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Design Solutions for Interactive Multi-video Multimedia Learning Objects

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Abstract. The increasing popularity of distance education courses, including Massive Open Online Courses (MOOCs), creates a demand for the production of quality video-based educational material. In order to reduce the costs involved in the production of video lectures, several researchers have investigated alternatives for capture and access systems which automatically capture lecture contents to generate corresponding video lectures. We also developed a system for this purpose; however our system generates Interactive Multimedia Learning Objects (iMLO) instead of a traditional (linear) video lecture. The iMLO's features and its interface are important issues for the development of the capture and access system. Interface aspects, such as which are proper ways to present content for users and which navigation facilities are more useful, are distinctive requirements and may impact the user experience. In this paper we present a novel design for the iMLOs which results from an evolution process supported by feedbacks from the main stakeholders: students and lecturers. The feedbacks have been acquired by analyzing the interaction of students with the iMLOs in real scenarios. Based on these feedbacks, we have identified several design implications. We present the proposed interfaces and proof-of-concepts implementations and report lessons learned during the development of the final design solution, which can guide other designers in the conception of new iMLOs. The whole process is documented by means of Design Rationale.

Keywords: Multimedia learning object · Design solution · Design rationale · Capture and access

1 Introduction

Although recording lectures is a common practice in many universities, the production of quality video lectures demands a high operational cost (cameraman, video director, editors and other audiovisual professionals). To reduce the operational cost, many tools for automatic lecture's capture were developed ([2, 4, 7, 11]). However, the majority of the capture tools only records video/audio streams and generates, as a result, a single video/audio stream, as a video lecture or a podcast.

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The classroom itself can be viewed as a rich multimedia environment where audiovisual information is combined with annotating activities [1]. Furthermore, the context of the class (e.g. the slide that is being presented, what the lecturer is saying, where he is looking, etc.) and how the different audiovisual contents relate to each other are also important. Such classroom experience and context are usually lost in a captured lecture. We developed a system to capture and retrieve lectures that aims to minimize such loss. Moreover, instead of a single video stream, the system produces an interactive multivideo iMLO that is made available for the students. From the iMLO, the lecture may be reconstituted and explored in dimensions not achievable in the classroom. The student may be able, for example, to get multiple synchronized audiovisual content that includes the slide presentation, the whiteboard content, video stream with focus on the lecturer, among others. The student has the option to choose what content is more important to be exhibited in full screen and may also perform semantic browsing using points of interest like slides transitions, spoken keywords, etc.

The set of features offered by the iMLO and its interface are key issues in the system developed. In this paper we present a design solution for iMLO which has undergone an evolution process supported by feedbacks from the main stakeholders: students and professors. The feedbacks have been acquired by analyzing the log of students' interactions with the iMLO and from case studies carried out in real scenarios. Based on these feedbacks, several interface elements were added to iMLO and evaluated. We report the design evolution for the iMLO, starting with a mockup interface, passing through some proof-of-concept implementations until reaching the final design solution. Thanks to experience of designing the iMLO, we are able to report some learned lessons which may guide other designers in the development of innovative learning objects. The interface evolution process is documented by means of the Design Rationale technique [8].

In the next sections we present other iMLOs' design solutions, a brief description of the system developed, the case studies carried out, the interface design evolution and learned lessons. We finish with conclusions and future work.

2 Related Work

In the work of Liu *et al.* [9], the iMLO is compound of a single video stream and a set of slides that are not synchronized with the video. Students do not have autonomy to choose the camera that gives them the best vie. Moreover, they cannot navigate by points of interest, as allowed in the iMLO generated by our system.

ClassX is a tool designed for online lecture delivery [7]. A live lecture is captured by a high definition camera split in several virtual standard resolution cameras. By using tracking techniques, the most appropriated virtual camera for a given moment is chosen. Students may choose a different stream from another virtual camera or even the original high definition stream. A synchronized slide presentation is offered.

