

# An interactive video-based learning environment supporting learning analytics: Insights obtained from analyzing learner activity data

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**Abstract.** Online videos are extensively used in education and a recent trend is the integration of interactive elements and web content into educational videos. This paper describes how open source tools can be used for developing learning environments where video content is aggregated with interactive elements, educator content and content coming from open internet resources. It also describes how such tools can be used for capturing and storing learner activity data which can then be used for data analysis and data mining purposes. Finally, the paper presents insights obtained from analyzing learner activity data that was gathered over an academic year's period.

**Keywords:** Interactive Educational Videos, Video Learning Analytics, Open Educational Resources.

## 1 Introduction

Educational video content was first delivered to public by mainstream media through scheduled television programs. Later the arrival of VCRs provided learners with the option to watch educational videos in their preferred place and time. An article published W. Reider (1985) highlighted the significant increase in the use of VCRs in schools in the mid 80's.

Today although learners still watch educational videos through VCRs and scheduled television programs (e.g BBC Video for Learning (2015) ) the Internet is the main medium for educational video distribution. The increase of online video usage in education is depicted by a considerable amount of publications that focus on the topic. Kay (2012) provided a literature review on the use of video podcasts in education from 2002 to 2011. In this review, Kay noted that research in the particular area before 2005 was limited but increased rapidly in the following years due to two factors, (a) the adoption of high-speed Internet access

in homes and schools between 2006 and 2010, and, (b) the appearance of the popular video sharing site YouTube (2015) in 2005, that is also a big repository of educational videos.

Similar findings are also reported in another literature review written by M. Giannakos (2013). In this review 166 papers from top Journals in Learning Technologies were examined and the investigation period was divided into two sub-periods (2000–2006 and 2007–2012). Although the duration of the first period was longer by one year, the papers published in the second period were over double in quantity.

The significant increase of video use in education is also depicted in a survey conducted by Kaltura (2015), a video technology provider. The information in this survey was gathered from professionals working in educational organizations around the globe.

Nowadays, educational video distribution over the Internet has literally exploded. A vast amount of educational videos is offered in either an organized or unorganized manner, by institutions and independent educators in video-sharing sites like YouTube and Vimeo (2015). Furthermore leading institutions deliver educational videos through open courseware initiatives, such as Coursera(2015) and edX (2015), and non-profit educational organizations such as Khan Academy (2015) have organized large collections of educational videos for a broad range of subjects. Educators typically use video as support material in K-12 and higher education and as a substitute for the physical lecture in distant education settings. Video also plays an important role in the pedagogical method of the “Flipped Classroom” (Bishop and Verleger, 2013, Giannakos 2014).

Online educational videos can contain video recordings, animations, screencasts or a combination of any of these forms. Video recordings are normally lectures captured in various settings (e.g., class, studio) or documentary style videos where various topics are explained. Animations are typically used to explain the details of various processes (e.g how a car engine works) and screencasts are mostly used for explaining functions of a software program. Educators and e-learning content creators can mix the above forms with video editing software or commercial e-learning software to produce an educational video.

Interactivity in video is a relatively new trend with the level and types of interactivity to be in constant evolution. The typical interactive features that could exist in an online video are the ones that are facilitated by the interface of most media players. By using the buttons (or the progress bar) of these media players, the viewers can perform various actions, such as pausing and resuming the video from the same point in the video timeline or performing backward and forward jumps. This basic level of interactivity that enables non-linear viewing has been proven to have better learning outcomes when compared to the linear viewing where control buttons for stopping, replaying, or changing speed are not present (Schwan and Riempp, 2004)

Besides the basic interactivity features that control the video flow, commercial e-learning providers were the first to provide additional means for enhancing the interactivity in video viewing. Some of the features that commercial e-learning packages such as Adobe Captivate (2015) and Articulate Storyline (2015) provide are the following:

- insertion of questions or other elements that require learner action at various points in the timeline
- creation of a content table -- the educator can organize the video into sections and learners can then navigate directly to these sections
- 'branching option' -- using this feature the educator can make videos that follow different routes depending on learner actions; for example, a video could jump to a different point in the timeline and show different content depending on learner input (e.g., answer given to a specific question)

Although these tools are great for introducing interactivity in videos and e-learning content that is created by educators, they do not offer an easy way for an educator to introduce interactivity in educational videos found in video sharing platforms like YouTube and Vimeo. From the survey conducted by Kaltura (2015), the most widely used source of video in classes is content from free online resources (73% of 1,200 respondents stated that they used it frequently).

To address the need of adding interactivity to videos found on video sharing sites, a new array of tools such as EDpuzzle (2015), eduCanon (2015) and Zaption (2015) were developed. Zaption, for example, is a platform that allows the educator to choose videos from the web and add content such as basic text and image slides and interactive elements such as open responses, multiple choice questions, check boxes, drawn responses and numerical responses. The content and elements are added at certain points in the timeline through a drag and drop interface to create a time based interactive video. Discussions can also be accommodated in a video, a feature that also exists in other platforms such as Vialogues (2015) and Grockit answers (2015). Learners can submit questions about the video content at any point in the timeline or give responses to other learners' questions. Popcorn maker (2015) is another tool which is used to remix web video, audio, images and content coming from internet recourses and web services in order to create an educational mash-up.

Although these tools provide an easy way for educators to bring interactivity into videos found in the web through user friendly interfaces, they contain only a subset of the possible features that could be supported in a video based learning environment.

