Collecting and Making Sense of Video Learning Analytics

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***Abstract*— Teachers have employed online video as an element of their instructional media portfolio, alongside with books, slides, notes, etc. In comparison to other instructional media, online video affords more opportunities for recording of student navigation on a video lecture. Video analytics might provide insights into student learning performance and inform the improvement of teaching tactics. Nevertheless, those analytics are not accessible to learning stakeholders, such as researchers and educators, mainly because online video platforms do not share broadly the interactions of the users with their systems. As a remedy, we have designed an open-access video analytics system and employed it in a video-assisted course. In this paper, we present a longitudinal study, which provides valuable insights through the lens of the collected video analytics. In particular, we collected and analyzed students' video navigation, learning performance, and attitudes, and we provide the lessons learned for further development and refinement of video-assisted courses and practices.**

Keywords- User Interactions, Learning Analytics, Video Lecture, Open Learning System.

I. INTRODUCTION

The use of video for learning has become widely employed in the past years, video-based learning techniques and practices are applied with a variety of ways, like flipped classroom and video based MOOCs. Video learning analytics can allow researchers and educators to understand and improve the effectiveness of the video-based learning tools and practices.

It is essential that students are actively involved in the learning process; however, content is still often taught via the lecture approach where students are placed in the role of passive learners. With the many technologies available today, a dilemma facing many instructors is how we can take full advantage of the instructional media to provide more effective student-centered instruction.

Video lectures have given rise to flipped (or inverted) classrooms. This specific type of blended-learning classroom utilizes technology, such as video, to move lectures outside the classroom, thereby giving students and teachers time for active learning in the classroom [1]. At the same time, recent technical and infrastructural developments [1] make the potential of video based learning ripe for exploration. Capturing and sharing learners' interactions in emerging learning technologies can clearly provide scholars and educators with valuable information.

With the widespread adoption of online video lecture communities, such as Khan Academy[1], it has become critical to conduct research to understand how students learn via video lectures. A significant body of related research into the impact of video lectures has been made [2]. However, the majority of previous efforts have been mainly focused on: a *sporadic or one time* use of video lectures in an educational context [3] and/or the investigation of only a *single factor* like student performance [4] [5].

Researchers have recently begun to study student interactions with video-based learning in order to provide educators with valuable information about students (e.g., Khan Academy, Coursera). However, the capture and analysis of this information is still in an embryotic research stage. The experimental instrumentation and methodology described herein will significantly enhance this critical research effort.

In the next section, the related work and the focus of this research are outlined; the third section presents the system and its validation; the fourth section presents the methodology of the study employed in this article; and the fifth section discusses the empirical results derived, while the last section suggests the implications and limitations and makes recommendations for future research.

II. RELATED WORK

Video lectures have emerged as one of the premier Open Educational Resource [6]. Many instructors in higher education are implementing video lectures in a variety of ways, such as broadcasting lectures in distance education [7], delivering recordings of in-class lectures with face-to-face meetings for review purposes [8] [9], and delivering lecture recordings before class to conserve class time and flipping the day for hands-on activities [10]. Other uses include showing videos that demonstrate course topics [11] [12], and providing supplementary video learning materials for self-study [13]. Researchers have delineated the educational advantages and disadvantages of video lectures [8] [14] [15]. However, previous efforts have been mainly focused on the sporadic use of video lectures and the investigation of a specific feature.

Students using video lectures enjoy control over when and where they learn [16], what they need to learn [17], and the pace of their learning [18]. In addition, for those students

[1] http://www.khanacademy.org/

using video lectures, improvements in study habits have been observed, including a fostering of independence [19], an increase in self-reflection [20], the heightening of efficient test preparation [21], and the practice of reviewing of material more regularly [22]. Learner control in well-designed video lectures can be beneficial in terms of convenience and supplemental practice [23]. Students use videos with many different patterns [24] and report a variety of reasons for using video lectures. Van Zanten et al. [25] indicate that students widely use video lectures for revision and review purposes during exam preparation.

