Can effective pedagogy be ensured in minimally invasive surgery e-learning?

Oropesa, Ignacio; Gutiérrez, David; Chmarra, Magdalena K.; Sánchez-Peralta, Luisa F.; Våpenstad, Cecilie; Sánchez-González, Patricia; Pagador, José B.; González-Segura, Ana; Langø, Thomas; Sánchez-Margallo, Francisco M.

DOI
10.1080/13645706.2020.1777165

Publication date
2020

Document Version
Final published version

Published in
Minimally Invasive Therapy and Allied Technologies

Citation (APA)
Oropesa, I., Gutiérrez, D., Chmarra, M. K., Sánchez-Peralta, L. F., Våpenstad, C., Sánchez-González, P., Pagador, J. B., González-Segura, A., Langø, T., Sánchez-Margallo, F. M., Dankelman, J., & Gómez, E. J. (2020). Can effective pedagogy be ensured in minimally invasive surgery e-learning? *Minimally Invasive Therapy and Allied Technologies*, *31*(2), 168-178. https://doi.org/10.1080/13645706.2020.1777165

Minimally Invasive Therapy & Allied Technologies

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/imit20

Can effective pedagogy be ensured in minimally invasive surgery e-learning?

Ignacio Oropesa, David Gutiérrez, Magdalena K. Chmarra, Luisa F. Sánchez-Peralta, Cecilie Våpenstad, Patricia Sánchez-González, José B. Pagador, Ana González-Segura, Thomas Langø, Francisco M. Sánchez-Margallo, Jenny Dankelman & Enrique J. Gómez

To cite this article: Ignacio Oropesa, David Gutiérrez, Magdalena K. Chmarra, Luisa F. Sánchez-Peralta, Cecilie Våpenstad, Patricia Sánchez-González, José B. Pagador, Ana González-Segura, Thomas Langø, Francisco M. Sánchez-Margallo, Jenny Dankelman & Enrique J. Gómez (2022) Can effective pedagogy be ensured in minimally invasive surgery e-learning?, Minimally Invasive Therapy & Allied Technologies, 31:2, 168-178, DOI: 10.1080/13645706.2020.1777165

To link to this article: https://doi.org/10.1080/13645706.2020.1777165

MINIMALLY INVASIVE THERAPY & ALLIED TECHNOLOGIES
2022, VOL. 31, NO. 2, 168–178
https://doi.org/10.1080/13645706.2020.1777165

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Can effective pedagogy be ensured in minimally invasive surgery e-learning?

Ignacio Oropesa[a], David Gutiérrez[b], Magdalena K. Chmarra[c], Luisa F. Sánchez-Peralta[d], Cecilie Våpenstad[e], Patricia Sánchez-González[a,f], José B. Pagador[d], Ana González-Segura[b], Thomas Langø[e], Francisco M. Sánchez-Margallo[d], Jenny Dankelman[c] and Enrique J. Gómez[a,f]

[a]Biomedical Engineering and Telemedicine Centre (GBT), ETSI Telecomunicación, Center for Biomedical Technology, Universidad Politécnica de Madrid (UPM), Madrid, Spain; [b]Everis Consultancy, Ltd, Valencia, Spain; [c]Department of Biomechanical Engineering, Faculty of Mechanical, Maritime and Materials Engineering (3mE), Delft University of Technology, Delft, The Netherlands; [d]Bioengineering and Health Technologies Unit, Minimally Invasive Surgery Centre Jesús Usón, Cáceres, Spain; [e]Department of Medical Technology, SINTEF Technology and Society, Trondheim, Norway; [f]Networking Research Center on Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN), Madrid, Spain

ABSTRACT
Introduction: Effectiveness of e-learning diminishes without the support of a pedagogical model to guide its use. In minimally invasive surgery (MIS), this has been reported as a limitation when technology is used to deliver contents without a sound pedagogical background.
Material and methods: We describe how a generic pedagogical model, the 3D pedagogy framework, can be used for setting learning outcomes and activities in e-learning platforms focused on MIS cognitive skills. A demonstrator course on Nissen fundoplication was developed following the model step-by-step in the MISTELA learning platform. Course design was informed by Kolb's Experiential learning model. Content validation was performed by 13 MIS experts.
Results: Ten experts agreed on the suitability of content structuring done according to the pedagogical model. All experts agreed that the course provides means to assess the intended learning outcomes.
Conclusions: This work showcases how a general-purpose e-learning framework can be accommodated to the needs of MIS training without limiting the course designers' pedagogical approach. Key advances for its success include: (1) proving the validity of the model in the wider scope of MIS skills and (2) raising awareness amongst stakeholders on the need of developing training plans with explicit, rather than assumed, pedagogical foundations.

Abbreviations: MIS: minimally invasive surgery; TEL: technology enhanced learning

ARTICLE HISTORY
Received 31 July 2019
Accepted 30 April 2020

KEYWORDS
Minimally invasive surgery; e-learning; cognitive skills; pedagogical model; MISTELA

Introduction

As social pressure against surgical errors increases and time constraints such as the European Working Directives are imposed, learning paradigms in minimally invasive surgery (MIS) are shifting towards structured, learner-centred approaches [1]. Hospitals and training centres are required to certify the skills of residents, balancing quality standards and an affordable expenditure in training resources [2–4]. These include technical/psychomotor, cognitive, teamwork, leadership or decision-making skills [5].

