotechnology Degree, during the first semester of the 2015–2016 academic year.

The groups EG and CG were selected depending on the schedule of the sessions. The EG corresponds to the morning sessions and the CG to the afternoon sessions. The EG is composed of 59 people and the CG is composed of 53 people.

Both groups follow the OFT model to perform the same tasks: first, they perform the activity at home (M1). Second, they carry out the link activity (M2), where they must complete a task, and finally the results of the task are used in the classroom activity (M3) as a didactic resource. The difference between EG and CG is in the actual process, whereby the EG group had access to the KM system BRACO [13, 39], while the CG did not. BRACO contains all the knowledge generated by students of the previous course and can be used both to complete the activity at home and to perform the link activity.

From the point of view of KM, both groups (EG and CG) performed the epistemological phase to create knowledge. However, the EG group also performed the ontological phase, since it used organisational knowledge that has been created by individuals (other students).

Of the surveys carried out, 54 valid answers were collected in the EG, from a population of 59 people. The CG group provided 42 valid answers from a population of 53 people. The participation rates, then, are 91% in EG and 79% in CG.

The individual final grade is obtained from the sum of the grades of three types of information: (1) individual evidence is obtained from the student–student interactions of the forums, since the messages are analysed to observe the students' commitment, responsibility, work done, leadership, etc.; (2) group evidence is comprised of the results of each phase of teamwork (Mission and objectives, Normative, Map of responsibilities, Chronogram, Execution, Storage), and each one of these phases corresponds to a complete session of the OFT model (composed of M1, M2 and M3); (3) the final result of the teamwork, which is usually included through a web page created by the team.

4 Results

This section presents the qualitative and quantitative results to verify the validity of the research, as well as to answer the research questions.

The first subsection (4.1) presents quasi-experimental research to prove that both EG and CG are homogeneous groups. The data are obtained through information regarding the students' profiles and their perception about the learning subject and their perception of the tutorial activity of staff.

The second subsection (4.2) presents the qualitative study about the students' perception of the learning process (teamwork development). These data allow us to test whether the students of both groups have spent the same time on the learning activities, and their perception of the activities' level of difficulty.

The third subsection (4.3) shows the quantitative study and refers to the impact of the learning model on students' performance. Two indicators are verified: the student–student interaction (this measures the active participation of students during the teamwork project's development) and the final grade (this measures the quality of the teamwork project's development).

4.1 Equivalence of EG and CG

The equivalence is checked against three types of variables. The first type is based on the variables of the students' entrance profiles (age, gender, entry mark to university and the number of previous years at the university). The second level is based on the students' perceptions about teamwork, since that is the topic through which students carry out the learning activities. The third level refers to the perception of the stimuli that students have received from teachers.

4.1.1 Student's profile

The first variables used to verify the equivalence of both groups are age, gender, length of time at university so far, grade on the university access test (relevant because students are first-year students and there are minimum access grades). The Wilcoxon test yielded a result for all the studied variables of *p* value >0.01; therefore, it can be considered equivalent. The detail of the means, standard deviation, *p* value and analysis for each of the variables has been included in a previous work [40].

4.1.2 Importance of teamwork

To complete the study of homogeneity between the EG and CG, in addition to the students' profile, it is important to know their perceptions of the importance of teamwork. This is because teamwork competence is the thematic of the learning activities carried out in this research work. For this reason, the perception of such competition must be compared to check whether it is homogeneous, since non-homogeneity may affect the research results. Table 1 shows the values obtained for this variable (Q26). A Likert scale ranging from 1 (nothing) to 5 (much) is used. The *p* value is higher than 0.01, allowing us to consider that the perceptions of both groups are equivalent.

4.1.3 Stimulus received from staff

The aim of this subsection is to verify that both groups have received the same stimuli and treatment by staff during the teaching/learning process (teamwork development).

In a previous research study [40], question Q02 is part of a set of variables whose objective was to measure the equivalence of the process of the experimental and control groups. In this work, the variable Q02 is used to verify that the individualised help that the students have obtained is equivalent, in both the experimental and control groups.

Table 2 shows the equivalent average in the answers of both groups, for the questions related to the staff tutorial actions. A Likert scale was used, ranging from 1 (totally disagree) to 5 (totally agree).

Table 2 also shows that all variables obtain a *p* value >0.01, which does not allow for a rejection of the null hypothesis of equality between the mean of both groups, for each of the studied variables.

4.2 Perception of effort in the accomplishment of the FT activities for EG and CG

The aim of this section is to compare the perceived effort in the accomplishment of the academic tasks corresponding to the teamwork phases, which are identical for EG and CG, along with each FT session. First, the degree of difficulty, as perceived by students of GE and GC, is analysed here. Second, the time invested to do the activities is studied for both groups.

