

Augmenting educational videos with interactive exercises and knowledge testing games

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Abstract—The use of online videos is a common practice today in education and this is evident from the abundance of free online courses that are delivered by universities, educational organizations as well as individual professionals. In most cases, the videos that exist in educational platforms are linear without any scope for interactivity and in cases where there is interactivity this is mainly restricted to in-video quizzes. The aim of this paper is to present ways for going beyond the standard in-video quizzes by augmenting videos with various interactive exercises and games that test learners' knowledge. Furthermore, the paper presents a learning environment built using the concepts explained as well as how this environment was used and evaluated in educational settings. The outcome of the evaluation showed that learners attained positive opinions regarding the interactive environment features and its effectiveness in learning.

Keywords— video based learning, interactive videos, gamification

I. INTRODUCTION

Video is everywhere in education reshaping the way we teach and learn. The delivery of educational videos mainly takes place through MOOC initiatives such as Coursera and edX that offer university level courses in a wide range of disciplines and Khan Academy that delivers short lectures in the form of YouTube videos for a variety of K-12 subjects (e.g. maths, physics, computing etc). A large number of Universities also have their own platforms for hosting recorded lectures. Furthermore there is a great number of educators and other professionals that deliver videos of educational content in known video sharing websites such as YouTube, Vimeo and DailyMotion.

Video is used in various ways in K-12 and higher education. For example it is used as part of the teaching material during class lessons, as support material for after class use, or as a complete substitute for the face to face lecture in distant education settings. Video is also a very useful tool in the application of the pedagogical method "Flipped Classroom" [15][16] where the instructional content is delivered online, rather than in class, and class time is saved for other activities (e.g. discussions, problem solving etc). The significant increase of video use in education as well as its increasing popularity in the perceptions of education professionals is portrayed in consecutive surveys conducted by Kaltura (from 2014-2017)[7], a company that develops video

based solutions for collaboration, communications and marketing.

The forms of videos used in education can take many forms such as recorded lectures, Khan style videos, documentaries, animations and so on. As far as interactivity is concerned the features found in educational videos are mainly limited to specific features such as annotations and in-video quizzes [17][18][1]. In-video quizzes are mainly multiple choice and open ended questions that appear at appropriate times within the video content. In-video quizzes have also been the focus of recent research studies [1][2]. S. Cummins, A. Beresford, & A. Rice research results demonstrated that in-video quizzes were successful in creating an engaging and interactive mode of content delivery.

The aim of this paper is to present ways of enhancing video interactivity and going beyond the standard in-video quizzes. More specifically the paper describes in detail an economical way for augmenting videos with various interactive exercises and games that test the learners' knowledge using free and open source tools. An interactive video based learning environment built using the concepts explained in this paper was used and evaluated in educational settings. More specifically the environment was used in teaching a University course the syllabus of which covers aspects of audiovisual productions amongst other topics.

II. AUGMENTING VIDEOS WITH EXERCISES AND GAMES

In order to develop interactive videos today there are various available options and one of these options is the use of open source HTML 5 players. Examples of such players are MediaElement.js [10], Flowplayer [11] and VideoJs [12]. These HTML 5 players can reproduce videos stored on a web server or can act as wrapper for videos hosted in video sharing web sites such (e.g. YouTube). These players provide an application programming interface (API) and through this API 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 that can be initiated is the retrieval (or storage) of content from (or to) a database and this is the basis for building time based interactive video applications. In our case we use the MediaElement.js and its API functions.

The mechanism for retrieving and storing data from and to a database is depicted in Fig. 1.

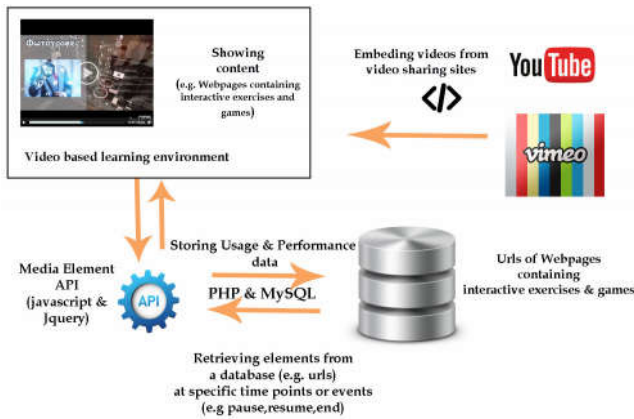


Fig. 1. Retrieval (or storage) of content from (or to) a database.