Furthermore, almost all of these applications are commercial and either are not free or offer only a limited set of features for free and have incremental paid account options for the rest of the features (e.g., Zaption, Educanon). Another drawback is that none of the above tools are open source (besides Popcorn

Maker), meaning that these tools are not open to further development or customization by independent developers.

As far as learning analytics are concerned, some of these tools provide basic level options mainly through visual reports (e.g., eduCanon, Zaption). Analysis of video viewing data is a relatively recent trend and there is a small but significant body of on-going research that focuses on the topic (e.g. Kim et. al 2014, Giannakos et. al 2015, Giannakos et. al 2014, De boer et al. 2011, Gorissen et. al. 2012, Guo et. Al 2014). Thus, it is certainly a plus for a tool to provide advanced analytics features as well as the whole dataset for further data analysis and mining.

The aim of this paper is to provide alternative solutions that tackle the limitations of the existing video based products that are used for learning and research. This is attempted by providing a roadmap of how to use open source solutions and open internet resources in order to build an interactive video based learning environment that supports learning analytics.

More specifically, in Section 2, we describe how open source technologies and open internet resources are used to create a learning environment where interactive elements, user content and web content are aggregated with educational videos in order to transform the video viewing process into a more interactive experience. In Section 3, we describe a module for gathering and storing viewing activity data for data analysis and data mining purposes. Details of the educational settings together with findings obtained from analyzing learner activity data are presented in Section 4. The aim of the data analysis is to a) obtain insights on how the learners used educational videos and the available interactive features within the environment, throughout an academic year's period, and b) to investigate if educational video viewing has better learning outcomes when accompanied by other activities such as written assignments and quizzes, that are related to the video content and are either distributed through an LMS, or within the video based environment (in-video quizzes). Other factors that may affect performance are also investigated (i.e viewing time). The paper concludes in Section 5.

## **2 Developing a video based learning environment using open source tools and open internet resources**

After conducting research in order to spot open source technologies that can be used to develop time based interactive videos we recorded two available options, the Mozilla Popcorn framework (2015) (used in Popcorn Maker and Grockit answers) and open source HTML 5 players such as Media Element (2015) and Flowplayer (2015).

To build the application that we have used in educational settings, we used Media Element, an HTML5 player that can be used for videos that are hosted on a web server or can act as wrapper for videos hosted in YouTube and Vimeo. By using the API of Media Element (or similarly the API of the other mentioned tools), actions can be initiated when specific time points (or intervals) are reached in the video timeline or when certain video events occur (e.g., pause, resume, start and end of video, volume change). A typical action is the retrieval (or storage) of content from (or to) a database and this is the basis for building time based interactive videos.

The basic components of the application are the ‘Administrator’ and ‘Viewer’ modules. The ‘Administrator Module’ is where various elements are defined by the educator at various time intervals or points. The elements can then be previewed by executing the video and are finally stored in the database if the result satisfies the educator. If the result is not satisfying the elements can be deleted or altered. The interface of the ‘Administrator Module’ is kept very simple and in Figure 1 we can see a picture of this module where multiple choice questions are set and previewed, before they are stored in the database. If answers are not defined then an open response answer is expected.

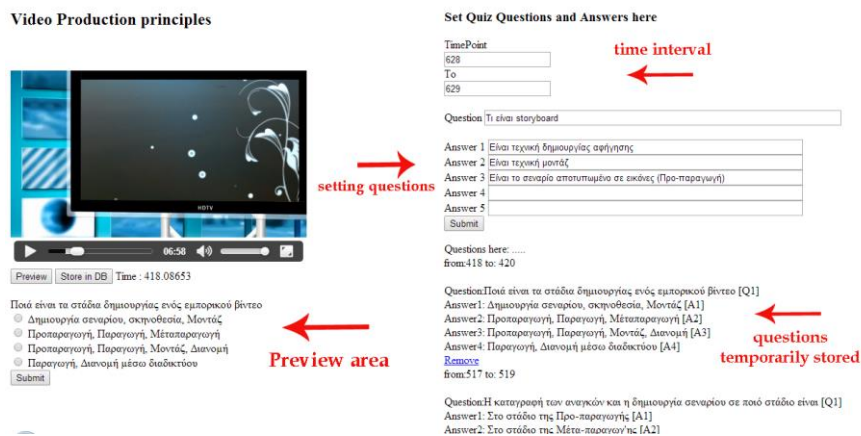


Fig. 1-Snapshot of the Administrator Module which is used for associating quiz questions (and open responses) with time points (or intervals) in the video

The other module is the ‘Viewer Module’. This is used by learners and in this module the elements are retrieved from the database and presented to the learner at the specified time intervals (or time points) during video execution.

Javascript (and JQuery) is used in the front-end of both modules. More specifically, it is used to track video time and video events and for handling input coming from the educator (e.g., insertion of multiple choice questions) and the

learner (e.g., submission of answers). At the back-end, for storing and retrieving content from the database PHP and MySQL are used.

