A pedagogically-supported TEL solution for learning nontechnical minimally invasive surgical skills across Europe.

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Abstract

Residents learning nontechnical skills in Europe face two problems: (1) the difficulty to fit learning time in their overloaded schedules; and (2) the lack of standard pedagogical models for all countries. Online video-based repositories such as WeBSurg or WebOP provide ubiquitous access to surgical contents. However, their pedagogical facets have not been fully exploited and they are often seen as quick-reference repositories rather than full e-learning alternatives. We present a new pedagogically-supported Technology Enhanced Learning (TEL) solution, MISTELA, designed by surgeons, pedagogical experts and engineers. MISTELA aims at building a common European pedagogical model supported by ICT technologies and e-learning. The solution proposes a pedagogical model based on a framework for pedagogically-informed design of e-learning platforms. It is composed of (1) an authoring tool for editing and augmenting videos; (2) a media asset management system; and (3) a virtual learning environment. Support of the European Association for Endoscopic Surgery (EAES) and validation of the solution, will help to determine its full potential.

1. Introduction

Training of minimally invasive surgical (MIS) skills is a serious endeavour comprising technical (psychomotor) and nontechnical (including cognitive, judgement and communication) abilities [1]. Residents undergoing training (and experts acting as mentors) must fit training time in their overloaded schedules with clinical hours [1], bearing in mind limitations set by the European Work Time Directive 2003/88/EC.

Education of MIS skills in the European Union (EU) lacks the agreement on the definition of standard pedagogical models, and each country has its own training programmes and certification criteria [2]. This poses a dilemma regarding the mobility of surgeons in the EU, since there is no guarantee that required competences are homogeneous in different regions. To change this situation, the European Association of Endoscopic Surgery (EAES) has recently introduced the Laparoscopic Surgical Skills (LSS) initiative as a means to standardize training in Europe [3]. At this point, it is still at an early stage of development to assess its full impact.

To support this effort of homogenization of different learning approaches and skills across Europe, we propose the use of Technology Enhanced Learning (TEL) for ubiquitous learning of nontechnical skills. TEL approaches are commonly used in MIS technical skills' training. (e.g.: virtual reality simulators and tracking systems to train and assess psychomotor abilities of residents [1]). For nontechnical skills, online video-based solutions such as WebSurg, WebOP or Surgytec have been developed [4][5]. However, their pedagogical foundations are not sufficiently detailed or non-existent, making comparison between and assessment of them complicated, if not impossible.

In this work, we present MISTELA, a pedagogically-supported TEL solution for learning MIS nontechnical skills. MISTELA proposes a new pedagogical model for online learning of MIS skills and is built following the example of the TELMA learning environment, which was validated for MIS cognitive skills' learning in Spain [5]. MISTELA extends the idea of TELMA to a European level, striving to consolidate a common pedagogical model for Europe and become a reference in self and collaborative online surgical training.

2. User requirements

User requirements of MISTELA were established by two means: (1) a systematic literature review; and (2) interviews with surgical stakeholders [6]. These include:

- Be easy to use.
- Provide interactive contents.
- Make use of visual contents, where sound and comments may be added.
- Be free of charge.
- Include tests and tracking of performance enabling competence-based education.
- Contain a minimum amount of content to make it productive/worthwhile.
- Contain relevant training materials approved by formal bodies.
- Contain augmented video capabilities (clips, insertion of text captions, etc.).
- Facilitate instructor-trainee online communication.

3. MISTELA pedagogical model

The MISTELA pedagogical model is rooted in the 3D pedagogy framework developed by Conole et al. [7]. The framework is a flexible tool for aligning learning theories with specific instructional approaches from different educational institutions, training providers, course designers and teachers, facilitating a standardised formal training practice. The framework proposes three axis that allow mapping technological tools according to the learning goals, and ensure that the resources available actually support the desired learning outcomes. The axis are defined by three pairs of opposing components:

- **Individual** (where a single learner is the focus of learning) - **Social**: (where learning is experienced through interaction with others).
- **Reflection** (where conscious reflection on experience is the basis by which experience is transformed into learning) - **Non-reflection** (where learning is experienced through processes such as conditioning, deliberate practice and memorisation).
- **Information** (where an external body of information such as text, artefacts and bodies of knowledge form the basis of experience and raw material for learning) – **Experience** (where learning occurs through direct experience, activity, and practical application).

The model contemplates outlining higher-level **activities** (e.g. carry out an anatomy lesson) based on learning outcomes (e.g.: identify anatomical structures) by means of chains of **actions**. One activity may be completed using different actions, depending on the situation, on what a trainee already knows, materials available, etc. (e.g.: review anatomical atlas, review video content, etc.). Finally, actions consist of chains of **operations**, which are well-defined habitual routines used as answers to conditions faced during performance of the action and progressively automated through practice (e.g.: name/identify anatomical structures).