In our case the data that will be retrieved from the database are links to webpages containing exercises and games. Javascript was used in the front end for dealing with the video API functions and PHP and MySQL were used in the back end. Both exercises and games appear at certain points of the video timeline and are related to the video content preceding the time of their appearance. The webpage urls are stored in a database together with the time points of their appearance and these time points are set by the educator. These entries are then retrieved through the MediaElement API. More specifically the “timeupdate” function is fired several times in a second and through this function we can check the playhead position and the video state (e.g. paused, playing etc).

The web content retrieved at the specified time points normally appears in an iframe next to the video player. This content can be created using various applications. In our case we used HotPotatoes [13] to create interactive exercises and Gdevelop [14] to develop knowledge testing games.

Hot Potatoes is a freeware software suite that includes six applications, enabling one to create interactive multiple-choice, short-answer, jumbled-sentence, crossword, matching/ordering and gap-fill exercises for the World Wide Web. Gdevelop on the other hand is an open source game creation software that is event driven and it does not require programming knowledge in order to create games. The software can produce HTML 5 games and also native games for different platforms. In our case we used both tools to create interactive exercises and games that would appear at certain points of the video in order to test the learners’ knowledge and provide instant feedback on whether the answer is correct or not. Using these tools a gamification of the video learning process also takes place.

According to various theories when interactivity is involved in learning then we have better outcomes in terms of engagement and performance. According to the ICAP framework [3] there are four levels of cognitive engagement that are typically encountered in the learning process and these levels lead to different learning outcomes. More specifically the ICAP hypothesis states that as students move up in the

levels of engagement (passive to active and then to constructive and interactive) the learning outcomes are improving.

The 4 levels in the ICAP framework are the following:

- Passive learning - simply receiving educational information. An example of passive learning is watching an instructional video in a linear fashion and without any interactivity.
- Active learning - receiving information but at the same time doing something with the educational material. An example of active learning is watching a video and at the same time carrying out some activity such as pausing or rewinding the video, or doing something more active such as answering quiz questions that are related to the video content.
- Constructive learning - generating new information beyond the information that already exists in the educational material (e.g. book, video content etc).
- Interactive learning - carrying out discussions and collaborative activities that are related to the educational content (e.g. video content)

By augmenting educational videos with the interactive activities created with Hot Potatoes and Gdevelop we move from passive learning to active learning.

III. ENVIRONMENT INTERFACE AND FUNCTIONALITY

In the produced environment learners are required to perform a registration procedure and after their details are checked for validity by the educator they are granted access and they are permitted to enter the system by entering the username and password given in the registration process.

The environment contains a number of videos and also a number of interactive features presented in some of our previous research work (e.g. [4][5][6]) where we also examined the effect that certain features (e.g. in-video quizzes, content table) have on learner viewing behaviour and their effectiveness in learning. In [5], for example, in-video quizzes (multiple choice & open ended questions) were utilized in a course assignment and the results showed that students who took part in this assignment engaged more with the video material when compared with students who did not participate in the assignment but viewed the video for exam preparation only (without the in-video quizzes). The findings also showed better achievements in the exam for the students who participated in the assignment and actively engaged with the video through the in-video quizzes. The positive effect of in-video quizzes was also recorded in [1] where in-video quizzes were also found to increase student engagement. Furthermore, the students’ perceptions regarding the in-video quiz questions were found to be positive.

In the current research, the video environment was augmented with new interactive features and this was done using Mediaelement.js together with Hotpotatoes and GDevelop. The new environment features were created for the purposes of a lesson called “Image and Video editing Principles” taught in the autumn semester in the Department

of Digital Media and Communication at the Western Macedonia University of Applied Sciences, Greece. Part of the course syllabus concerns audiovisual productions and more specifically the stages that are followed in these productions (pre-production, production and post-production). For this part of the course a student that worked in the audiovisual productions sector produced a 30 minute informative video as part of his dissertation. The video explains in detail the process followed for producing promotional videos. The video also contained interviews with professionals working in the area (script writers, directors, video editing professionals).

The video was augmented with time based exercises created with Hot Potatoes and knowledge testing games created with GDevelop. More specifically Hot Potatoes was used to create fill-in blanks, multiple choice, matching, and crossword puzzle exercises. Thirteen exercises were created in total using Hot Potatoes (e.g. Figures 2,3,4).