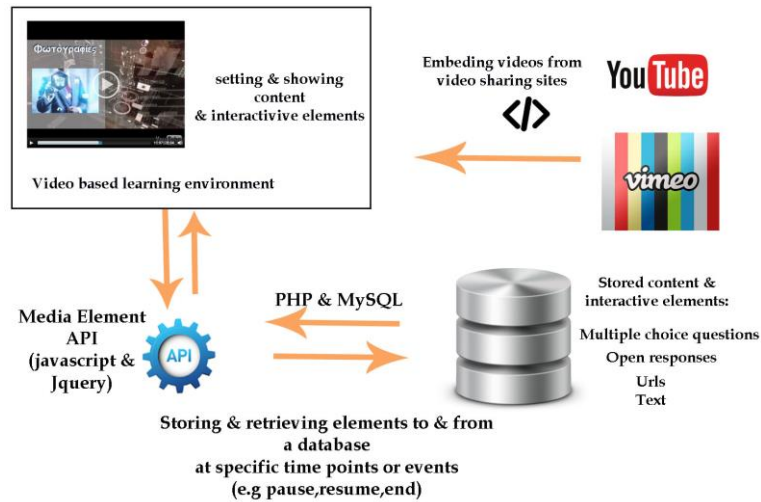


Fig. 2- Storing and retrieving elements to and from the database at various time points (or time intervals) and events

The features that are present in the learning environment are the following:

**a) Questions that appear at various points in the timeline (in-video quizzes).** In-video quizzes are a relatively new feature that can be found in educational videos including educational videos found in Coursera and Edx. In-video quizzes are even the focus of some recent research (Cummings et. al 2015) Quiz question elements can be defined and stored in the database by the educator. These are then retrieved when the learners view the video (in the Viewer Module). The quiz questions appear when the player head reaches specified time points and the video pauses at these points. So far we have implemented quiz questions and open response answers but other types of questions can also be implemented. Feedback can be provided to the learner after the answer is given, but in our setting since the in-video quizzes were part of an assignment this feature was not present.

**b) Sections and the Table of Contents.** Very often it is useful to logically (rather than physically) segment an educational video into sections where each section covers a particular subtopic. Then a pause can be initiated at the end of each section in order to give the learner the opportunity to reflect on the video material or alternatively in video quizzes can be placed at the end of sections to test the learners acquired knowledge. The learner can also be provided with a table of contents, a feature that will allow him/her to access the video sections at will. This feature aids learner navigation by providing better control over the learning process and is particularly useful for long videos. As a result the linearity of traditional video is eliminated. The table of contents enables efficient random

content access in video, and past research has proved that random content access in video increases learner engagement and satisfaction (D. Zhang 2005, D. Zhang et. al 2006 ).

Furthermore, the breakdown of multimedia in logical segments is supported in the literature as a way to make multimedia learning more effective and is referred to as the “segmenting principle”. According to E.R Mayer (2005) The segmenting principle is that people learn more deeply when a multimedia message is presented in learner-paced segments rather than as a continuous unit.

In Fig. 1, we can see an instance of the environment where both of the above features are used (i.e., table of contents and questions).

The screenshot shows a learning environment with the following elements:

- Video Player:** On the left, a video player shows a man speaking. Subtitles in Greek are visible at the bottom: "Επίσης graphic design είναι να επιλέγουμε τις σωστές γραμματοσειρές και να χρησιμοποιούμε τις γραμματοσειρές αυτές με ελκυστικό και καθαρό τρόπο."
- Table of Contents:** On the right, under the heading "Πίνακας Περιεχομένων Βίντεο", there is a list of chapters:
  - 1 ΟΜΙΛΗΤΗΣ 1
  - 2 ΟΜΙΛΗΤΗΣ 2
  - 3 ΟΜΙΛΗΤΗΣ 1 (2Η ΟΜΙΛΙΑ)
  - 4 ΟΜΙΛΗΤΗΣ 2 (2Η ΟΜΙΛΙΑ)
  - 5 ΟΜΙΛΗΤΗΣ 1 (3ΤΗ ΟΜΙΛΙΑ)
  - 6 ΟΜΙΛΗΤΗΣ 2
  - 7 ΟΜΙΛΗΤΗΣ 4
- Questions:** Below the table of contents, under the heading "ΕΡΩΤΗΣΕΙΣ", there is a question:
 

Ερώτηση 2  
Ποιο από τα παρακάτω σφάλματα με τον 1ο ομιλητή δεν ανακαλύφεται στην δουλειά του δουλιού του σχεδιαστή γραφικών και επομένως δεν έχει αναφερθεί.

  - Να δημιουργεί γραφικά με άμεση διάθεση
  - Να δημιουργεί γραφικά που φανερώνουν καθαρά
  - Να δημιουργεί πολυλογία με την χρήση κλειθριών, κλώνων και βίντεο
  - Να εκολογή γραμματοσειρές που θα συνδυάζονταν τα γραφικά
- Navigation:** A "Submit" button is located at the bottom of the questions section.

Fig. 3-A snapshot of the learning environment where an educational video is used to support the course “Graphic Design”

c) **Subtitles.** There is a vast range of educational videos on YouTube or Vimeo but these videos are mostly in English. To be used in countries where English is not the native language the educator can carry out the subtitling process by associating subtitles with specified time intervals. Then, during learner viewing these subtitles are fetched from the database and shown in a text box underneath the video (figure 4).



Fig. 4- Associating subtitles with specified time intervals in the “Administrator Module”

**d) Content aggregation.** Another feature is the integration of web content to educational videos. More specifically, web content coming from web pages and web services can appear next to the video. Using the Administrator Module the educator defines the web pages that will appear when the player is within certain time intervals. The web pages will appear next to the video either as links (and the learner will have to follow the links) or as embedded web pages in an iframe. For example a Google forms questionnaire can appear at a certain time points to test learner knowledge, a Google map can show up presenting an exact location that is mentioned in the video or a wiki page can appear presenting relevant content in text form. Another useful option is the synchronization of an educational video with content coming from web services. This is achieved with the parallel use of the Media Element API and other web services APIs. For example, in the developed learning environment, video content can be synchronized with slides from Slideshare (2015) (Fig 5.)