Planning of a course starts, therefore, by localising its learning outcomes in the 3D schema. Learning outcomes are structured in knowledge of: 1) anatomy; 2) equipment and instruments; 3) indications, contraindications and steps of the procedure and 4) complications. The MISTELA model addresses primarily individual learning for highly specialized professionals and focuses on cognitive skills, so most of the actions would be proximal to the individual and reflective poles.

4. MISTELA TEL solution architecture

The MISTELA TEL solution is built as a video-oriented collaborative e-learning platform. It consists of three main modules:

- An **authoring tool** for the creation of augmented video resources, offering the means to boost the didactic capabilities of hospitals' and training centres' video repositories.
- A **media asset management system** (MAM), for intelligent storage, annotation, transcoding and edition of augmented/non-augmented videos.
- A **virtual learning environment** (VLE), providing means for (1) creation, edition and visualization of courses; (2) interactive collaboration between users and (3) tools for assessment and monitoring of skills.

The core of the MISTELA TEL solution lies in the VLE. Therein, course creators will have at their disposal the tools and resources to build the activities of a course. However, since augmented videos are a special type of resource, they require a dedicated creation and management scheme. Augmented videos are created via an ad hoc authoring tool and are uploaded directly to a dedicated media server (the MAM) [5]. This server connects directly with the VLE, which can process and present videos to the learner. The following sub-sections provide details about each module and the communications protocols between them.

4.1. AMELIE authoring tool

The AMELIE authoring tool provides the means to edit and augment laparoscopic videos in order to enhance their didactic value [8]. The tool comes as an independent offline application running on Windows OS. The tool allows users to open, edit and upload videos to the MAM.

Functionalities of the tool have been presented in detail in [8]. The most relevant functionalities are:

- **Insertion of dynamic overlays:** The main feature of AMELIE is its capability of inserting dynamic layers of information to a video. These layers can be turned on/off during playback, depending on the learners' preferences and characteristics. Included layers include text, audio and segmentation/tracking of anatomical structures.
- **Clipping:** AMELIE provides the means to create clips from an original video. Clips are fragments of video with an internal semantic meaning (e.g.: a step of a surgical procedure), to which a start and end pointers are assigned. For each clip, a title, description and key frame can be assigned.
- **Documentation and upload:** Videos edited with AMELIE can be documented by dynamic fields provided by the MAM. In this way, changes can be easily made in the documentation schema in the

server, and updated every time the tool is opened. Furthermore, this opens the door to using AMELIE in other application fields. Once a video is documented, it can be directly uploaded to the MAM along with its documentation, clips and overlays' information.

AMELIE has been implemented in C++ using Microsoft Visual Studio 2013. OpenCV and Audiolab.net libraries have been used for video and audio processing respectively. Communications with the MAM are handled via Web Services (WS) using SOAP. Overlays and clips information are sent via an XML file.

4.2. Videoma media asset management

The Videoma MAM is responsible for the whole management of augmented video content feeding any ordinary operation of MISTELA. As a tool for audio-visual content management, it allows for content ingest, forming or changing the content formats, content granular documentation and marking/clipping of points of interest.

Videoma acts as the main bridge between the authoring tool and the VLE. All augmented videos are uploaded, stored and transcoded from AMELIE to the MAM. Transcoding converts all incoming videos to the format that will be recognizable by the VLE's video player (H.264). On the other hand, the MAM communicates the updated documentation layers to the authoring tool. Communications with the VLE are handled by SOAP and GET calls from the client side. Every time the user wishes to include a new augmented video in a course, connection with the MAM is established and the list of available videos is presented to him/her.

4.3. Moodle virtual learning environment

The VLE is built using Moodle due to its flexibility, modularity and extensive community. Moodle is based on PHP, runs on any OS and offers full interoperability with open source databases such as MySQL. Thus, it was deemed the most suitable choice to implement a VLE able to accommodate the MISTELA pedagogical model.

All users must authenticate when accessing the VLE. Considered user roles include:

- **Trainee:** Student/resident, who acts as a recipient of didactic contents in an active search for knowledge.
- **Professor:** The professor defines the teacher's role in the TEL environment. His/her main profile is that of a MIS surgeon with ample teaching experience. He/she acts as main content facilitator.
- **Experienced Surgeon:** The experienced surgeon's interests focus on his/her lifelong learning experience and continuous formative requirements. He/she acts both as content recipient and facilitator.
- **Visitor:** The visitor defines the default profile for all participants visiting MISTELA for the first time.
- **Administrator:** The administrator is responsible of all management/technical aspects of the VLE.

The main basic didactic unit in the pedagogical model is the course (Fig. 1, right). Enrolment to courses can be open or restricted to certain groups of users. Following the guidelines of the pedagogical model, the VLE offers a wide variety of tools and resources for course designers and learners to build the activities with which the learning outcomes will be addressed. These include:

- **Assignments:** Enables the communication of tasks, collection of work and grade/feedback provision.
- **Chat:** Enables participants to engage on real-time discussions related to a specific topic.
- **Forum:** Enables participants to engage in asynchronous discussions related to a specific topic.
- **Glossary:** Enables participants to create and maintain a list of definitions, resources and information.
- **Lesson:** Enables content delivery and/or practice activities in flexible ways, such as non-sequentially or conditioned to the completion of a task.
- **Quiz:** Enables a teacher to create question-based tests. Question types contemplated in MISTELA include multiple choice, true/false, short answers, embedded answers, sorting and matching questions.
- **Wiki:** Enables the creation of collaborative authored pages on a specific topic.

