

# LEVERAGING DISTANCE LEARNING OF ENGINEERING SKILLS THROUGH VIDEO EXERCISES

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## Abstract

This paper summarizes the initial results of an experience with the usage of video exercises in order to provide learners with supplementary online multimedia material created by the teachers. The video exercises depict the statement and the resolution process of a single problem, being solved by the teacher in a sort of digital whiteboard. These learning objects thus turn into educational pills that can be reused by the teacher in different scenarios such as distance learning, out-of-class material, office hours, etc. This experience has been performed in subjects related to computer science and telecommunications engineering during the 2010/2011 academic course. The paper describes the methodology and process from recording the problem-solving videos to their online delivery. This approach required the combination of different technologies such as a graphics tablet, sketching software, screencasting, video transcoding and closed captioning, among others. These efforts resulted in a pool of online accessible video exercises that can be employed for the students to gain the appropriate skills in order to solve other related problems. In addition, the ubiquity of Internet enables these new materials to outreach potential learners from outside the university.

Keywords: Video, Distance Learning, Engineering.

## 1 INTRODUCTION

The introduction of technology at the University has traditionally been focused on increasing the computer-per-person ratio in the learning centres. However, the widespread adoption of broadband connections, combined with the fact that hardware prices have plummeted during the last decade, has put technology and online access right in our fingertips. Nowadays, the massive adoption of smartphones, tablets, netbooks and other kinds of equipment by current students forces the professors to adopt new strategies more aligned with their student's digital life.

Many technical degrees require the students to solve problems by applying certain methodologies and techniques that can only be achieved by developing the appropriate skills. These skills are traditionally learned by mimicking professors during problem solving. After exercising these capabilities a certain number of times, students are usually offered with a collection of problems together with their solution. However, the procedure to achieve these solutions, in order to develop the aforementioned skills, is traditionally only carried out during the class lessons. This is a major handicap, especially for distance learners, or in courses with limited time. Those who cannot attend the classes must rely on the office hours or even on other students in order to understand how to solve a certain problem.

In order to leverage distance education, but also as a complementary material to all students, the combined use of graphics tablets and screen recorders arises as a powerful tool to document the process of exercise solving. This produces a win-win situation for teachers and students. On the one hand, teachers only devote time to the creation of the video exercise together with a clear audio explanation of the problem solving approach. On the other hand, making these videos available online enables students to access these educational objects on demand, whenever and wherever they like and on the platform (PC, mobile phone, etc.) they choose.

In the very last few years, there has been a common trend in Spanish universities to produce learning objects in the shape of multimedia material (combining audio, video, diagrams, etc.) that can be seamlessly accessed by the students. This has been the case of the *Universitat Politècnica de València* (UPV), which, for the last years, has encouraged its professors to develop the so-called *Polimedias* [1]. These are 10-minute videos that include a set of slides that are explained by the teacher, who physically appears on the video to better capture the attention of the viewer. These

videos have played a fundamental role for distance learners and have also been a crucial supplementary material for the students that want to complement their attendance to the classroom. We firmly believe that producing learning videos that can be seamlessly accessed by our students paves the way to increase the student's autonomy during their learning process. However, one of the main drawbacks of Polimedias is that they require special equipment for their production and, thus, the videos are recorded in specific installations at the university. In addition, they are recorded as a single entity (no post-editing is available) and require the teachers to arrange an appointment for recording them. Therefore, in this paper we advocate to complement these recordings by videos generated by the teacher specially focused on the resolution of engineering problems. This approach offers greater flexibility to the teacher.

In fact, the usage of video technologies to encourage learners is not a new a topic. In 1989 a study from the Vanderbilt University showed that students working actively and collaboratively with interactive video improve their learning outcomes [2]. From that moment, several research teams from a number of universities have also reported positive findings based on collaborative learning using video technologies [3]-[5]. The DIVER (Digital Interactive Video Exploration and Reflection) platform developed at Stanford was the first attempt to export video learning to the web so that other teachers can observe and comment on the materials [6]. Today, more and more videos are designed for educational purposes, which can help students to build their own knowledge. Commercially, web based video content delivery platforms have attracted an enormous popularity for information spreading, entertainment and social networking areas. This popularity is reflected in the video sharing tool YouTube where complete courses can be followed remotely. There are also several online platforms available based on video e-learning, like Khan Academy [7] or eduFire [8].