REPLAY [12] offers similar features to the aforementioned systems. In addition it uses computer vision to recognize written words, and employs MPEG-7 to index the videos. Although REPLAY allows more navigation alternatives than the previous systems, it does not offer spatial navigation facilities.

Other authors report iMLOs with more features ([2–5]), however, the authors did not consider issues related to interface.

3 Capture and Access System

In this section we present a brief description of the system for capturing lecture-style presentations. A more detailed discussion can be found elsewhere [14].

Figure 1 depicts an overview of tools and components that compound the system. A lecturer goes to an Intrumentalized Classroom where he or she delivers a lecture. The instrumentalized classroom contains physical devices, such as video cameras, microphones, electronic whiteboard, slide projector, etc. Computers connected to the physical devices capture all data and store them as video and audio streams. Our system allows to lecturer split presentation into modules. This is useful to better organize the content of lecture. It also allows the lecturer to take breaks during the recording process and the students to navigate in the modules of the iMLO.

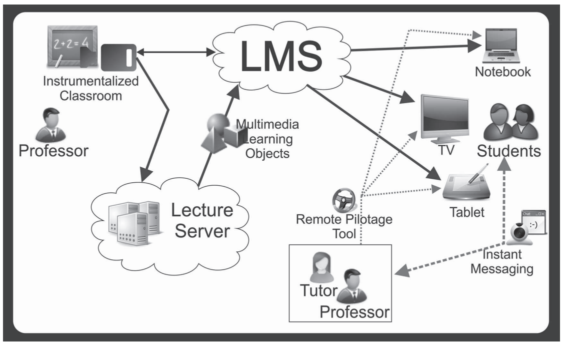


Fig. 1. System overview

When capture process is finished, captured streams are sent to the *Lecture Server*, where they will be analyzed and engineered in an iMLO. By using computational vision techniques, we extract contextual information from the streams, such as a slide transition or when the professor interacts with an electronic whiteboard. We named this contextual information as *Points of Interest* and they are used to provide semantic browsing on the iMLO. By combining the video streams with the contextual information, an interactive multi-video multimedia learning object is generated. This iMLO is stored on the Web and can be integrated with a Learning Managing System (LMS).

The iMLOs are built using Nested Context Language (NCL), a language for authory of hypermedia documents. NCL also support Lua scripts to implement features that are beyond the media synchronization domain. Since NCL is a standard for iDTV and IPTV [6], the iMLO can be presented at compatible set-top-boxes (STB). Moreover, they can be presented in HTML5-compatible browser thanks to WebNCL [10].

4 Case Studies

4.1 Pilot

This first pilot case study used an iMLO generated with the interface of the first proof-of-concept (see Fig. 5(a)). The iMLO was presented to 10 students and 3 professors which had the opportunity of interacting with the iMLO for how long they wished. Afterwards, in an informal interview, we asked them to evaluate the interface. Feedback pointed out some enhancements on the interface and missing features like the play/pause and stop buttons. Some users did not notice the possibility to view a video in full screen. Users missed information about how long is the iMLO and the playback current time. They also reported that navigation controls was taking too much space in the iMLO interface.

4.2 Students in a Real Scenario A

We captured an educational presentation for an Analyze and Design of Algorithms course. The resulting iMLO (see Fig. 5(b)) had duration of 49 min and was divided into 3 modules. The iMLO had three video streams: a camera focused in the traditional whiteboard, slide projector's output and a wide-shot camera. Users could navigate by modules, closes, slides transitions and traditional whiteboard interaction. We logged the interactions performed by the students. Sixteen students interacted with the iMLO for more than 4 min (data from students that interacted less than 4 min were ignored). Students were from presential modality of Computer Science and Computer Engineering undergraduate courses. Through analyze of interaction data, we figured out that students almost did not choose the wide-shot camera as the main video during playback. Moreover, in an informal interview, students said that missed the navigation by time slider.