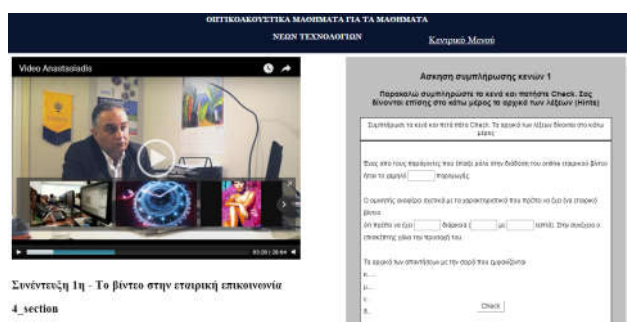


Fig. 2. Fill in the blanks exercise

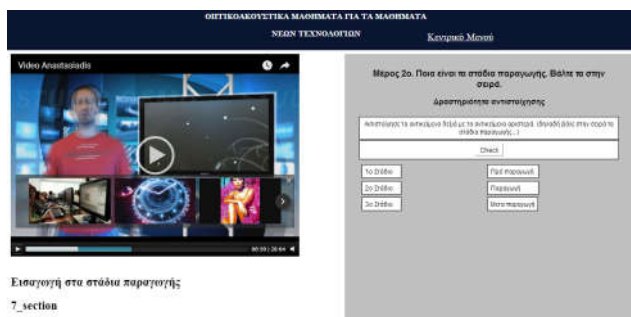


Fig. 3. Matching exercise



Fig. 4. Crossword puzzle

Similarly Gdevelop was used to create three Angry Bird shoot'em up games. In these games a question is shown on the game stage and angry birds with different labels (answers) and appearance are moving along the stage and learners are required to shoot the bird with the right label (e.g. Figures 5 and 6).



Fig. 5. Angry birds shoot up game



Fig. 6. Angry birds shoot up game

The games and exercises appear at certain points of the video (defined by the educator) and next to the video player in an iframe. The video pauses when these points are reached. In every activity (exercise or game) the learners are informed whether their answers are correct or not with appropriate feedback.

A. Exercise and game results

In the described environment the learner scores for each activity are stored in the database. More specifically for the Hot Potatoes exercises this is achieved by modifying the code produced by the software and by calling a PHP program to carry out the insertion of the scores in the database. Similarly with Gdevelop at the end of the game a PHP program is again called in order to insert the score in the database.

For the Hot Potatoes exercises the learner is given the chance to perform the exercise again if the exercise is not completed successfully. This option was not initially present for the Angry Bird games and the games would end after shooting the right or wrong bird. However the option to try again after an unsuccessful attempt was incorporated on the way after taking into account the comments of students that used the environment. If an activity (exercise or game) is completed successfully then this activity does not appear anymore. Instead, in the specific time of the activity a message appears saying that the activity is completed.

The learner can also obtain a detailed report of his/her achievement at any time by clicking at a relevant link at the bottom of the page. This report presents the exercise titles, the exact video time point of each exercise, the score achieved for each exercise as well as the average score obtained from all the exercises. In case where there were more attempts in one exercise (a typical scenario) then the score for the exercise would be the average of all attempts.

B. Video viewing behaviours

Besides learner performance the environment also has the ability to record the learner behaviours if such data is needed for learning analytics purposes. The module that is developed to carry out this task tracks video events triggered by learner actions and changes in the video state and stores this information in an appropriately designed database. The module has been described in detail in our previous research work (i.e. [4][5][6]) and we will also give a short description in this section. The data stored by this module is necessary for understanding in more depth the way that learners use this interactive multimedia environment.

Learners, as already mentioned are asked to perform a login procedure in order to enter the system. All the activity data recorded from that point onwards is associated to the specific user and its user id.

Viewing activity data is stored in three tables, **Sessions**, **Session_videos**, and **Session_events**. A session is initiated on learner login and at that point a unique session id is stored in table Sessions. Videos that are started after that (and within the session interval) are associated with the specific session and are stored in the table Session_videos with a unique video id. Events that take place during the video execution are associated with the video id and stored in table Session_events. Date and time are recorded for all database entries. A session ends when the learner exits the application either by closing the browser window or by logging out.

The events that are specific to the Media Element API and used in the module for tracking learner activity are the following: **loadeddata** - triggered when the video loads in the player; **seeked** - triggered when the video playhead is moved to a new position by the viewer; **play** - triggered when the video starts playing or resumes after a pause; **pause** - triggered when the video is paused either by the viewer or by an event; **ended** - triggered at the end of the video; **volumechange** - triggered when the sound volume is changed; **muted** - triggered when the sound is deactivated. When these events occur a set of properties can be fetched using the API such as the video time (position of the playhead), the current date and time, etc. A complete list of these properties and events can be found in the Media Element web page [10].

The 'timeupdate' event, as already mentioned, is an event that fires few times in every second and it can be used to track the state of the video. This event can also be used to build more events. For example, if at some instance the current video time is higher than the video time recorded a second before, by two seconds or more, then we can safely assume that a jump took place (in our setting we use the threshold of 5 seconds to record a jump).