This paper summarizes the initial results of an experience in the fields of computer science and telecommunications engineering with the recording and the online delivery of problem solving videos. These efforts resulted in a set of online accessible video exercises that can be employed for the students to gain the appropriate skills in order to solve other related problems. As an additional side product, the use of a graphics tablet allows the professor to create digital diagrams that can be enriched over time and can be delivered to students through digital channels as a replacement of traditional photocopies.

After the introduction, the remainder of the paper is structured as follows. First of all, section 2 summarises the workflow involved in creating and distributing the video exercises, with a special emphasis on the tools and technologies employed. Next, section 3 describes a couple of video exercise samples in the field of computer science and telecommunications engineering. Then, section 4 discusses the impact of the experience both from the perspective of the students and the teachers. Finally, section 5 concludes the paper and proposes future research lines.

## **2 PROBLEM-SOLVING VIDEO EXERCISES**

The learning video exercises that we propose consist of a combination of audio and video in which a white background serves as the canvas for the teacher to propose and solve a problem, just like writing on a paper. The video captures the resolution process of the problem while the teacher creates diagrams, draws equations or sketches an idea in order to clarify the explanation. The video is accompanied by an audio narration of the teacher in which the resolution process is explained. Thus, these video exercises can be considered the digital counterpart of the problem solving process using pen and paper. Adapting these old and well known concepts to the new digital era enables to produce new learning materials that are not disruptive with the procedures already known by the students.

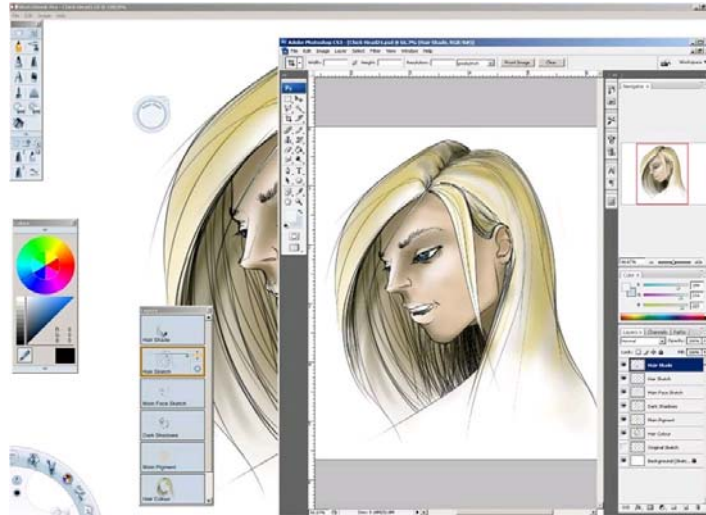
Creating these video exercises requires several hardware and software components. The hardware equipment comprises a computer and, optionally, a digital tablet, which behaves as a mouse, and enables the user to draw just like with a normal pen. The audio input to narrate the video exercise is generated by means of a headset microphone in order to reduce the background noise. Concerning the software requirements, the following items are required. First of all, a screencasting software that allows recording the audio and actions of the computer made by the teacher. Moreover, it is needed a video editing software in charge of post-processing the video. Then, video codification software is required to export the recorded screencast into a suitable format. Finally, an online video distribution platform should be employed to enable access to the recordings through the Internet. The following section describes the underlying technologies employed to support this work.

## 2.1 Tools and technologies

This section summarises the tools and technologies employed. It provides an overview of some of the currently available software, including the specific tools employed in the experiences.

### 2.1.1 Sketching Software

Sketching is the typical scribbling of an idea on a piece of paper. It's just a quick way to get an idea down on paper, or to solve a problem on a blackboard. Figure 1 shows an example of what sketching is. Sketching software tools provides the user the capability of drawing sketch using a computer.



**Figure 1. Example of sketch with Adobe and Autodesk tools**

The first important element that should be considered for computer-aided sketching is the interface device. Of course a simple mouse could be used, but the manageability is in this case quite limited and our experience advises against this kind of devices. The preferred interface is a graphics tablet that supports both pressure and pen tilt. Pressure is used to control the variable-width brush whereas pen tilt controls the rotation and allows a more personal styling. In the market there are several graphics tablets with a number of sizes that support pressure and tilting. One of the most reputed manufacturers is Wacom and the Intuos series. It is generally a good idea to get a large tablet since this reduces the overhead of time required to manage several sheets along the explanation.