When video lectures are available, students typically use them. For instance, Harley et al. [9] found that almost all students (95–97%) viewed video lecture at least once. Our **motivation** for this work is based on emerging developments. First, the use of videos for learning has become widely employed in recent years [2]. Video-based technological tools have been developed, and many educational institutions and digital libraries have incorporated video into their instructional media portfolio. Second, despite the growing number and variety of video lectures available, there is limited understanding of the nature and quality of their effectiveness, in terms of how students use and learn from video lectures. Specifically, limited research currently exists regarding guidelines for the use of video lectures and the design of pedagogical systems for their use.

In summary, students are using video lectures for a variety of subjective and objective benefits and students perceive the video technology as a practical learning resource. *However, some aspects remain unexplored: are students viewing the entire video lecture; what segments of the video lecture do students select to view, and why; how many times do students view any given video lecture; and what video applications are more attractive or engaging, individually or in groups. To address these critical issues, this study will try to provide a first step towards the understanding of students' multi-faceted interactions with video lectures.*

III. Methodology

A. Sampling and Procedures

In our effort to investigate students' viewing patterns and interests we conducted a small-scale longitudinal study. The sample of the study consisted of science majors who selected to enroll in an undergraduate reading course. The instructors developed a video lectures syllabus to assist students' before-the-class preparation.

In our study eleven freshmen (18-20 years old, 6 females and 5 males) were participated. All students were Science majors and selected to participate to the course. The course lasted approximately 10 weeks, and enhanced with video lecturers to assist students during a 7-week period (in the first 2 weeks and the last one we did not use video lectures). For the distribution and management of the video lectures, we employed an open-access video analytics system.

B. The video analytics system

In this section, we present the video analytics system. We used the Google App Engine (GAE) cloud platform and the YouTube Player API to develop the system. The system has several advantages in comparison to stand-alone applications. Users do not need to go through an installation process (http://socialskip.appspot.com/); rather, they just have to visit the link. If there is an updated version, they simply have to refresh the page. In addition, system's architecture is modular and allows re-use of the components. Web developers might employ the open-source application logic (https://code.google.com/p/socialskip/), in order to develop new or custom features.

Practically, every user with a Google account can be a researcher. To do so, one has only to sign in to the service (http://socialskip.appspot.com/), connect the selected video from YouTube, configure the video player buttons or slider, and copy-paste the address of the online survey he/she wants to use (see Figure 1, up). By taking these few steps, a respective video assessment (or experiment) URL is created (Figure 1, down).

Then the instructor/researcher can share this URL with his students, or post it in course's blog/wiki webpage. Hence, this video analytics system simplifies and makes feasible for everyone to incorporate video assessments on his/her syllabus.

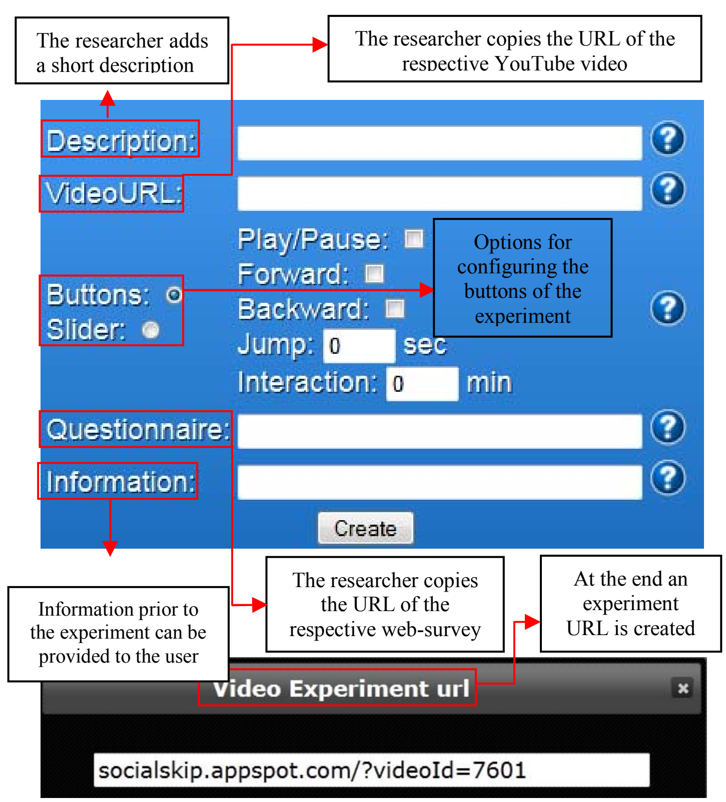

Figure 1. Experiment creation window (up); video experiment url (down)

This URL contains the learner/user-interface of the video analytics system (Figure 2). The video analytics system employs the utilities selected by the researcher buttons.