In our environment we also perform a segmentation of the video into logical content segments that reflect different conceptual topics (e.g. interview with an expert, a video production stage etc). Another way of segmenting the video is through equal time intervals.

The events that are created using the 'timeupdate' event are the following: a) section enter, b) time section enter, and, c) jump event. 'Section enter' event is called when the play head enters one of the logical sections. The 'time section enter', event is triggered when the playhead reaches one of the time intervals either during sequential video execution or after a jump. The time interval is set by the educator and stored in a general parameters database table. For the specific video the interval was two minutes meaning that the 30 minute video was split into 15 intervals.

Finally, the jump events are called when a jump takes place and two entries are stored in the database (with two different codes). The first entry indicates the video time point of where the playhead was before the jump, and the other entry the video time point after the jump.

The section enter events together with the events pause, play and jump can give us a good estimate of the video intervals viewed by learners and when these intervals were viewed. One advantage of logging viewing activity into a database is that many things can be quickly calculated by using the SQL query language (e.g., number of jumps and logical sections visited, time sections visited etc).

IV. THE USE OF THE SYSTEM IN EDUCATIONAL SETTINGS

The environment that was described in detail in the previous section was used in the winter semester 2017 in the department of Digital Media and Communication of the Western Macedonia University of Applied Sciences, Greece. The environment consisted of a video (related to audiovisual productions), and 16 activities: 5 fill in the blanks, 3 matching, 3 multiple choice, 2 crossword puzzle, and 3 angry bird shoot'em up games. The environment was used for the completion of an optional assignment that would give students a bonus which would count towards their final mark. More specifically students that wanted to take part in the optional assignment were split in groups of 17-20 and were asked to come to a specific lab with their own set of headphones.

A total of 92 students (43 male & 49 female) turned up in order to complete the assignment. These students were told that 3 things would count towards their mark: their participation 30%, the average overall score in the time-based activities 30%, and the mark obtained in a post test 40%.

The students were asked to perform the system registration by entering some personal details as well as their student id and a password. Then, students were given access and after logging in they encountered a webpage with four links. A link to a pre-test, a link to the video environment, a link to a post-test and a link to an evaluation questionnaire. The questionnaires were created with Google Forms and they were activated at appropriate times during the process.

The students were asked first to take a pretest in order to identify their initial knowledge regarding the aspects covered in the video. After completing the pre-test the students were asked to view the video and complete the video related activities. After completing the video the students were asked to take the post-test and, finally, to evaluate aspects of the environment by completing the last questionnaire. A number of questions in the post test were the same as in the pre-test. None of the questions in the pre-test or the post-test were addressing the same issues as the in-video activities.

Regarding the pre-test the outcomes showed that the students were able to answer some questions with success. However this success was due to the fact that these questions could be answered based on logical assumptions. On the other hand in questions where this was not possible the large majority of students were not able to give correct answers and thus we assume that the students possessed very little knowledge concerning the concepts presented in the video.

During the assignment a number of students showed enthusiasm and completed the assignment without major difficulties while others seemed to get tired due to the video duration and the high number of activities. We knew that the number of activities was indeed high and if we were targeting solely on student satisfaction then we would have to include a smaller number of activities. On the other hand we also wanted to carry out an assignment which would give a certain bonus to the students and in this sense it was meaningful to raise the level of difficulty. Students who took part in the assignment had an 1 hour and 30 minutes limit to complete the assignment and this was sufficient for all students to complete the assignment with ease.

Thirteen questions were the same in the pre-test and the post-test and for these questions the results showed an average of 22% percent increase for the questions answered successfully (3,9 minimum and 59,6 maximum). As mentioned, a number of questions could be answered based on logical assumptions and for these questions the students performed well on the pre-test and thus the overall increase was small. For the rest of the questions though the increase was much larger. Of course, this result does not reveal whether this increase is attributed to the active way of learning and in order to compare the learning outcomes between active video viewing to passive video viewing we plan to carry out a similar experiment (same conditions and sample size) in which students would be asked to complete the same assignment but without the in-video interactive activities.

The evaluation questionnaire showed that students evaluated the environment positively. In a 1-5 scale 19% gave score 3, 39,1% score 4 and 41,3% score 5. The results are given in Figure 7.