Concerning software tools, there are several alternatives of conventional software and also of online applications. From the former group, *painter sketch pad* from Corel, *SketchBook Pro* from Autodesk and *ideas* from Adobe are probably the best professional tools. All of them reproduce the look of traditional media (pens, chalk, pencils, markers etc.) and they are especially suited to work with pen and drawing tablets that let you control shading and vary stroke width by angling your pen on the tablet. From the latter group, that is, the online applications, there are several ones such as *Odosketch*, *Canvastic* or *Sketchpad*. All of them allow making good sketches, although these tools do not support pressure and pen tilt sensibility, which reduces the quality of the final product. A fairly comprehensive list of online tools can be found in [9].

### 2.1.2 Screencast Software

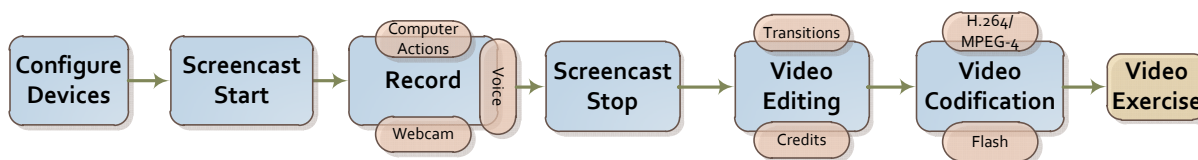
Screencasting is the process of recording the computer screen output, typically combined with an audio narration. This process is commonly employed to let others visualize the same set of actions performed with a computer together with a verbalised description of the procedure.

There are different tools currently available for this purpose. The software Camtasia [10], developed by TechSmith, combines in a single software package both screen recording and video editing software. There are versions available both for Windows and for Mac. Jing [11], also developed by TechSmith, is a very simple tool for the Mac that enables screencasting of up to 5 minutes. There is a free version that generates an Adobe Flash-based video. The *pro* version allows exporting the video to MPEG-4 format. ScreenFlow [12], developed by Telestream, is a screencast application for the Mac that includes video editing capabilities and can export the video to both MPEG-4 and Adobe Flash.

### 2.1.3 Online Video Hosting Services

With the advent of broadband connections, online video hosting services have bloomed. They allow users to upload their videos and make them available to the whole Internet or to a specific set of users. Authors might also try to monetize their videos according to the number of times that they have been watched. There is currently a myriad of different available services. For example, YouTube [13] is a video-sharing website whose content is uploaded both by individuals and media corporations. Blip.tv [14] is a platform for distributing independent shows that consists of different episodes. Some universities are also developing their own video sharing platforms in order to leverage distribution of educational content. This is the case of poli[Tube] [15], created by the Universitat Politècnica de València (UPV) in Spain. This platform enables users to upload videos and provide access control to their content. The videos can be public, i.e. accessible by everybody, private, i.e. the user must be a valid user of the UPV and if the video belongs to a private group, then the user must belong to that group, and, finally, non-advertised, i.e. the video is available by the users that access a specific link but it cannot be searched by other users of the platform.

## 2.2 Creation and Distribution



**Figure 2. Workflow to generate a video exercise**

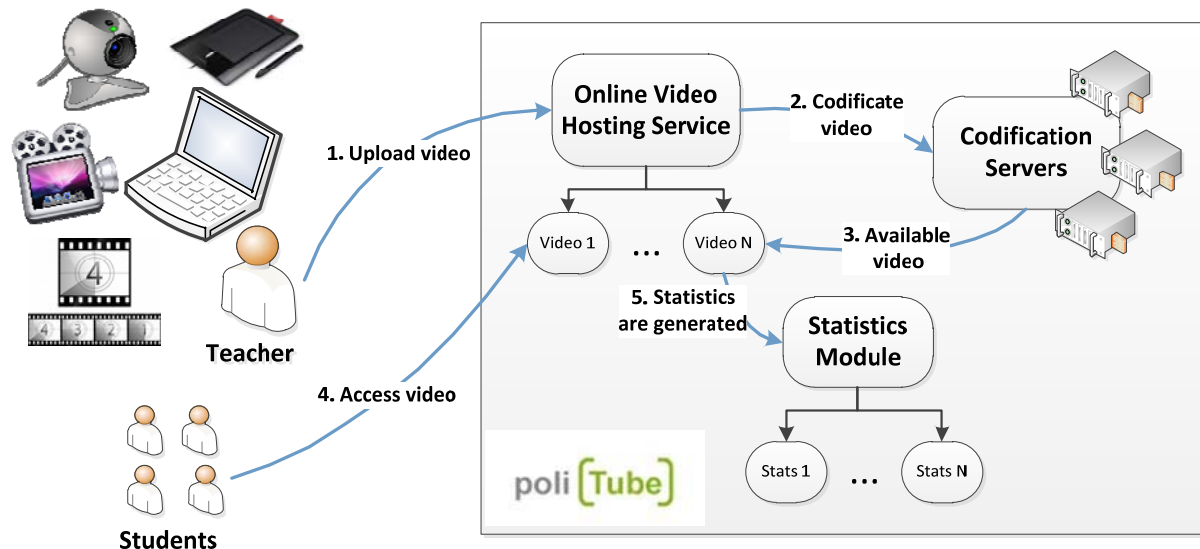
Figure 2 depicts the typical workflow (from left to right) employed to create the video exercise. First of all, the devices should be properly configured. This includes adjusting the audio settings to the noise level of the room and configuring the virtual pencils in the sketching software. The usage of a set of pencils allow to create more dynamic drawings by combining different pencil widths and colours in order to stress different areas of the problem. After the setting, the screencast session can proceed.