4.3 Students in a Real Scenario B

One professor captured a problem solving session for a Computer Organization course in which he solved a total of 15 exercises. The presentation was organized into 12 modules, performing a total of 1 h and 18 min of content. Figure 5(c) depicts the iMLO generated from the presentation. There are four video streams: slide projector output; camera focused on the conventional whiteboard; camera focused on the slide projection; and wide-shot camera. Although the generation process allows orchestration of videos (e.g., the automatic selection of which video stream would be presented as the bigger video), we did not use this feature because the aim was to exploit the students' interaction, forcing them to choose which would be the video to be presented in the main window at each instant. Eighteen students interacted with the iMLO for more than 4 min. The average playback time was 59 min. The average number of interactions of the students was 118.55. Students are from presential modality of Computer Science and Computer Engineering undergraduate courses. We asked to the students to answer, anonymously, a survey which was organized in three parts: (i) questions about the proposal of capture lectures, (ii) about their experience in interacting with the iMLO and (iii) about iMLO's interface.

Figure 2 presents which streams were more selected as the main stream in each moment of module 1. Each line represents how many times a stream was watched in a specific moment. Figure 3(a) summarizes the number of interactions of each category performed by the students. Table 1 and Figs. 3(b), (c), and (d) present data collected from surveys.

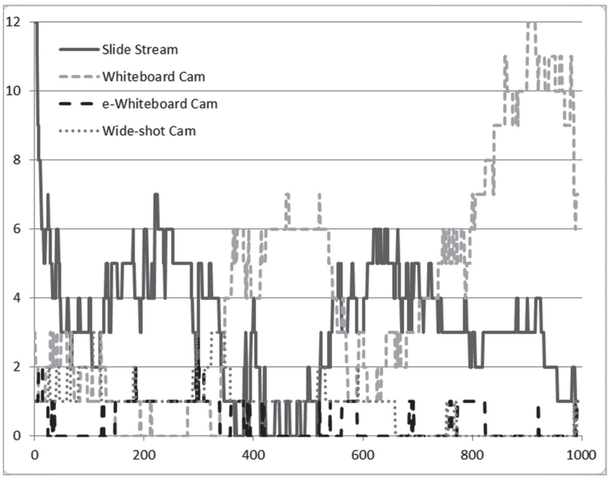


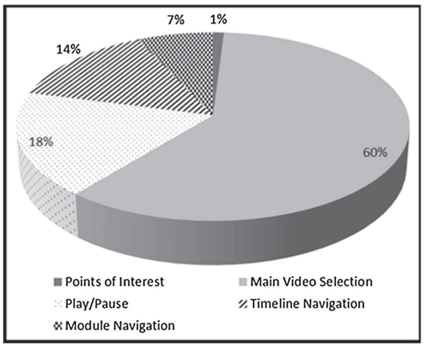
Fig. 2. Main video over time

4.4 Professors

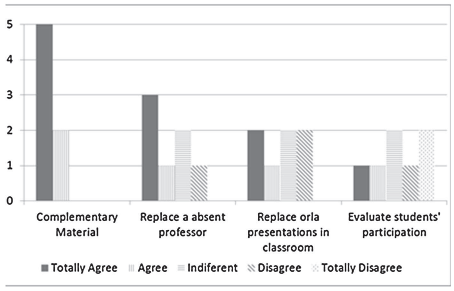
We invited 8 professors to record presentations. Seven recorded a lecture simulation (without students); one captured a lecture with students. After a short explanation of how to use the instrumentalized classroom, all lecturers could carry out the capture alone, meeting the proposed self-service approach. Most of them did not modularize the presentation and record a single long module. The system generated iMLOs for the captured lectures using the design solution depicted in Fig. 5(c). Each generated iMLO was made accessible to the respective professor. After interacting with the iMLO, we asked to the professors to answer, anonymously, a survey. The survey was organized in five parts: (i) questions about the proposal of capture lectures; (ii) about the instrumented classroom infrastructure, (iii) about the experience of capturing a lecture; (iv) about the user interface available for control the capture process; and (iv) about the iMLO interface.