Optionally, learners can use a personal Google account in order to sign in and watch the uploaded videos. In this way, we can accomplish user authentication and avoid the necessity of implementing a user account system just for the application. Thus, users' interactions are recorded and stored according to their Gmail addresses. Each time a user signs in the web-video player application, a new log is created. Whenever a button is pressed, an abbreviation of the button's name and the time it occurred are stored.

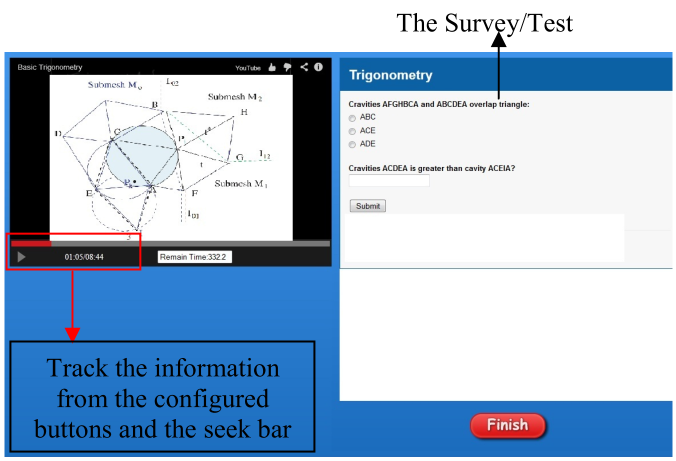

Figure 2. The interface of the system has familiar buttons, seek bar, as well as questionnaire functionality

When the researcher terminates the specific experiment, he can visit the configuration/management area of his experiment; and 1) download all the collected data, 2) visualize the activity of each video, 3) configure the experiment, and, thereafter 4) delete it (Figure 3). These options give the researcher the flexibility to test different activities or functionalities on different groups of students, analyze the results, and develop useful conclusions about how students use and learn from video-based learning systems.

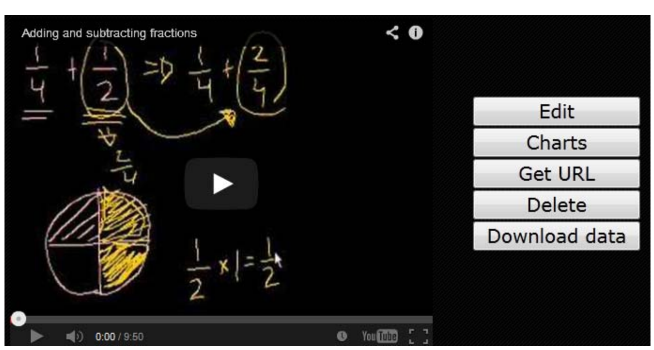

Figure 3. The interface of researcher's configuration/management area

Concerning the visualization capabilities of the system, we have opted to use time series to represent learner activity. A time series is a sequence of data points, measured typically at successive points in time and spaced at uniform time intervals. Time series analysis provides methods for analyzing time series data, in order to extract meaningful statistics and other characteristics of the data [26]. Figure 4 exhibits an example of the visualization of the learner activity via time series technique. We provide two types of time series: The first one (important) depicts only the replay user interactions, which have been found to be the most representative for user activity [27]. The second one (summary) depicts of all user interactions (pause, play, seek), In addition to the preselected visualizations of time series, the user of the system has the option to download the data-set locally in a Comma Separated Values (CSV) format. Then, the researcher might import the CSV file into a visualization program of preference (e.g., R) for more advanced analysis and graphics.