Fig. 5- Synchronizing Video content with slides in Slideshare in the ‘Administrator Module’



Furthermore, using the same mechanism, where various elements are stored and called from the database at specific time points, other features can be facilitated also, such as learner video annotation and discussions. Practically by using the API of HTML 5 video players, and the mechanism for associating actions (such as retrieving database content) with specific time points or time intervals, the number of features that can be supported in a video based environment are really up to the creator's hands and imagination.

Branching for example is a feature that can be present in an educational video where the video can follow different routes depending on user input. (e.g the video can advance to different points in the timeline depending on an answer that a student gives on a multiple choice question).

Another option is to find other web based tools that are typically used in learning and to use them within the video based environment to accompany related videos.

At the moment for a course with title "Image and Video editing Principles" we have incorporated Pixlr, an image editing online software, into our video based environment. The students in this particular setting after following a logging procedure are prompted to watch a video explaining image editing techniques using Pixlr. During video execution exercise links appear at various time points together with a short description of the exercise. If these links are followed the Pixlr environment is opened on a separate browser tab together with the necessary for the exercise image files. Once an image editing exercise is completed by the student, and the "save" menu item is selected the output is stored on the server. The students are able to see their files and replace them if they are not happy with the result (by continuing their work and pressing "save" again). Pixlr API is used for the communication between the server and the Pixlr application. In this way students watch the related video and perform the given exercises from within their environment account.

Furthermore collaborative activities can also be incorporated in the video based environment. For example an online collaborative quiz can be incorporated into the environment and performed by a group of students while watching a related video. The effectiveness of in-class collaborative quizzes in performance and student satisfaction has been researched in past papers (Yokomoto and Ware, 1997, Slusser and Erickson, 2006) and it can also be investigated if their presence is effective in an online video based environment. Other collaborative activities such collaborative writing (answers to questions, short essays etc) can also be facilitated. Students can be asked to write a text in groups at the end of a relevant video segment. At the moment we are experimenting with etherpad (2015) a collaborative word processing web application that supports group synchronous and asynchronous collaborative writing. Etherpad contains also a live chat for communication amongst the authors. Below we can see a snapshot (Fig. 6) where a question appears at a specified time and then a collaborative writing activity

takes place in order to answer the question. The text that each user contributes is highlighted by different colour.

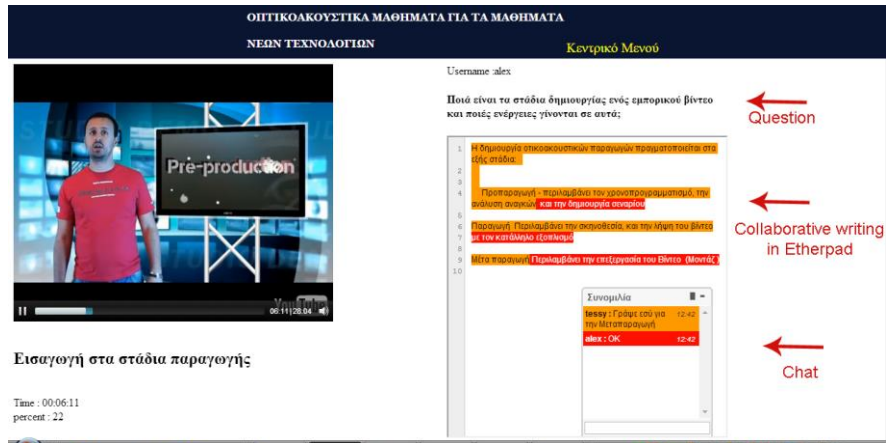


Fig. 6- Incorporating collaborative writing activities in a video based learning environment. Experimenting with Etherpad.

As mentioned the options for integrating web content and web activities into the video based environment are many and its really up to the creator's hands to adopt the features that are useful for learning. Although the usefulness of some interactive video features are supported by literature, such as segmenting a video into portions that reflect different concepts (Mayer 2005) and providing a table of contents for random access to these portions (D. Zhang 2005, D. Zhang et. al 2006 ), it is still a research question of what features and activities actually assist learning. It can be argued that some of the described features may cause frustration and slowdown the learning process instead of assisting it. Video based environments such as the one described in this paper however can be used to answer such research questions. More specifically the environment can be enhanced to facilitate new features and used to conduct experiments in order to test the effectiveness of the incorporated features in learning.

### 3 Video learning analytics

In the heart of the learning environment lies a module with the task of collecting and storing learner viewing activity for data analysis and data mining purposes. The module consists of a program that tracks and stores video events that are triggered by learner actions and changes in the video state. A database with a suitable schema is used for storing all the relevant information.

Learners are required to perform a login procedure to be able to view the videos. All the activity data stored is then associated to the current learner id and

is not anonymous. It is also possible to associate the collected data to IP addresses rather than user ids if ethical issues are raised.

In the application database, viewing data is stored in three tables **(a) Sessions**, **(b) Session\_videos**, **(c) Session\_events**. The database schema is an extended version of the schema presented in a former research by the authors of the current paper (Kleftodimos A and Evangelidis 2013). A session starts on learner login and at that point an entry is stored in table **Sessions**. Videos started within a session are associated with the specific session and stored in the table **Session\_videos**. Similarly, events triggered during video execution are associated with the particular video and stored in table **Session\_events**. Date and time are stored for all the database entries. The same database schema can also be used to accommodate viewing activity data if a different technology is used (e.g., Flowplayer, Adobe Captivate). The tracking program however will need to be specific to the technology used and its underlying API function calls.