4.5 Summary of Results

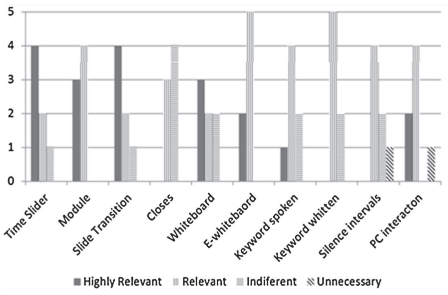
Students and professor said that the generation of iMLO from the capturing of lectures is relevant. Students also said the iMLO contributed in their learning and understanding of the subject. However, Fig. 3(b) demonstrates that students think the iMLO should be used as complementary material. The case studies were carried out with students that



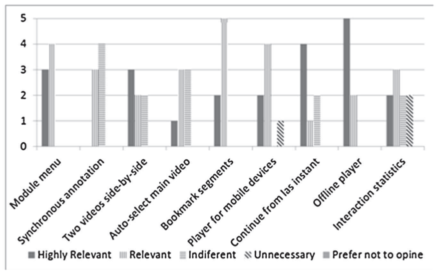
(a) Interactions by category.



(b) Uses of iMLO



(c) Uses of iMLO



(d) Temporal Navigation

Fig. 3. Data from survey and log

are used to have classroom activities with the presence of professors. Students with other educational background may have a different view about iMLO utilization.

The graphic in Fig. 3(b) also shows that students are unwilling in use interactions statistics to evaluate participation. By the other hand, professors agree that users' interactions with iMLO can be used for this purpose. A student declared: "*Some access statistics could be used to suggest the most relevant video or segments*". When asked about how they felt interacting with the iMLO instead of with a professor in a classroom, most students declared they were satisfied. This result may appear contradictory with the previous statement that iMLOs should not replace the instructors. However, even if a student, especially one that does not interact with professors in classroom, feels satisfied to be in control when interacting with the iMLO and taking advantage of its facilities, he or she still feels safer with the professor presence in classroom.

A student declared "*I really liked the multimedia lecture, especially be able to move backward and listen to an explanation again. The different videos are cool. I believe it suits to help and not to replace the professor, because it is complicated (almost impossible!) to make questions or to ask him to talk more about a subject*". Other students' answers also state that they enjoyed being in control and be able to performed both temporal and spatial navigation.

Table 1. Video importance ranking

Video	1st	2nd	3rd	4th	5th
Traditional whiteboard	4	1	2	0	0
Slide projection camera	2	3	0	2	0
Slide presentation capture	1	2	4	0	0
PC Screen	0	1	1	4	1
Wide shot camera	0	0	0	1	6

When asked about the iMLO interface, students' answers pointed out positive feedback. Among the adjectives available to characterize the interface, most students choose "*intuitive*", "*satisfactory*", "*efficient*". Professors' answers were similar. They also highlighted some interface elements, such as the time slider and the possibility to put the most important video in detail. This answer can be confirmed by consulting the graphic in Fig. 3(a), which shows that 60 % of the users' interactions were performed in order to select the main video; while 14 % were navigation by the time slider. Note that the time slider was an element of design suggested by users' feedback.