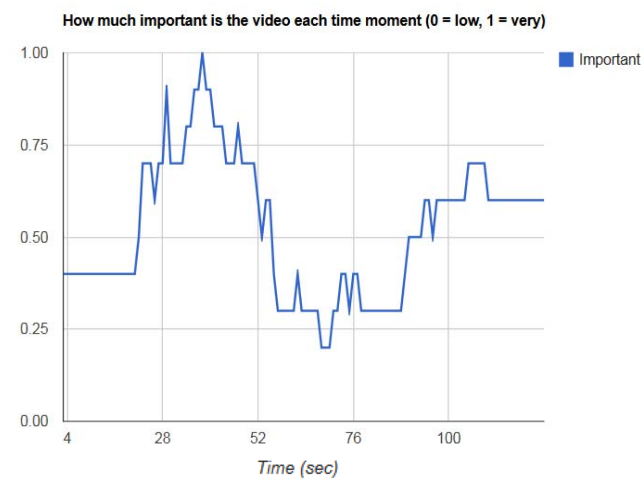

Figure 4. Exemplar visualization of learners' viewing activity

C. Measures

On every video lecture we incorporated a respective video assessment. Each assessment consisted of questions that could be answered based on the content of the video lecture. The video-assessment integration provided students' with higher cognitive level learning and urged them to navigate and have deeper engagement with the video lecture.

Except the data collected via the assessment and the video learning analytics system (students' navigation). We integrated a short questionnaire at the first (pre) and the last (post) video assessment. The questionnaire included measures of 1) easy to use, 2) control, 3) intention to use and 4) usefulness of the video-assisted course. Table 1 lists the operational definitions and the number of items (questions) of each of the constructs (measures), as well as the source from which the measures were adopted. We employed a 7-point Likert scale anchored from 2 ("completely disagree") to 7 ("completely agree").

TABLE I. THE MEASURES AND ITS DEFINITIONS

Construct	Definition	# of quest.	Source
Easy to Use	The degree to which an individual believes that participating in a video-assisted course is easy for him/her.	3	[28]
Control	The degree to which a person perceives how easy or difficult it would be to perform an operation during a video-assisted course.	2	[29]
Usefulness	The degree to which an individual believes that participating in a video-assisted course is useful for him/her.	3	[28]
Intention to Participate	The degree of students' intention to participate in similar video-assisted courses in the future.	3	[30]

In summary, the data collection of our study can be divided in three basic categories:

a) *Students' video navigation (collected via video learning analytics system).*

b) *Students' learning performance/score (collected via the integrated with the system assessments) and,*

c) *Students' attitudes for the video-assisted course (collected via the integrated with the system questionnaires).*

D. Data Analysis

As aforementioned, the collected data consisted of three different types. As such an appropriate data analysis was used for each different set of data. As per students' video navigation, we used the aggregated time series visualization, in order to identify the peaks of students' video views (global maximums). Afterwards, we investigate any potential relation of students' views and learning performance in the respective video based assessments. At the end of our analysis, we watch the respective global peak of each video and we attempt to give an explanation of why those segments are so important (many repeated views) for students.

Regarding students' learning performance, we captured all students' assessments scores and mapped them in a week-by-week diagram. In this way we are able to address students' progress throughout the video-assisted course. In addition, we divided video assignments in those with low and high score (based on students' learning performance scores); afterwards we tried to understand any difference in students' video navigation between them.

In order to identify any potential shift on students' attitudes during the video-assisted course, we used t-tests between the pre- and the post-results of their attitudes as exhibited from the questionnaires. Hence, we were able not only to capture students' attitudes for the video-assisted course, but alto to identify and potential shift during the course.

IV. RESEARCH FINDINGS

During the exploration of the students' activity graphs, we reach to the conclusion that there is a positive relation among students' learning performance scores and their views on the respective video assessment. As we can see from Figure 5, in videos where students' exhibited low score they had less repeated views as exhibited from the low level of importance (most of the time was < 0.5). On the other hand, in videos where students' exhibited high score (e.g., fig. 5, right) they had many repeated views, as exhibited from the high level of importance (almost always > 0.5). Hence, we can indicate that video lecture production (which results different video navigations) effects students' learning performance; and that "attractive" videos result better learning outcomes.