The events that are specific to the Media Element API and are used in the module for tracking learner activity are listed in the following table:

1	<b>loadeddata</b>	called when the video is loaded
2	<b>seeked</b>	called when the learner “seeks” by moving the video progress (or slider) bar,
3	<b>play</b>	called when the video starts playing or resumes after a pause,
4	<b>pause</b>	called when the video is paused
5	<b>ended</b>	called when the video reaches its end
6	<b>volumechange</b>	called on volume change
7	<b>muted</b>	called on sound mute

Table1. Events specific to the Media Element API that are triggered on video execution.

A set of properties can be retrieved when these events occur such as the video time, the current date and time, etc. The full list of properties and events is provided in the Media Element web page (2015).

The database also contains tables to accommodate administrator-educator and learner input (e.g., questions defined by the educator, answers given by learners, subtitles, web content - urls and embedded code - and topic sections, again, defined by the educator).

Another feature that plays role in analytics is sections. As already mentioned, sections defined by the educator reflect different conceptual topics. Sections can also play the role of marker points in the video. When a marker point is reached, an entry is stored in the database together with the current date and time. Another way of splitting the video is through equal time intervals (rather than different conceptual topics). In this case the markers are inserted in equal time intervals.

The time interval is again set by the educator and stored in a general parameters database table.

The insertion of cue markers that initiate events (section enter event), which are then stored in the database together with other events (e.g., pause, resume), can give us a good estimate of the video portions viewed and provide us with a dataset of viewing behaviors that can be used for data analysis and data mining purposes.

Currently, in the developed application we use both markers for topic sections and markers for time intervals. Although this causes more database accesses (and scalability problems are possible), we concluded that this option is necessary for Media Element in order get more accurate approximations for the segments viewed by learners.

By storing all these events, we obtain a very rich database of learner viewing activity. The acquired data can then be processed and analyzed by using a variety of open source packages, such as R (2015) and Weka (2015). At the moment the environment does not incorporate data analysis modules but once research confirms the usefulness of certain data analysis tasks the incorporation will take place.

In the following section, we describe the educational settings in which the environment is used and present insights obtained from analyzing activity data using graphical representations and statistical methods. The purpose of the research conducted is to understand the activity behavior of the learners with respect to the environment features in use (e.g., table of contents) and other factors that affect the viewing behaviour (i.e. assignment and exams), throughout an academic year. The analysis also investigates if more active ways of learning such combining video viewing with parallel completion of a related assignment benefits the learning process.

## **4 The educational settings and findings**

The developed learning environment is used at the Department of Digital Media and Communication at the Technological Education Institute of Western Macedonia, Greece. The application was first used in the autumn semester 2014-2015 to support the theoretical part of the first semester courses “Introduction to new Technologies in Communication” (5 videos from YouTube) and “Image and Video editing Principles” (1 video, Fig.7). It was then used in the spring semester 2015 to support the second semester course “Graphic Design” for both the theoretical part (1 video from YouTube, Fig. 3) and the laboratory part (10 videos for learning the vector graphics software Inkscape).

ΟΠΤΙΚΟΑΚΟΥΣΤΙΚΑ ΜΑΘΗΜΑΤΑ ΓΙΑ ΤΑ ΜΑΘΗΜΑΤΑ  
ΝΕΩΝ ΤΕΧΝΟΛΟΓΙΩΝ  
Κεντρικό Μενού



**Το βίντεο στην επικοινωνία**

Time: 00:00:03  
percent: 0

**Πίνακας Περιεχομένων Βίντεο**

Μπορείτε να μεταβείτε στις ενότητες του βίντεο κάνοντας κλικ στα παρακάτω link

- 1 Το βίντεο στην επικοινωνία
- 2 Συνέντευξη 1η - Το βίντεο στην επαγγελματική επικοινωνία
- 3 Εισαγωγή στα στάδια παραγωγής
- 4 Πρε-Παραγωγή (Προσχεδιασμός)
- 5 Προ-παραγωγή Το σενάριο
- 6 Συνέντευξη 2η - Το σενάριο και η σημασία του
- 7 Ανάλυση σενάριου της παραγωγής
- 8 Η παραγωγή (παραγωγή)
- 9 Αποτέλεσμα στοιχεία μιας παραγωγής
- 10 Η υλοποίηση της συγκεκριμένης παραγωγής-παρακολούθηση

Table of Contents

Fig. 7: A snapshot of the learning environment where an educational video is used to support the course “Image and Video editing Principles”

Part of the syllabus is covered by the videos. The features activated in the application for the courses are the following: a) **Table of contents**, for the courses “Image and Video editing Principles” and “Graphic Design” b) **Subtitles**, for the course “Introduction to new Technologies in Communication”, and, c) **Questions** (in video quizzes with multiple choice and open responses) for the theoretical part of the course “Graphic Design”. The data recording module is activated for all the lessons mentioned above (theoretical and laboratory). For the courses “Image and Video editing Principles” and “Graphic Design” we have defined sections that reflect different subtopics (e.g interviews by different professionals or information about a stage in the video production phase). For the rest of the videos sections were not defined and a table of contents was not provided. This was done in order to observe the learners viewing behaviour in the presence and absence of this interactive feature. The videos were however split in equal time intervals for data analysis purposes. For the rest of the section we will concentrate only on the videos for which we have defined sections that reflect different subtopics, and have provided the learner with a table of contents.

#### **Autumn semester 2014-2015.**

During the autumn semester 2014-2015 students attending the course “Video and Image editing Principles” were given a video to watch as part of the syllabus. The video length was about 30 minutes and it contained information about the promotional video creation process as well as the professionals involved in this process (script writer, director, video editing specialist, etc.). The video also contained interviews with such professionals. The video had been produced by a student with a professional experience in the field as part of his thesis.