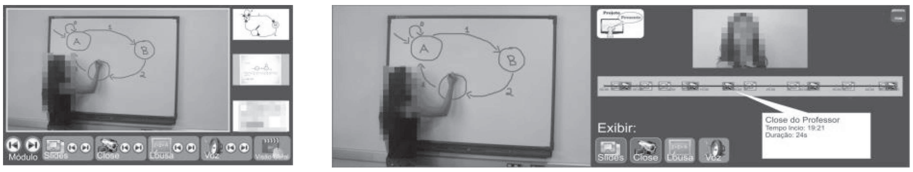
When asked about the relevance of the navigation mechanisms, as shown in the graphic of Fig. 3(c), the users pointed out that timeline (time slider), modules, slides, interaction with computer and with the traditional and electronic whiteboard are relevant. Navigation by professors' close and by keyword, spoken or written were considered indifferent by the students. Since students interact with an iMLO which did not have navigation by keywords, students may not have understood the concept. Moreover, the lecture style may not favor closes as point of interest, given that the educational presentation was focused on the traditional whiteboard and on slides. For professors, all but silent intervals options were considered relevant.

We asked to the students to classify the videos presented by the iMLO in order of importance. The most important video were the traditional whiteboard camera, followed by the slide projection capture and by the camera that frames the slide projection. The fourth position went to the PC screen and the last position went to the wide-shot camera. This result is consistent with the graphic presented in Fig. 2, in which the most watched videos were the traditional whiteboard camera and the slide projection capture. Note that students pointed out the camera that frames the slide projection as one of most important videos, but they almost did not select it as the main video. This may suggest the video is important, but as secondary video most of the time.

We listed some features that could be added to the iMLO and asked to students and professors to pointed out which are relevant. As the graphic presented in Fig. 3(d) shows, the more relevant features are the module menu, bookmark segments and the offline playback of the iMLO. The other features also had a positive acceptance, but some students considered them as indifferent, which suggest these features are secondary. Note that despite annotation was considered a secondary feature, bookmark — a type of annotation — was considered relevant. This suggests that students prefer to use simple forms of annotation. For professors, all the listed features are relevant.

5 Design Solution Evolution

Figure 4 depicts a mockup interface designed to meet both temporal and spatial navigation requirements for the first iMLO version. There are four different synchronized video streams; one of them is the main or bigger video. The other three videos (see Fig. 4(a) right) can be promoted to main video by clicking over them. In addition, clicking over the main video put it on full screen (see Fig. 4(b)). A user can navigate by modules (see Fig. 4(a) left-bottom) or by points of interest. There is also a button (see Fig. 4(c)) to open the overview interface. In the overview interface, there is a timeline representation of the iMLO with icons for each point of interest. By clicking on the icon, the presentation is moved to the instant in which the point of interest occurs.



(a) Multiple videos (b) Full screen (c) Overview

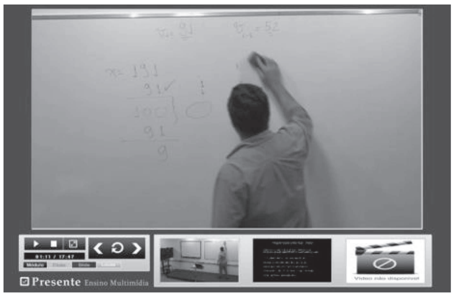
Fig. 4. Mockup interface

We implemented a proof-of-concept for the iMLO using NCL. We have considered alternatives for NCL, such as HTML5, SMIL and flash platform, but the choice for use NCL was taken because it is a powerful language for media synchronization and it is under active development. Moreover, our previous experiences suggested that iMLO's initial requirements were covered by NCL. Figure 5(a) depicts a screenshot from a proof-of-concept implemented in NC. We noticed that are necessary three buttons for points of interest navigation: (1) move forward the next point of interest; (2) move backward the previous point of interest; and (3) return to the beginning of the current point of interest. We also found out that the overview interface is trick to be generated and implement in NCL, so we discarded this feature in this implementation.