When the screencast session starts, the teacher proceeds to carry out the exercise combining the drawings in the digital tablet and the narration through the headset. The screencast software proceeds to record all this information in the background, while the teacher focuses on the exercise resolution. If the teacher does not feel confident about a certain explanation or simply introduces a mistake during the process, the screencast session can be restarted. This trial and error iterative procedure enables the teacher to gain confidence with the video exercise generation methodology.

When the teacher finishes and the screencast stops, it is time to edit the video. Some screencasting software includes basic video editing tools that allow trimming the video and to include transitions at the beginning and the end of the video. It is also interesting to include a mark in the video to clearly identify its authorship. This can be achieved by means of a watermark introduced in the video during the post-processing stage. However, the author identification can also be created by using different layers in the sketching application. The lowest layer can include the authorship identification details. On top of that, there can be a layer dedicated to state the problem. Finally, the uppermost layer can be devoted to drawing the solution of the problem. The usage of different layers eases the work by the teacher, since a mistake during the resolution only requires erasing a single layer.

Then, the video should be codified with an appropriate codec. Examples of these codecs are H.264 (MPEG-4) or Adobe Flash. The proper choice of the codec should consider the requirements imposed by the online video hosting service to be employed. Most of these providers accept H.264 videos. If the videos are to be put online in a personal web page, then the Flash format should be enough. The final size of the video depends primarily on its length and the quality configuration of the codec. Our experience shows that we should expect a size of approximately 30 Mbytes for a 7-minute video.

It is important to point out that videos should not be longer than 5-10 minutes in order to capture and maintain the attention of the viewer. Given that the exercises must be self-contained, it is important to cut straight to the point when addressing a large problem to be solved.



**Figure 3. Workflow of video exercise distribution and student's access**

Figure 3 depicts the workflow employed for video distribution and its access by the students. The teacher uploads a video to the online video hosting service (step 1). In our case, we are using the poli[Tube] service offered by the UPV. Once the video has been uploaded, the server might decide to encode the video using another codec and, therefore, this process is typically delegated to a group of codification servers (step 2). This process might take several minutes. Once the video is available (step 3), the teacher is notified so that the link to the video can now be accessed. This enables the teacher to publish the video as a new learning object. Then, the students access the video (step 4). This automatically generates access statistics in the poli[Tube] platform. These statistics typically include aggregated data about the number of times a certain video has been viewed and the country of origin of the viewer. These data are of importance for the teacher, who can gain immediate feedback about the impact of the videos.

As an additional side product, the use of the graphics tablet allows the professor to create digital diagrams that can be delivered to students through digital channels in the shape of a PDF document. This has several benefits. On the one hand, the diagrams can be progressively enriched over time by the professors since they always own the digital copy of the diagram. On the other hand, this approach serves as a simple replacement for traditional photocopies. Putting these diagrams online enables students to access this information via their laptops, notebooks and even mobile phone during the classes and as an out-of-class material.

### 2.2.1 Feedback and Student Assessment

In order to gather feedback from the students we have relied on the Google Apps platform to create an online questionnaire that allows the students to express the good and the bad points regarding each individual video. Using an online platform to gather the opinion of the students offers several benefits. Firstly, there is no paper wasted. Secondly, the poll can remain opened several days for the students to fill in the information. Thirdly, the results can be automatically obtained in a spread sheet from which data analysis can be performed.

This information is of paramount importance for the teachers, who can integrate this feedback into their methodology to progressively improve the quality of the videos. This would enable teachers to refine the pool of video exercises under a survival of the fittest approach, where the lowest ranked videos would be replaced by improved versions. Since this paper focuses on an early experience with these technologies, there is still not enough aggregated data to draw some statistically significant conclusions.