4.2.1 Complexity of activities to be carried out by each team

A FT session is completed when the three modules (M1, M2 and M3) have been carried out. The modules M1 and M2 are done outside the classroom (at home) and M3 is done inside the classroom. Each teamwork phase corresponds to a FT session. In M1, the steps are explained and complementary material is provided. In M2 the task, corresponding to each teamwork phase, is performed (e.g. to elaborate the normative in a cooperative way). In M3, in the classroom, students work with the results generated in M2.

To evaluate the students' perception of the difficulty of each task performed during each teamwork phase, a set of 7 questions (Q11_i-CG and the even answers of the Q11_i-

Table 1 Importance of teamwork for EG and CG

Variable	Mean EG	Mean CG	Test	*p* value
Q26—Importance of teamwork	4.51	4.4	Wilcoxon	0.2767

Table 2 Homogeneity of staff tutorial action

Question	Mean EG	SD EG	Mean CG	SD CG	p value
Q02.1. The teacher has been accessible	3.666	0.890	3.380	1.080	0.1704
Q02.2. The teacher has answered to me correctly when asked for help or advice about the work	3.777	0.793	3.547	1.040	0.3361
Q02.3. The tutor's style of communication has made sessions and activities enjoyable	3.629	1.051	3.619	0.986	0.7704

Table 3 Difficulty perceived at each teamwork phase

Question	Mean EG	SD EG	Mean CG	SD CG	p value
Q11.1. Phase "Mission and objectives" seems to be complicated	2.629	0.896	3.261	0.938	0.0008
Q11.2. Phase "Normative" seems to be complicated	2.425	0.963	2.500	0.862	0.7529
Q11.3. Phase "Map of responsibilities" seems to be complicated	2.629	0.917	3.095	0.878	0.0085
Q11.4. Phase "Chronogram" seems to be complicated	2.629	1.014	3.142	0.925	0.0109
Q11.5. Phase "Execution" seems to be complicated	2.685	0.907	3.238	0.849	0.0040
Q11.6. Phase "Storage" seems to be complicated	2.537	1.040	2.547	0.771	0.7331
Q11.7. Phase "Final result" seems to be complicated	2.537	0.945	3.119	0.802	0.0009

EG, namely, after using BRACO), with a Likert scale of 1 to 5, is used (1-totally disagree and 5-totally agree). Table 3 presents these results.

Questions Q11.1, Q11.3, Q11.5 and Q11.7 have obtained a p value less than 0.01, indicating that there are significant differences between EG and CG. Students in the EG have a simpler perception of the complexity of tasks to be performed than the CG perception. Questions Q11.2 and Q11.6 have a p value higher than 0.01. Therefore, for these phases the perception of the difficulty of the work is similar in EG and CG. For question Q11.4, a p value $= 0.0109$, slightly higher than 0.01, was obtained. However, since this p value is lower than 0.05, it is possible to consider that there are differences between GE and GC, with the perception of difficulty being higher for GC.

The significant difference appears in the tasks that involve more difficulty for students. For the tasks that have less academic difficulty—such as the Normative, the Chronogram or the storage of files in an online system—there are no significant differences on the degree of difficulty.

These results are more clearly shown in Fig. 6, which shows the evolution of the means of EG (lower line) for each of the teamwork phases, as opposed to CG (upper line).

4.2.2 Workload perceived by student

The workload measures, in hours, the effort employed by students to perform the learning activity. A Likert scale is used for each question ranging from 1 (less than 1 h), 2 (between 1 and 3 h), 3 (between 3 and 5 h), 4 (between 5 and 7 h) and 5 (more than 7 h).

These data are used to prove the improvement in the efficiency of the OFT model, by showing that EG participants have not worked for a longer period of time compared to CG participants. Thus, with the same time spent, a higher scholar performance is obtained and the complexity decreases. This would therefore show an increased efficiency of the learning process, due to using the OFT model.

Table 4 presents the results of the question (Q14) regarding the workload perceived by the student, comparing the results of EG with CG.

In a previous research study, these variables were used to measure the equivalence of the experimental and control groups [40]. However, in this work the same variable has a different use: to measure the improvement in the effectiveness of the OFT model.

In this case, there is also no significant difference between the perception of the workload by students in the EG and CG, for a p value >0.01, which does not allow a rejection of the null hypothesis of equality between the averages of data for both groups.

4.3 Learning impact

This subsection considers the quantity and quality of the messages exchanged among the students, as well as the final grade obtained in the group work.