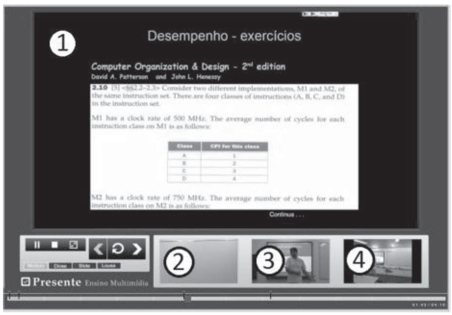
We carried out pilot case studies (i) (detailed in Sect. 4) and used the feedback pointed to perform some enhancements in the interface. Figure 5(b) depicts a screenshot of iMLO redesigned based on these feedbacks. We added the play/pause and stop buttons which are necessary for Web environment, differently from iTV environment where these buttons are present in the remote control. We also added a button to the full screen feature. The users also pointed out the need for information about how long is an iMLO and the current time they are watching. In response, we added a timer in the interface with the current playback time and total module duration. Since NCL is a language for media synchronization, it would be complex to implement a timer in pure NCL and we opted to use a Lua script instead. We opted to favor the content rather the control interface. The different navigation indexes (module, slides transitions) share the same next, previous and return buttons. There is a control similar to radio buttons in which the user set which index she wishes to navigate by.

We carried out the case study (ii) in a real scenario. Although the iMLO offered innovative forms of navigation, the students complained about the absence of time slider. In response, we implemented another proof-of-concept prototype, depicted in Fig. 5(c). It was not trivial to implement a time slider component in NCL and Lua as reported elsewhere [13]. Moreover, note that there are indications in the time slider for the points of interest. The time slider with these indications replaces the overview interface from the mockup (Fig. 5(c)). We carried out the case studies (iii) and (iv) with professors and students in a real scenario.

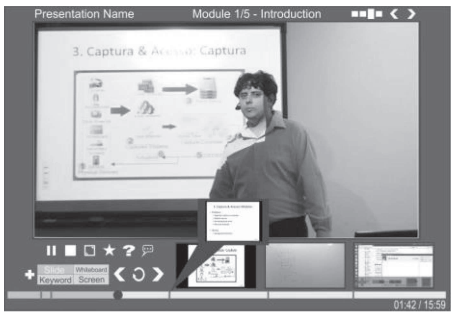
(a) 1st proof-of-concept implementation.



(b) 2nd proof-of-concept implementation



(c) 3rd proof-of-concept implementation.



(d) Final Design Solution.

Fig. 5. Design solution evolution

After analyzing the data collected from the users' interactions log and from surveys, we designed the mockup interface depicted in Fig. 5(d). The new mockup interface has a status bar (top). The title bar holds information about the iMLO' name, the current module's name and how many modules the iMLO has. The status bar also has three buttons, one for advance to the next module, one for return to the previous module and one to open the module menu. The module menu is another interface with the name and information of all modules. The user can access any module from the module menu interface. In addition to the play/pause, stop and full screen button, the new mockup interface brings annotation buttons. Via annotation buttons, a user can bookmark segments or add a time-synchronized text comments. These annotations are represented in the time slider like points of interest. There is also a button for enable or disable the main screen auto-selection based on points of interest. There is a plus button which allows users to choose other types of points of interest rather the four default types available in the interface, which are the more relevant suggested by the case studies: slides transition, traditional whiteboard interaction, electronic whiteboard interaction and computer interaction. When a user moves the mouse near a video's bottom border, a video options menu will be displayed. This menu holds buttons for put the video as main stream (however, clicking over the video does the same), for put the video side-by-side with the main video and for replace the video with other available content such as other video stream. The four default video streams are the more relevant suggested by the case studies.

The design decisions taken during the iMLO's interface project, which had as input the stakeholders' feedbacks, are summarized in the Design Rationale diagram depicted in Fig. 6. Under a white area are the solutions presented in the 1st proof-of-concept implementation. Areas shaded in light gray indicate the solutions added in the 2nd proof-of-concept prototype. Areas shaded in dark gray indicate solutions added in the 3rd proof-of-concept implementation. The solutions shown in the other areas correspond to the final design solution.