The VLE enables dedicated repositories for each course where different didactic resources (e.g.: assessment questions) can be stored and re-used. The repositories also provide the API to connect with the MAM, in order to upload augmented video contents into the environment.

Playback of augmented videos is handled via an ad hoc player implemented in Adobe Flash (Fig. 1, right). The player interprets the XML overlay file and depicts (in the case of text/segmentation overlays) or inserts (in the case of audio files) the layers' information for their timespan. The user can dynamically toggle on/off this information in real time. The documentation and the complete list of clips associated to the video is also shown. When the user clicks on a clip, the video will automatically start playing from its starting point. If overlays are enabled and present from that point, they will also be represented.

Finally, all courses can make use of a grade book where trainees and professors can keep track of course progress. Trainees have access to an overview report with the global qualification obtained in all of their active courses. Clicking on any of them will lead them to the user report, where a detailed breakdown of each activity is provided. Activities in the user report may be reviewed for mistakes and reception of feedback; or if enabled, may be repeated.

The professor has also access to a grader report, providing an overview of the scores obtained by students enrolled on the course. Additionally, he/she may consult the statistics of an activity to look for performance patterns (e.g.: in which question do trainees make more mistakes).

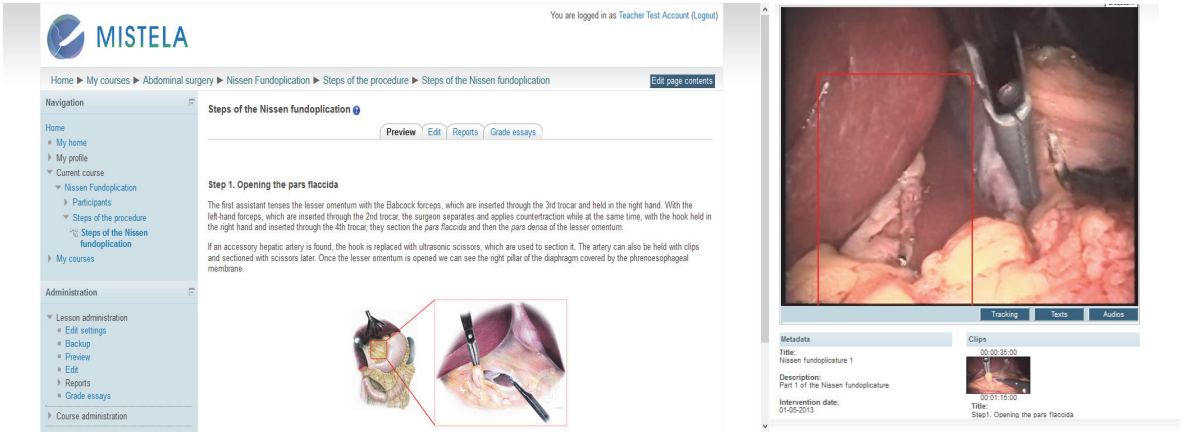

Figura 1. *MISTELA VLE. Left – Example of lesson depicting the Nissen fundoplication. Right – Augmented video player. The video shows a segmentation layer tracking an anatomical structure (red box). Blue buttons below toggle on/off overlays. Documentation and clips are shown under the main window screen.*

5. Validation

In order to validate MISTELA, a demonstrator course has been implemented, following the precepts of the pedagogical model and making use of the tools and resources of AMELIE and the VLE (Fig. 1, left). The course is based on the Nissen fundoplication technique. Content of the course has been designed and approved by surgical experts.

Validation will take place in two phases: (1) an initial pilot with technical and surgical experts; where the usability and functionality of the solution will be evaluated (in order to refine the implementation); and (2) the final trials which will include surgical residents as participants. Phase one of the validation is currently being carried out, while phase two will commence on summer 2014 in Spain, The Netherlands and Norway.

6. Conclusions

MISTELA offers a new paradigm for video-based online learning of MIS nontechnical skills. This paradigm strives to consolidate a new pedagogical model in Europe to help standardize training processes and favour people mobility across the EU.

The current version of the MISTELA TEL solution should be considered at this point as a prototype of what it could become. Its main purpose is to support and enable the validation of the pedagogical model. Validation of MISTELA is still under way, which admittedly supposes a limitation at the time of writing this report. Results (which ultimately will be available by November 2014) will be key to further expanding and consolidating both the MISTELA model and TEL solution.

In an effort to consolidate the model and favour a European integration, contacts are already being made with the EAES, who fosters the LSS programme for standardizing laparoscopic training in Europe. The ultimate goal is to make the MISTELA model and TEL solution as the online reference hub for training surgical residents across the continent.

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