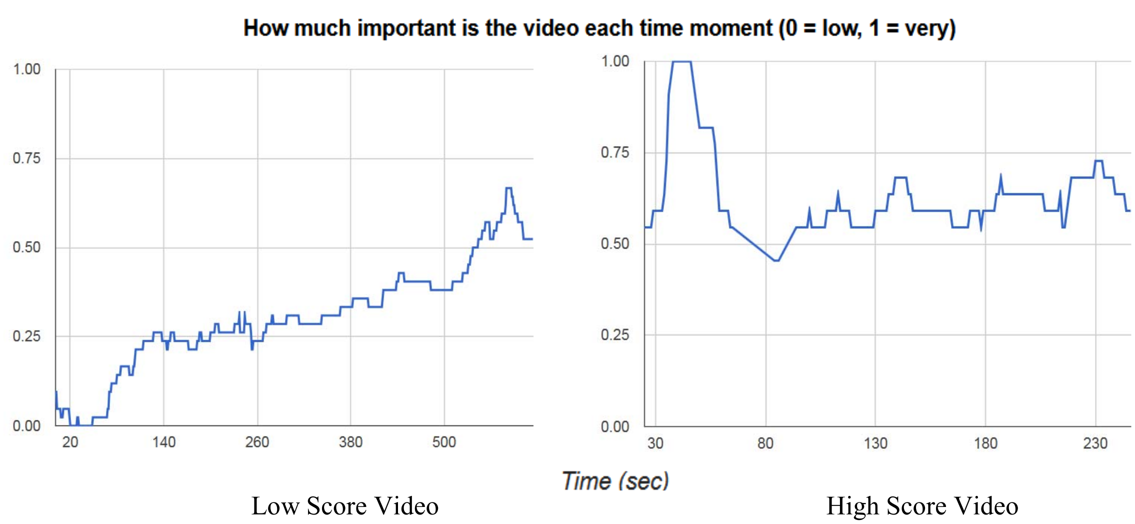

Figure 5. The visualization of students' activity in a low (left) and high (right) score videos

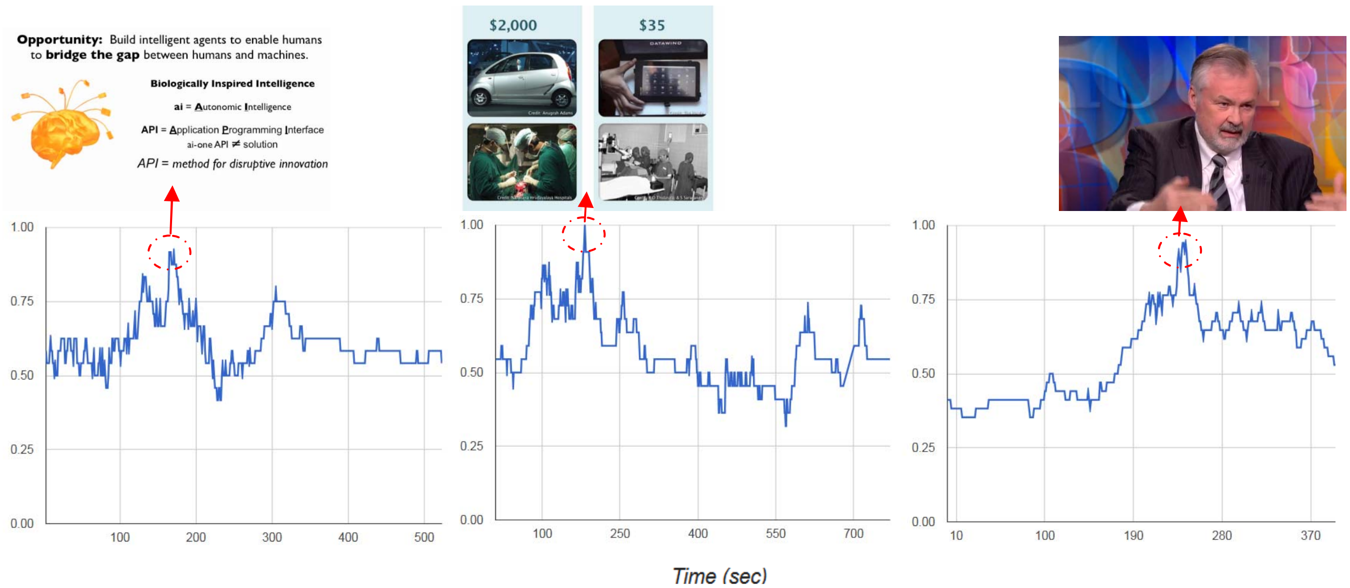

Figure 6. Students' activity graphs, identifying the extremely important (global maximums) video segments

Trying to identify the "attractive" (many views) video segments, we found that activity peaks (global-local maximums) where identified near to the video segments with the information related to the answers of the assessment and to the segments where the presenter was giving the solution of the respective problem. So the main quality of the "attractive" video segments was the rich and useful amount of the transferred information and knowledge.