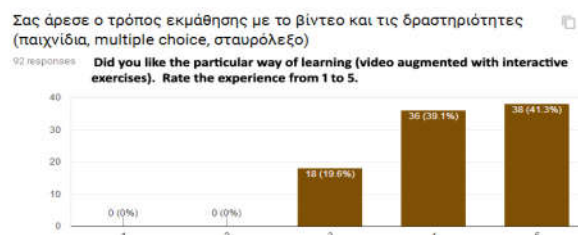


Fig. 7. Evaluating the environment

The results on the overall level of difficulty were also satisfactory. In a 1-5 scale where 5 was “high difficulty” most students rated the level of difficulty of the activities as average (e.g. 44,6% gave score 3) or below average (35,9% gave score 2 and 10,9% score 1).

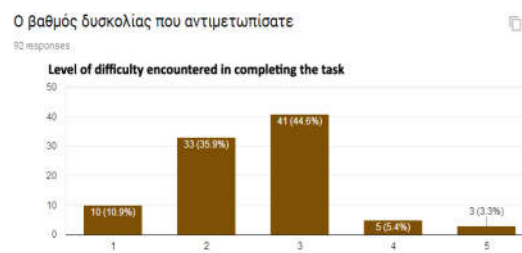


Fig. 8. Rating the level of difficulty

Furthermore 79,3% of the students in a question asking if they think that they would be able to perform as good in the post-test if the video did not contain interactive activities they answered that they wouldn't. The validity of these perceptions however remain to be tested.

When students were asked to evaluate the activities they evaluated some better than others. For example, the crossword puzzles were high in their preferences while the angry bird shoot'em up games and the fill in the blanks exercises were evaluated lower especially amongst the first groups that completed the assignment.

This was a surprising result especially for the shoot'em up games. By examining the comments given in the evaluation questionnaire and through talks with the students after the experiment and during lecture hours it became evident that the low evaluation score for the games was attributed to the design of these activities as well as the required difficulty in giving the correct answers (shooting the correct birds). For example the angry bird games did not give students a second chance in case of failure. Also the questions presented in two of the three games were according to the students hard to answer and this was a reason for giving a low evaluation score. Some students also said that they evaluated the angry birds activity low for other reasons such as variations in the volume of the sound during the activity (a clapping sound that occurred after a successful attempt was louder than the video narration and music audio). However the majority of students agreed that the angry bird games were a very good and entertaining feature and that the games should remain in the environment if the issues mentioned were dealt with.

As far as the fill in the blanks exercises are concerned some of these were not designed properly and did not count a slightly different answer (the same word in plural, in capital letters, accented in a different letter, etc). This was again a reason for giving a low evaluation score. Also, few students had dyslexia although we think that this did not pose problems as these students were provided with the necessary assistance by the educator who was in the lab organizing and inspecting the whole procedure.

When the reported deficiencies were corrected then the student satisfaction showed an increase and these activities were evaluated higher. The final results are depicted in Figure 9.

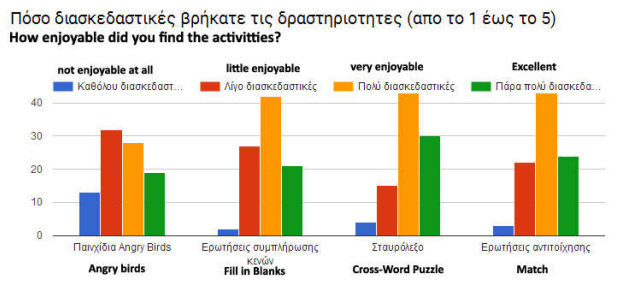


Fig. 9. Evaluating the activities

V. CONCLUSIONS

The purpose of this paper was to present a video based learning environment where video is augmented with interactive exercises and knowledge testing games. Videos today are mainly linear and their viewing is passive. In cases where we encounter interactive features these are mostly confined to in-video quizzes. This paper attempts to introduce ways for going beyond the standard in-video quizzes. The solution presented is cost efficient in the sense that it makes use of free and open source technologies. The interactive exercises were built using Hot Potatoes and the knowledge testing games using GDevelop. Mediaelement.js (an open source HTML 5 video player) was used for synchronizing the video content with the activities. The learning environment was used in educational settings and more specifically for teaching part of a course syllabus related to audio visual productions. Students evaluated the environment positively and their comments were valuable in improving the environment. According to their perceptions if the video was not augmented with the interactive activities it would not be as effective in learning. The validity of these perceptions remain to be tested and as future work we intend to carry out the same experiment (same sample size and conditions) using plain video in order to investigate differences in the students' acquired knowledge as well as satisfaction. As future work we also intend to investigate learner behaviours and more specifically the way learners view and interact with the video

and the in-video activities presented in this paper. This task will be carried out by analyzing the learner usage data.

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