### 3 EXAMPLES OF VIDEO EXERCISES

This section summarises a couple of video exercises that illustrate the usage of the aforementioned technologies. These are examples that are being used in the degrees of computer science and telecommunications engineering at the UPV.

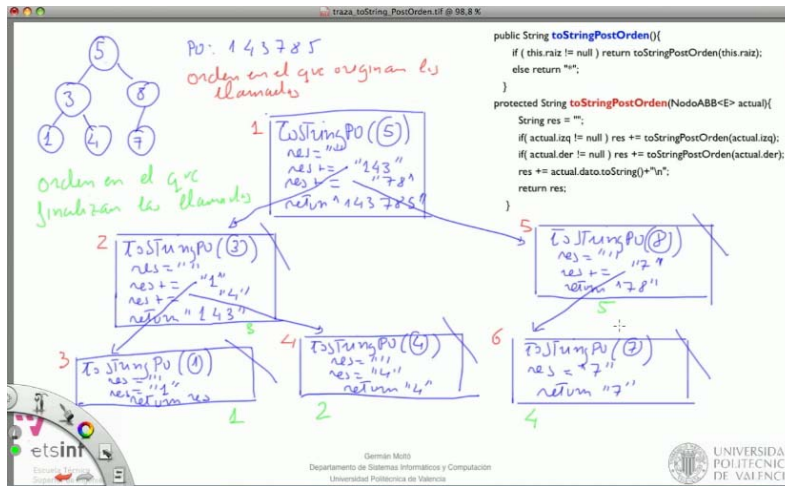


Figure 4. Example of the final result of a video exercise (traversal of a binary search tree)

Figure 4 shows a caption of the final results of a video exercise<sup>1</sup> employed in an undergraduate computer science subject called *Data Structure and Algorithms* to illustrate the post-order traversal of a binary search tree. This involves developing a trace of the execution of a given recursive Java method which, being multiple recursion, ends up creating a tree of activation records in the call stack of the Java Virtual Machine. This procedure is far from being a trivial task and, therefore, requires the students to pay careful attention when these concepts are explained during the class lessons. Creating these videos enables the students to have a second chance (in fact many chances) of understanding the underlying concepts in case they missed the explanation in the class. In particular, this video was created on a Mac using Autodesk SketchBook and Screenflow to create an MPEG-4 encoded video prior to uploading it to poli[Tube].

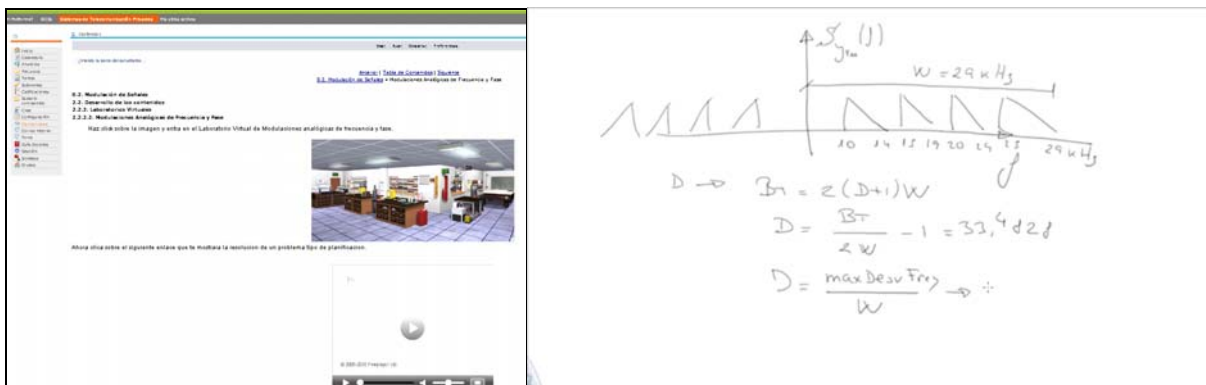


Figure 5. Integration of the video exercises in PoliformaT (left) and capture of frame (right)

As another example, Figure 5 includes another video exercise example<sup>2</sup> that further evolves this strategy, integrating the video exercise with PoliformaT, the Sakai-based Learning Management System (LMS) at the UPV. The video illustrates the solution of a planning exercise using a frequency

<sup>1</sup> The video is available at: <http://politube.upv.es/play.php?vid=47794> (in Spanish).