However, it was still unclear why students found some video segments extremely important (global maximums). In order to be able to provide an explanation about this issue, we went through the seven video activity graphs and we located the global maximums (see figure 6), then we reviewed those segments in correspondence with the rest of the video and the local maximums.

TABLE II. BLOOMS TAXONOMY, REVISED [31]

Level of cognition /thinking	*Action words*
Remembering: can the student recall or remember the information?	Define, duplicate, list memorize, recall, repeat, reproduce, state
Understanding: can the student explain ideas or concepts?	Describe, discuss, explain, identify, locate, recognize, repost, select, translate, paraphrase
Applying: can the student use the information in a new way?	Choose, demonstrate, dramatize, employ, illustrate, interpret, operate, schedule, sketch, solve, use, write
Analyzing: can the student distinguish between the different parts?	Compare, contrast, criticize, discriminate, distinguish, examine, experiment, question, test
Evaluating: can the student justify a stand or decision?	Appraise, argue, defend, judge, select, support, value, evaluate
Creating: can the student create a new product of point of view?	Assemble, construct, create, design, develop, formulate, write

By doing this explorative investigation, we reach into the conclusion that there is a correspondence between the level of cognition/thinking each question required and the size of the respective peak. Using the revised taxonomy of Bloom (see Table 2) [31] we ended up that all the global maximums where identified in questions where higher order thinking/cognitive skills was required.

At the end of the course, we collected students' assessment scores (Fig 7), we noticed that students had the lowest score on the first assessment and the highest score on the last one. In addition, the last assessment has the smaller standard deviation value. Based on the results we can indicate that after the first three video assessments, student exhibit better and more robust (lower standard deviation) scores. Given that all the video assessments had the same difficulty, since always the answers were inside the video and were presented with similar way; we can assume that the video assisted process became more familiar after the third week and students' adjusted their studying with it. In addition, the fact that the standard deviations minimized, allow us to support that low performers benefited more, this is also in alignment with instructors' notes and comments.

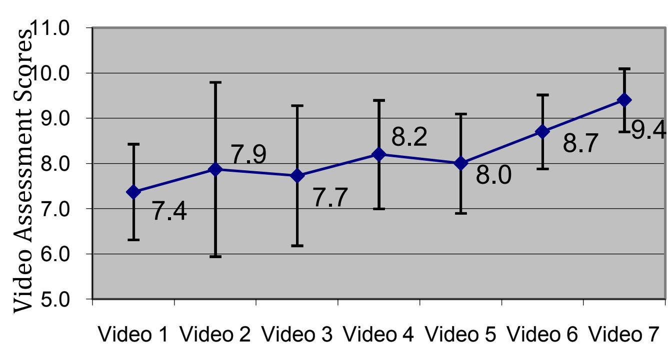

Figure 7. Students' week by week video assesments scores

Regarding students' attitudes with the video-assisted course, we used an attitudinal questionnaire to assess them (table 1). Students expressed high Control and Usefulness (6.5/7) during the video enhancement. Additionally, they expressed slightly lower, but still very high level on the Easy to Use (6.27/7) of the video enhancement and their Intention to Use (6.35/7) it in the future. High levels of these constructs indicate positive views concerning usability, control and usefulness regarding the video-assisted course.

To examine any potential shift of students' attitudes during the video-assisted course, we used t-tests between the pre- and the post-scores of the attitudinal questionnaires. As we can see from figure 8 students' responses were at very high levels, in both the pre and the post questionnaires. Performing a t-test between the pre- and post-scores of the questionnaire, the results showed no significant difference in all of our constructs, Easy to Use $t(20) = 0.59$, $p > .05$; Control $t(20) = -0.36$, $p > .05$; Intention to Use $t(20) = 0.18$, $p > .05$; Usefulness $t(20) = 1.09$, $p > .05$. As a consequence, there was no shift on students' attitudes after the 7-week period, hence it can be resulted that the video-assisted course is considered stably useful, usable and well received from the students.