Students were given an optional assignment that was related to the video. The assignment consisted of two parts, a questionnaire (20%) that was delivered

through Google Forms and a written assignment (80%) that consisted of several open-ended questions. The assignment counted 15% towards the overall mark.

The assignment was not incorporated in the video environment but was distributed through the institutional learning management system. The video content was also included in the exam syllabus and students were notified that some questions in the exam would be related to the video content. The period for the assignment completion was about 20 days and the period between the deadline of the assignment and the exams was about 24 days.

Sections were defined for the video and the headers of these sections appeared as a table of contents next to the video (Fig. 7). The video consisted of 14 sections (reflecting different subtopics). The learners were able to use the table of contents to navigate directly to the specified sections. They were also able to use the typical player buttons (i.e. pause, play, mute sound etc.)

In Fig. 8, we see some temporal aspects of the learner viewing behaviour. Fig. 8.a represents the views in the time interval from the time that the video was delivered to the students and the assignment was set, until the exam.

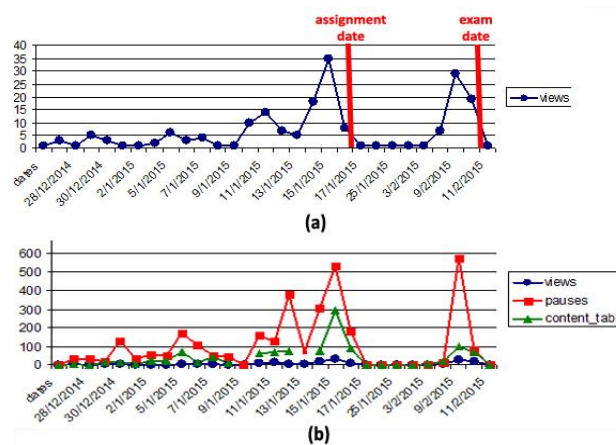


Fig. 8: Views and actions

In Fig. 8.a we can clearly see two peaks, one before the assignment and another before the exam. We can also see that there are views in the period before the peak related to the assignment but almost no views in the period between the assignment deadline and the peak related to the exam. In Fig. 8.b, one can also see in a relative scale the views but also the number of pauses as well as the clicks in the table of contents. From this representation one can clearly see that the table of contents received more clicks during the assignment period.

Another aspect that we focused on is the section transition matrix. By the term section transition matrix we mean a table depicting the number of transitions (or jumps) from section to section. Transition matrices can be obtained through various ways. We used a) the TraMiner package (2015) within R and the seqtrate

function, to obtain a table of transitions and b) the Heatmap2 function of R to obtain a graphical heatmap representation of the transitions. In this investigation, we excluded transitions from one section to itself (e.g., section 1 to section 1) that typically occur via a pause/resume action within a section.

The most typical transition that can be encountered in a transition matrix is the transition from one section to the section that succeeds it (e.g., section 1 to section 2). In a video that is viewed linearly without dropouts or backward jumps, the number of transitions from one section to the next would remain constant. However this is rarely the case and because of these two factors transitions amongst sections can either decrease or increase.

In Fig. 9 we see two heatmap graphs depicting section transitions, one from the period before the assignment and the other from the period after the assignment and before the exam. In these heatmap graphs the lines correspond to the start sections, the columns to the destination sections and the numerical values are the number of transitions from the start sections to the destination sections. It is noticeable in the Fig. 9.a that besides the typical transitions from one section to the next (e.g. 90 transitions from section 1 to section 2), there are also transitions to other sections that stand out. Among these transitions, the ones to the previous sections are the ones that stand out clearly meaning that learners performed

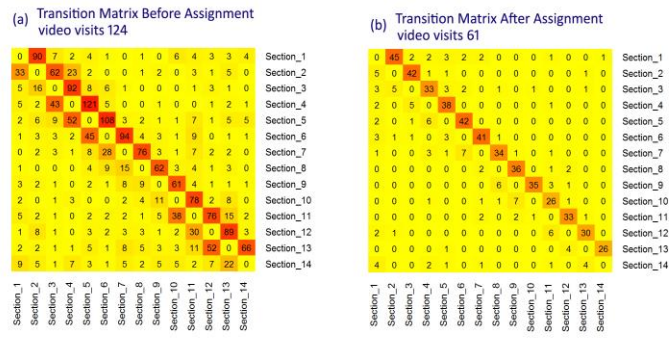


Fig. 9: Section Transition Matrix for course “Image and Video editing Principles”.

backward jumps probably because they wanted to view again a video segment before answering an assignment question.

When comparing the two images of Fig.9, we can say that the 2nd transition matrix (Fig. 9.b) is less ‘turbulent’ than the 1st one (Fig. 9.a), meaning that learners viewed videos in a more linear fashion in the period close to the exam. Moreover, we can say that although the table of contents was used for completing the assignment, students used it mainly to navigate to a previous section rather than making arbitrary jumps. The majority of the questions in the assignment followed the sequential order of the sections (e.g. a question related to section 2 was followed by a question related to section 3). However, there were exceptions

to the rule and some of these (but not all) can be distinguished in the graph. For example there are 23 transitions from section 2 to 4 and 15 transitions from section 11 to 13. Both of these cases reflect exceptions in the sequence of questions.

At last we observe that besides the two peaks in fig.8 and despite the fact that the pre-assignment period and the post- assignment period were almost equal (post-assignment period was by 4 days longer) the number of views were more in the pre-assignment period. We can say that the assignment caused more engagement with the video material. Also this engagement was more interactive as we observed in fig.9.