<sup>2</sup> The video is available at: <http://politube.upv.es/play.php?vid=47147> (in Spanish).



modulation system within an undergraduate course called Communications Theory in Telecommunications Engineering. This kind of exercises is hard to understand because of the mathematical complexity and the required reasoning capacity. To create this video, the following material was employed: The Intuos 4 Wacom digital tablet for the user interface, the SketchBook Pro to create the drawings and Camtasia as a screen recorder. All the recordings were shared with the students through PoliformaT whereas the poli[Tube] service was employed as the video streaming service. This allows students to watch the videos embedded in the same rich content platform provided by PoliformaT.

On clicking the video the resolution of the problem can be followed including the professor's speech and the reasoning process the solution includes. The student experience is quite similar to a master class in which the professor uses the blackboard to solve an exercise. In this sense the usage of a good graphics tablet is essential to achieve this personal styling that resembles the class sessions together with their familiarity and closeness.

In the course in which this method was used, all partial exams and proposed exercises were digitally solved and made accessible for the online review of the students.

## 4 DISCUSSION

This section aims at assessing the potential benefits and drawbacks of video exercises from both student's and professor's point of view.

For the students, video exercises have several advantages. For distance learners, or even for those students who missed a lesson, the time required to catch up significantly reduces, since the students can use these videos to develop the required skills. In addition, the students can seamlessly access these recordings on demand through an online video service provider. Therefore, they can repeatedly watch the resolution process of a certain problem until the problem solving skills are acquired. In addition, since they can asynchronously move through the video, they can focus on specific areas of the resolution process that might represent certain difficulties for the student. Moreover, the ubiquity of the Internet enables learners to access these materials on a 24/7 basis from virtually every possible device. Most online video platforms can be accessed from a myriad of different devices such as computers, laptops, netbooks, tablet PCs, mobile phones and the iPad. Therefore, the students no longer have a strong dependence on the schedules of their professors. Instead, since they have instant access to the learning material, they can have a better sense of responsibility of their own learning process.

In addition, digital natives, i.e. our younger students, typically find this learning approach very challenging. The early experiments conducted with students showed that access to the videos was very high and distributed along the course. Videos were watched by almost all the students, but with a higher rate by those who did not strictly comply with the class attendance. Specifically, on average, each student accessed the video exercises 2.3 times what means that the reinforcement learning was not only interesting but also required to understand the explained concepts. Concerning digital immigrants, i.e. those students not familiar with new technologies, the simplicity of the web-based platform guaranteed a reduced learning curve that resulted in a fast assimilation of the concepts.

Concerning teachers, the main advantage of the video exercises lies on the fact that they do not have to repeat the same exercise several times. Video exercises can help to solve common problems, especially for office hours where professors often have to solve the same problem for different students. Besides, the learning success is increased, as experience demonstrated, being also higher the students motivation and hence their course satisfaction.

The main drawback of the video exercises is the additional effort required to get used to the new hardware and software tools. However, after some training, the video generation proved to be as simple as solving a problem on a paper. The time needed to learn compared to the waste of time arising from solving the same problem several times, justifies without any doubt the initial time investment. In addition, the set of video exercises produced (or at least a subset) can certainly be reused for different courses, where the highly ranked videos should be considered an important material to be offered to future students. Finally, we would like to stress that the usage of online video services enables to use this material for foreign learners or even prospective students. Therefore, if the teacher decides so, the produced videos can be released to the worldwide academic community so that others can benefit from the work done.

## 5 CONCLUSIONS AND FUTURE WORK

This paper has described the early experiences of using video exercises that can be accessed online in which the teacher solves a certain problem using a digital tablet together with a narration of the procedure. These videos can be seamlessly accessed by the students in order to gain the appropriate skills. These techniques have been employed in the degrees of computer science and telecommunications engineering at the Universitat Politècnica de València. The advantages introduced by this approach, both for professors and students, encourages us to continue with this research line.

In the near future, we plan to continue with the development of additional videos, incorporating the feedback gained in the early experiences. It should also be important to address additional techniques such as closed captioning in order to reduce the limiting barriers for students with special requirements. Introducing subtitles in some of the videos could address some of these barriers.

## ACKNOWLEDGEMENTS

The authors would like to thank the “Vicerrectorado de Estudios y Convergencia Europea” of the “Universitat Politècnica de València” for the economic support for the project “Aprendizaje virtual síncrono mediante entornos colaborativos en un contexto multidisciplinario (A001/10).”

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