Fig. 6 Perception of difficulty in each phase of teamwork for EG and CG

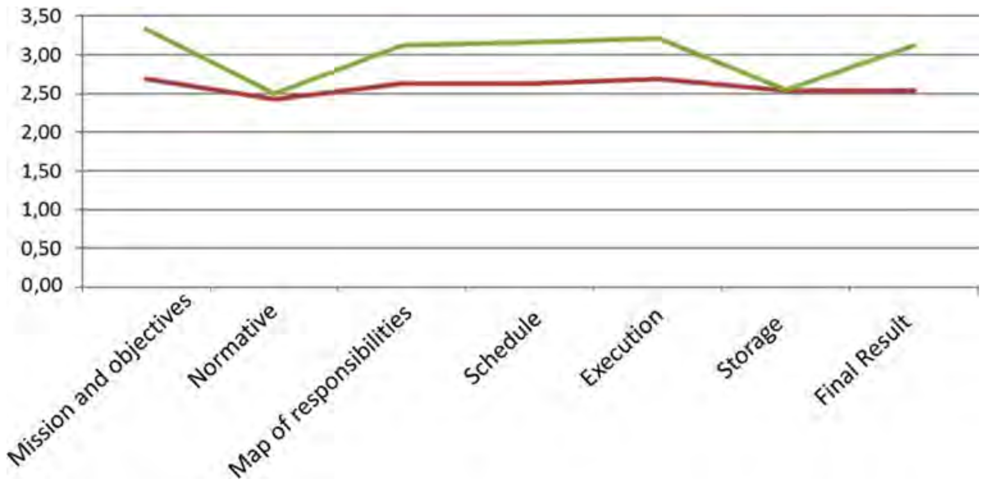


Table 4 Perceived student workload

Question	Mean EG	SD EG	Mean CG	SD CG	*p* value
Q14.1. Workload in phase "Mission and objectives"	2.592	0.942	2.619	0.824	0.5681
Q14.2. Workload in phase "Normative"	2.388	1.035	2.404	0.885	0.8619
Q14.3. Workload in phase "Map of responsibilities"	2.888	1.127	2.880	1.040	0.9508
Q14.4. Workload in phase "Schedule"	2.777	1.058	2.857	1.049	0.8622
Q14.5. Workload in phase "Execution"	3.981	0.921	3.690	1.047	0.2177
Q14.6. Workload in phase "Storage"	3.203	1.139	3.119	1.130	0.72
Q14.7. Workload in phase "Final result"	3.777	1.207	3.88	1.086	0.7667

4.3.1 Messages exchanged by team members

The message information is provided by a learning analytics system [11]. Regarding student–student interactions, the system distinguishes between two types of messages: short and long. A message is considered short if it has a maximum of 140 characters and long if it has more than 140 characters. The system takes the log (trail left by the student) from the Moodle forum that students have used to exchange messages. The forum is private, so each group can only exchange messages among its members.

Table 5 shows different averages relative to the number of messages exchanged by the work teams in EG and CG.

First, the mean of messages exchanged per group is presented. This value is obtained by dividing the total number of messages by the number of participants in the group; this average is the same for both groups (EG and CG), with p value >0.01. It is also similar to the total number of messages per team, with p value >0.01, which does not allow for a rejection of the null hypothesis of equality between the mean of both groups.

However, if we now consider the characteristics of these messages, by distinguishing between short messages and long messages, we see that there is a significant difference between the messages sent by EG versus CG. The number of long messages in the EG, for p value <0.01, is greater than in the CG. This fact allows the rejection of the null hypothesis of equality of means in both groups. This result proves a higher quality of communication among the participants in the EG, compared to the CG.

4.3.2 Differences among grades

The final grades of the work teams are obtained by adding three partial grades, i.e. the acquisition of individual competence (which measures how each team member performs the work), the outcome of each phase (which is usually a short document describing the intermediate steps) and the final result (which is basically a measure of the final work quality).

The variables considered here are the individual performance (acquisition of the individual competence, valued with a maximum of 7.5 points) and the final result (final product, delivered as the results of the teamwork accomplishment. The final result is usually shown on a web page, wiki or blog and is valued with a maximum of 8.75 points).

Table 5 Messages exchanged

Number of messages	Mean EG	SD EG	Mean CG	SD CG	p value
Messages per team	51.117	16.556	47.317	19.842	0.2209
Total messages per team	310.4	110.5	283.9	119.0	0.4352
Mean of short messages per team	15.766	12.571	15.833	9.638	0.469
Mean of long messages per team	34.716	17.123	28.814	22.471	0.004218

Table 6 Individual grades of each team member and grade of final product

Grades	Mean EG	SD EG	Mean CG	SD CG	p value
Individual grades	6.35	1.33	5.09	1.51	2.24e−06
Grade of final product	7.52	1.12	5.90	1.65	8.85e−08

Table 6 shows that the p value obtained is much lower than 0.01. Therefore, there are significant differences in both the individual grades of each student and the grades of the final result obtained from the teamwork project.