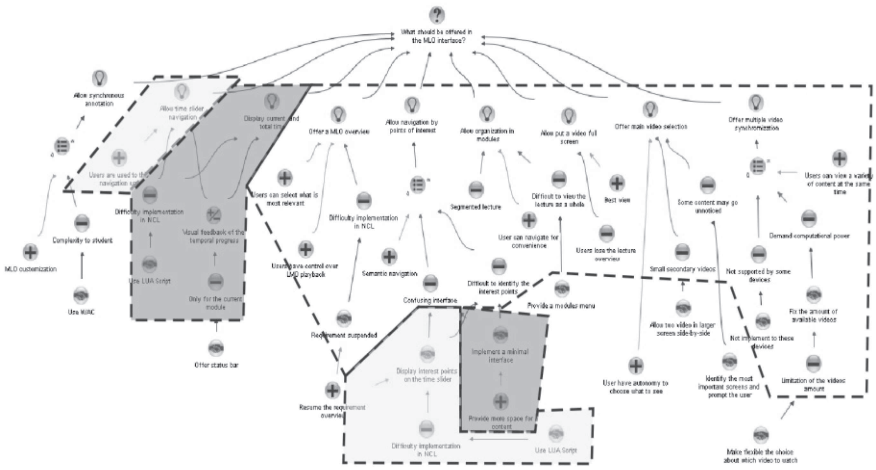


Fig. 6. Design rationale diagram - *what should be offered in the interface of an iMLO?*

6 Lessons Learned

As result of the experience shared with students and professors during the elaboration and build process of the iMLO's design solution, we present some learned lessons that may guide others designers in the conception and implementation of multimedia learning objects.

They are: (1) Students and professor enjoyed to be in control of the learning object playback. The navigation mechanisms that most promotes this control is the time slider; (2) Students and professors liked multiple videos interface proposal and highlighted the possibility of choose one video to see in more detail as the main video or in full screen; (3) Video size and position should be flexible to meet the needs of users (or the content itself); (4) The content is the more important, so the control interface must be minimalist; (5) Semantic navigation, such as by points of interest, appears to be a relevant requirement; (6) Plotting the points of interest in a timeline representation allows users to get an overview of presentation and a visual feedback of its organization (e.g. a user can see how many time the professor spent on each slide); (7) Offer information about the iMLO duration and the current playback time are important requirements to professors and students; (8) The full screen button should be visible and intuitive; (9) The points of interest pointed out as more relevant for lectures focused in whiteboard and slides presentation are: slide transition, interaction with the whiteboard and interaction with the PC; (10) Silence intervals appear not to be relevant as point of interests; (11) Students are favorable to add annotation facilities into the iMLO, but they prefer simple annotations such as bookmark; (12) The video captured by the wide-shot camera appears not to be interesting for students. However, it still can be useful in scenarios in which the lecturer needs to show interactions that the other cameras are not able to capture accordingly and; (13) Some users can consider some videos captured unnecessary. However, it is important that all captured video are present in the iMLO. A possible strategy is to occult such videos, but leave cues of their existence in the interface.

7 Conclusion

In this paper we presented the evolution of a design solution for multimedia learning objects. The evolution was guided by case studies performed with students and professors. The feedback provided several design implications in the iMLO interface, such as the most relevant videos and navigation mechanisms. The results obtained from the case studies have allowed us to report some lessons learned during the design process which can guide other professionals. The case studies also suggest that students are comfortable interacting with the iMLO instead of a professor in a classroom. However, they are unwilling to replace the classroom experience and prefer to use the iMLO as a complementary material. Students and professors also gave positive feedback about the iMLO's interface. In addition, design elements suggested by users, such as the time slider, were well evaluated. This may suggest that the design solution is on the right direction. We plan to implement a proof-of-concept for the last mockup interface and carry out new case studies which should consider other scenarios, such as distance education or middle school students. Studies about usability and accessibility of the iMLO are also of especial interest.

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