### **Spring semester 2014-2015.**

During the spring semester of the Academic Year 2014-2015 students attending the course “Graphics Design” were given a video from YouTube where professionals are talking about Graphic Design. The video length was about 7 minutes.

The video was segmented into 7 different sections where sections reflected different issues covered by the professionals. A table of contents was again provided for quick access to the sections contents. This time however in-video quizzes were incorporated into the video environment and next to the relevant video. Quiz questions appeared at the end of each section (multiple choice and open ended). The quiz questions were part of an assignment and the assignment counted 10% towards the overall mark. The pre-assignment period was 23 days and the post assignment period was 41 days. Learners had only one go at each question. Once the question was answered by a learner, the answer was stored in the database and the question would no longer appear in the video for the particular learner. The video could be watched as many times as the learners wished and only the unanswered questions would appear on each video viewing. The questions were of low cognitive complexity (Krahwohl 2002) and required simply to remember content exhibited in the video.

Graphs similar to the ones depicted in Fig. 8, concerning the views in time and also the pauses and the table of contents clicks were also obtained for this course. The patterns were similar as in Fig. 8 as far as the views and the pauses are concerned. The clicks in the table of contents however were a lot less probably because the length of the particular video was shorter and learners thought it would suffice to navigate just by using the time slide bar. Moreover the heatmaps for the periods before the assignment and between the assignment and the exam were also identical and this was somehow an unexpected observation because almost all questions that concerned a particular section appeared before the end of the section and therefore there was no obvious reason for jumping back to a previous section.



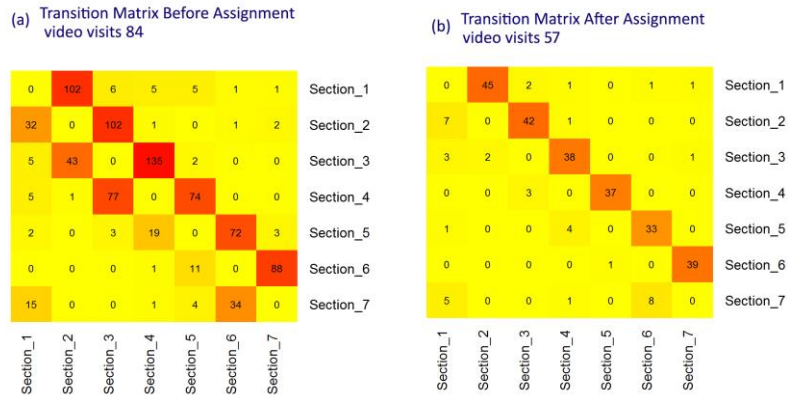


Fig. 10: Section Transition Matrix for course “Graphics Design”

We tried to obtain an answer to this unexpected behaviour by observing the learner viewing patterns.

In our setting there were 2 questions associated with section 1, 2 for section 2, 1 for section 3, 3 for section 4, 1 for section 6 and 1 for section 7. Questions appeared at the end of sections and the video paused so that the learners could give their answer. Learners were expected to answer questions associated with a particular section right before entering the next section. For example after entering section 1 (S1), and towards the end of the section, learners were expected to answer the two questions associated with S1. After the appearance of the questions, S1 will again play for one or two seconds and the video will advance to section 2 (S2). Thus the viewing pattern up to section 2 would be S1-A1-A1-S1-S2 where A1 is an abbreviation for the answers given by learners to the questions associated with section 1.

Following this logic the viewing pattern that we expected to be dominant for the whole video would have the following form “S1-A1-A1-S1-S2-A2-A2-S2-S3-A3-S3-S4-A4-A4-S4-S5-S6-A6-S7-A7” where “S” stands for ‘section’ and “A” for answer. We soon realized that a small error was occurring in the video and the second question that was associated with section 2 was appearing at the first second of section 3 (rather than before it). So the expected prevalent viewing after taking this abnormality into account would be S1-A1-A1-S1-S2-A2-S2-S3-A2-A3-S3-S4-A4-A4-S4-S5-S6-A6-S7-A7. However out of the 84 viewings that took place before the assignment, only two viewings followed this state pattern. In particular we obtained 80 distinct viewings meaning that 80 viewings had a different pattern. Some were short (videos viewed partially) and some were long (with many jumps from state to state). The maximum sequence length was 33.

From a careful observation of the state sequences it was obvious that the backward jumps occurred mainly due to 3 reasons:

a) learners did not submit their answers as soon as the questions appeared but rather skipped the question and continued viewing by advancing to the next section. After staying in the next section for a short time they came back to the previous section to submit their answer.

b) learners encountered a question and went back in video time to review content but without using the table of contents. By using the time slide bar instead they landed to the previous section. This behaviour explained the large number of visits from section 4 to section 3. Learners when encountered the first question of section 4 had to track the content which contained the answer. This content was located at the very beginning of the section and when students tried to reach it by using the slide bar, they landed in section 3 instead.

c) learners returned to the video after answering all questions in order to search for unanswered questions. These viewings are not linear and they contain a number of jumps to previous sections where these jumps probably occur because learners wanted to be certain that they had not left anything unanswered.

From the views we observed that many learners did not submit all the answers on their first viewing but rather submitted answers in two or more viewings. We also identified a strategy where some students viewed the whole video and the related questions one or more times without submitting any answers, and at some subsequent point in time they accessed the video again to give their answers.

The sessions after the assignment were less turbulent as it was observed in the first semester course with only a small number of jumps. Thus again besides the fact that the pre-assignment period was much shorter than the post-assignment period, there were more viewings in the pre-assignment period and these viewings were also more interactive.