5 Discussion

This section includes the discussion of the research questions. We will start with the first one, *RQ1: Does the use of videos, created by other students, imply an additional workload?*

In a research study on education, it is very important to show that the improvement in results is not due to an increase in the workload. If students spend more time on their learning, an improvement in the results is a logical conclusion, so this research question is pertinent. The measurement of students' workload has always educational, curricular and organisational impact, and especially when a new learning methodology is carried out [25, 31].

Table 4 shows that the perception of workload is equivalent, since the average of the results of the perception of the workload, in each phase of the teamwork development, is the same for students in the EG and CG, with p value >0.01. We can then claim that students, under the conditions of the experiment, did not perceive a greater workload when using the videos produced by other students, along with the ones produced by the teacher.

The previous results have a special relevance in the answer to the second question, *RQ2: Does the use of videos, created by other students, reduce complexity in the performance of a given task?* If the answer is negative, then the complementary material would not increase the students' effectiveness in carrying out the activity.

The results of Table 3 support the responses given by the students of EG, since, with Fig. 1, we can affirm that their perception of the complexity of carrying out the teamwork phases, after seeing other students' videos, has been reduced below that perceived by the CG students for the same phases. That is, by integrating the knowledge shared in the teacher's video with the additional videos made by students of previous courses, the students of the experimental group have better understood the purpose of each task and their perception of complexity has diminished.

If the workload in the tasks has been the same for both EG and CG, then this proves that the knowledge generated by the students of other courses has diminished the complexity of the task for the current students. The use of these resources (videos) created by more experienced students is a scaffolding activity, "an effective conceptual metaphor for the type of teacher or student intervention in other students' learning" [39]. Therefore, experienced students provide additional proactive tutoring to other students, the task-specific support is designed to give timely and progressive support to learner needs to complete the same or similar tasks [23] with the subsequent benefits, such as the decrease in difficulty to start the new task. This confirms that collaborative document creation enables humans to benefit from synergistic effects, among others [37].

The two previous research questions allow us to conclude that the knowledge provided by other students does not increase the workload; the use of additional resources has been compensated for by the reduction in the tasks' complexity.

To demonstrate the efficiency of the proposed model, we seek to answer the third research question *RQ3: Does the use of videos, created by other students, improve the learning outcomes?* This question is answered through two indicators, namely the analysis of the messages exchanged between the students and the final grade obtained in the work. The first indicator is considered in the context of previous research on teamwork [11], which shows that an increase in the number or quality of the messages among students, during teamwork development, influences their final grades, i.e. their performance.

Regarding student–student interaction, as measured through the messages exchanged on the forums, a high level of communication can be observed in both groups, with a mean of 51.117 per student in EG and 47.317 in CG. Although the statistical analysis determines that the number of messages per student is equivalent for both groups, Table 5 also shows that the quality of communication was higher in EG, since a significant difference was established in the number of long messages (more than 140 characters). That is, there has been more information sharing in EG than in CG.

The variables used to answer the third research question included the number of student–student interactions represented by the messages [11], the individual grades and the grade of the final product (which are the official indicators of learning performance). The higher number of long messages exchanged by the students in EG shows that they have been more participatory and with more significant contributions compared to the students in CG. Likewise, the students in EG obtained a better individual grade and a final result (work delivered) of higher quality than in the control group.

The answer to the three research questions shows that the inclusion of knowledge provided by other students, as complementary material to teachers' videos, makes the new FT method more efficient. The workload has been the same in EG and CG. However, the tasks have been simpler and better results have been obtained in EG versus CG. With the same workload, the obtained performance is higher for EG than for CG.

This improvement in learning efficiency supports Nonaka–Takeuchi's organisational learning theory [30]. The inclusion of the ontological spiral and the time variable means that the knowledge acquired by individuals (students who have contributed with their experience) has improved and increased the organisational knowledge (of the subject). This organisational knowledge has, at the same time, impacted on a more efficient improvement in learning in individuals (students who have participated in EG).

6 Conclusions

The epistemological, ontological and time dimensions of the theory of creation of organisational knowledge have been applied to several different subjects of study. This research shows that students of any subject behave as individuals of an organisation that acquires knowledge. That knowledge can be managed to increase the variety and quality of organisational knowledge, as represented by said subjects. The OFT model is a vehicular medium to integrate the three dimensions in academic subjects. This integration improves both the efficiency of the methodology itself and the knowledge of the individuals in the organisation.

Future work is framed in two lines of proposed research. The first is based on applying the OFT model along with the knowledge generated by students in other subjects, grades and universities. This is possible because the model is exportable and the knowledge generated course after course is sustainable. It is therefore feasible, and desirable, to export and transfer the model and knowledge to the entire university community. Another proposed line of research is based on continuing the research—including the new knowledge provided by the students, but replacing the videos where the teacher explains the concepts and tasks to be performed with videos generated by students—and investigating the new role that is acquired by the teaching staff in this new situation.

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