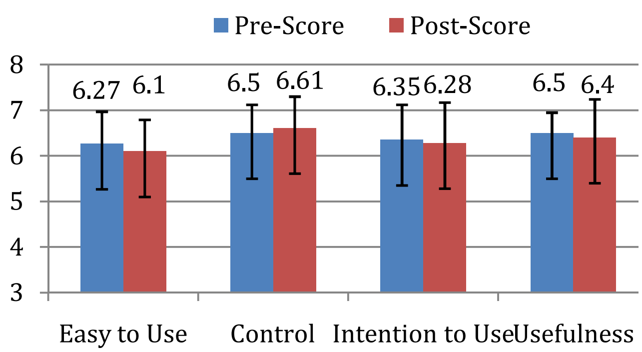

Figure 8. The interface of researcher's configuration/management area

V. DISCUSSION AND CONCLUSION

As millions of learners enjoy video streaming from different platforms (Coursera, Khan Academy, EdX, Udacity, Iversity, Futurelearn) on a diverse number of terminals (TV, desktop, smart phone, tablet), they create billions of simple interactions. This amount of data might be converted into useful information for the benefit of all video learners.

As the practice of learners' watching videos on web-based systems increases, more and more interactions are going to be gathered. Dynamic analysis of this wealth of data will allow us to better understand learner experience. In addition, the combination of richer user profiles and content metadata will provide opportunities for adding value to data obtained from video- based learning.

Although many corporations and academic institutions are making lecture videos and seminars available online, there have been few and scattered research efforts (i.e., [14]) to understand and leverage actual learner experience. Moreover, Kim et al [32] have provided analytics for million of interactions, which have been produced by thousands of MOOC students. Nevertheless, video analytics in controlled conditions provide more than just loads of video interaction data and allows us to make more interpretations, between group comparisons and investigating hybrid learning settings [33-36]. To the best of our knowledge, there are no efforts using diverse data like interactions with the system, students' performance and attitudes, in order to triangulate them and derive valuable information about how students use and ultimately learn via video systems.

In this paper, we presented a video learning analytics system and the first results of the captured data. The system is open source, web-based, and can be used by anyone who wants to design his own experimental design and perform experiments on student learning. The open-source video learning analytics system is easy to use, may be applied to any viewer, and easily incorporates any video lectures from YouTube. The system is available for further improvement and experimentation.

In our study, we investigated students' video navigation and we explained how video production affects students' learning performance in a video-assisted course. In addition, we indicated the correspondence between the level of cognition/thinking each video segment requires and the size of the respective student activity peak. Last but not least, we exhibited students' progress throughout the video-assisted course and we examined students' attitudes regarding easiness, usability, usefulness and acceptance of the course.

We want to emphasize that our findings are clearly preliminary with inevitably limitations. One important limitation is the small scale of the study (11 students), however, capturing and analyzing the experiences of eleven students through a long time of period, allow us to understand how students' use the respective materials; in addition by collecting repeated interactions the limitation of the small sample size was minimized. Our future research will concentrate on further refinement of the proposed framework by applying and evaluating it on larger scale classes. This study can provide a springboard for other scholars and practitioners to further examine the efficacy of video assignments and in particular of this specific tool. In particular, for those interested in using the flipped classroom approaches, this is an established flexible tool that can be used and adapted to meet their needs.

Our future work will focus on collecting and triangulating analytics from different sources. By taking into account learners' interactions and much other data—such as students' demographic characteristics (gender, ethnicity, English-language skills, prior background knowledge, their success rate in each section, their emotional states, the speed at which they submit their answers, which video lectures seemed to help which students best in which sections, etc.) — new avenues for significant research will open. Captured data can feed powerful algorithms and create seemingly personalized feedback. Future work will help to collect diverse data (i.e., success rate, emotional states), which will allow the community to consider the challenges for developing more personalized and effective video learning systems. These advancements will lead us to several earlier interventions (e.g., to prevent drop-out), or to adaptive services and curricula.

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