#### **Testing various hypothesis.**

Taking in to account that the designated assignments caused more viewings and more interactivity within the viewings (as depicted in figures 8,9,10), we wanted to test if the completion of the assignment had also an effect on learning.

For both courses the number of students that enrolled for the course was larger than the number of students that accessed the videos and these were mostly students that attended the lectures. The study that follows focuses only on the students that viewed the related video lessons at least once and participated in the exam.

For both courses besides the overall exam mark, the student marks on the questions associated to the video were recorded and only these marks were used in

the study conducted. These marks will be referred to as “video exam marks – VE marks”. In the investigation conducted, we tried to spot any differences in the VE marks between students that completed the assignments and those who did not. This test was carried out for the two courses separately since the assignment activities were not the same.

An independent sample t-test was conducted for the students of the course ‘Image and Video editing Principles’ in order to check for differences in the final VE mark, between the students that participated in the assignment and those who did not. The sample of students was divided into two groups. The first group was comprised of 30 students who completed the assignment and the second group consisted of 27 students who did not complete the assignment. Findings from the t-test indicate that significant differences ( $p < 0.05$ ) exist in the mean scores of the two groups ( $t = 3.289$ ,  $p = 0.002$ ). Students who completed the assignment received higher VE marks ( $M = 6.63$ ) than those who did not pass or take the assignment ( $M = 4.09$ ).

For the course “Graphic Design” in order to test whether there were differences in the VE marks obtained by students who completed the assignment (31 students) and those who did not (20 students) we carried out a Mann-Whitney U test. A t-test was not used for this course since the VE marks did not follow a normal distribution for the two groups and the two groups were not of equal size (nor nearly equal size). The test showed that VE marks for students that performed the in-video quizzes successfully (mean rank = 31.58) were statistically significantly higher than for the students that did not (mean rank = 17.35),  $U = 137$ ,  $z = -3.59$ ,  $p = .000$  ( $p < 0.05$ ).

According to the ICAP framework (Chi and Wylie, 2014), there are 4 different levels of cognitive engagement while learning and there are differences in the learning outcomes depending on the engagement involved. The ICAP hypothesis predicts that as students become more engaged with the learning materials, from passive to active and then to constructive and interactive, their learning will increase.

The levels are the following:

- Passive - simply receiving information, as in watching an educational video
- Active -receiving information but at the same time doing something with the material, such as manipulating the material by carrying out motoric actions (e.g pausing, rewinding) as well as answering quiz questions that are related to video content.
- Constructive -generating some information beyond the information presented in the material.

- Interactive -when students engage with each other through dialogue or collaborative activities.

Since the assignment questions that were related to the video did not require from the students to generate new information we can say that the level of cognitive engagement did not go beyond the “active” level. Thus we can say that in our case we have support that active engagement is better than passive.

But what actually causes this better performance? Is it the higher level of cognitive engagement caused by the video related questions or does it also have to do with the level of behavioural engagement such as the number of video visits or the total viewing time spend by the learners during the assignment?

As we have seen from the graphs in the previous section, the video visits were higher (and also more interactive in terms of rewinding) during the assignment period and it is likely that viewing time also played a role in performance.

In the past we have also used videos for supporting lab classes where various software programs were taught. The topics were taught in class and video was used as support material. Assignments that contributed to the final mark were also set. For those courses we did not observe any correlations (using the Pearson test) between the final marks and indicators such as the total time spend on viewing the videos, or the percentage of the videos covered by the student. From questionnaires it became clear that a number of students who performed well did not rely much on videos since they grasped most of the necessary knowledge from class. However the settings described in this paper were different in the sense that the video related knowledge had to come entirely from viewing the videos and thus we wanted to see if a linear correlation existed between the viewing time and the final VE mark in these particular settings.

To find out if video viewing time is correlated to the final VE marks for the particular settings, the total viewing time was calculated for every student and then a correlation test was conducted using the Pearson’s correlation coefficient

Regarding students that attended the video editing course (57 students), results indicate that there is a significant ( $p=0,001$ ) positive correlation between the time spent by students viewing the video and their final VE mark ( $r=0,435$ ). The significant correlation found could be regarded as moderate ( $0,30 < r < 0,50$ ).

In a similar vein, for the graphics design course (51 observations), a statistically significant ( $p=0,03$ ,  $p < 0,05$ ) moderate positive correlation was found between the video viewing time and the final VE mark ( $r=0,406$ ).

From the two statistical tests we can conclude that for the particular educational settings where the educational video is the only source of knowledge (for answering the video related exam questions), there is a positive association between the total viewing time and the final VE mark.

## 5 Conclusions

The purpose of this paper was to present how open source tools are used to build a video based learning environment where video content is aggregated with interactive elements and content that comes either from the educator or from open web resources. In the heart of the environment lies a module that records learner viewing behaviors and learner interactions with the aggregated elements. The acquired activity data can then be analyzed with data analysis, data mining and visualization techniques in order to understand learner viewing behaviors with respect to various parameters, such as the elements integrated (e.g., quiz questions, table of contents), the type of videos used (e.g., instructional videos, documentaries, lectures), and, the educational settings and learning scenarios in which the video learning activities take place. Some findings obtained from such analysis were presented in this paper. As future work we intend to incorporate more features into the environment (e.g., discussions, collaborative activities), use these features within learning scenarios and conduct further data analysis and mining. Another goal would be to do the necessary work in order to be able to distribute this environment as open source and to integrate into the environment visualizations as well as R and Weka functions, that prove to be useful in analysing video activity data.

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