Technology-enhanced learning (TEL) plays an important role in the transformation of MIS learning processes. Whilst its focus has mainly been simulation for technical skills [3], cognitive skills are among the key competences for surgeons [6]. TEL for cognitive skills training can be an effective way of breaking time, space and cost barriers by offering e-learning alternatives potentially more viable and feasible than on-site courses [7]. However, successful strategies require a clear definition of the learning outcomes (what to learn), learning approaches (how and when to learn) and assessment criteria (what has been learnt). Thus, the development of educational applications should not be solely based on technology, but on careful analysis of learning aims aligned with the

CONTACT Ignacio Oropesa ioropesa@gbt.tfo.upm.es Biomedical Engineering and Telemedicine Centre (GBT), ETSI Telecomunicación, Center for Biomedical Technology, Universidad Politécnica de Madrid (UPM), Avda Complutense, 30, Madrid, 28040, Spain
This article has been republished with minor changes. These changes do not impact the academic content of the article.
Supplemental data for this article can be accessed here.

pedagogical paradigm followed by course designers. How learning theories are translated into practice will impact the quality of a learning experience [7]. Moreover, making explicit which components of a learning theory are reflected in different learning experiences makes both tutors and students aware of the interactions with the learning resources that are expected from them [8].

Both course designers and teachers without pedagogical background may have a good grasp on the learning processes they need to elicit on students for reaching a learning goal, but might feel less secure when deciding on how to bring those to the field in the manner of online resources, exercises or lectures, not being sure about the pedagogical basis for choosing one or another. A supporting pedagogical model is, therefore, required to help matching the learning outcomes with a pedagogical orientation and any available technology. Models can be used by course designers to track their alignment to their pedagogical approach of preference and, conversely, to support decisions about instructional activities or learning environments that endorse their pedagogy of choice [9].

The fact remains that, in general, design of e-learning contents is rarely supported by a pedagogical model or informed by a learning theory [8]. This is also the case for surgery, where a recent review on e-learning platforms showcased that when technology is used to deliver contents without a sound pedagogical background, student performance is hampered [7]. Moreover, recent studies on the quality of video-based e-learning portals show that, despite their wide acceptance as an online resource for surgical recordings, their reliability, transfer of knowledge and/or content structure need to be improved [10,11]. A sound pedagogical model may therefore help increase the effectiveness of these platforms beyond that of content repositories [8].

The context of this work has been carried out under a European consortium of clinical, pedagogical and technical experts to analyse the current status of e-learning in MIS, and to propose a pedagogical model to create e-learning courses addressing MIS cognitive skills. The model was sought to support any approach or combination of approaches (problem or case-based, experiential, inquiry, collaborative learning, direct instruction, etc.) to the teaching-learning process, since the design of computer-based learning has often roots in more than one learning theory [12,13]. This eclectic strategy considers it best when 'designers and instructors […] choose for themselves the best mixture' of learning experiences to include in their courses [14].

For this reason, we consider a generic model, the 3D pedagogy framework, which provides a systematic mapping of tools and resources to expected learning outcomes and pedagogical theories of preference [9]. The mapping gives an answer to the designer's question: 'Is this course/tool/resource adequate for what and how I want my students to learn?' This is suitable for e-learning platforms, where not only there is a wide array of tools and resources, but there is a great variability in the way they can be used. For example, a discussion board can be used to submit and receive feedback from assignments, or as a communication tool for collaborative tasks.

The study is oriented to MIS teachers and course designers who:

- have available tools and resources to build online courses but lack a standardized set of rules to optimize their use in the achievement of a learning outcome;
- require a framework providing flexibility with respect to their preferred learning theories and pedagogical approaches;
- require a reference to measure the deviation of their current training with respect to their ideal training.

A practical application of the model is described with a real case study implemented in an e-learning platform for video-based MIS courses: the MISTELA learning platform. A demonstrator course was developed and validated for a specific laparoscopic procedure, the Nissen fundoplication [15].

Material and methods

The 3D pedagogy framework

The 3D pedagogy framework relates higher-level training activities (such as courses) to outcomes by means of actions supported by specific tools (e.g., taking a test, watching a video), a process called 'mapping' [16]. One activity may be designed using different actions, depending on, e.g., the available resources. To determine whether an action is adequate for a given activity, the framework defines its pedagogical profile and matches it with the action's suitability to reach one or more of the activity's outcomes. The process is done through the following four steps:

- **Step 1 – Activity:** outline the overall learning activity. The result of this step is the definition of the learning outcomes of the training.
- **Step 2 – Context:** describe the nature and traits of the learners and tutors and the conditions under which the training is conducted. The result of this step is a description of variables that condition which actions are suitable for learning.
- **Step 3 – Actions:** identify suitable learning actions for reaching each learning outcome, and the potential tools and resources that can support them. The result of this step is a catalogue of actions and a mapping of potential tools to implement them.
- **Step 4 – Coordinating actions:** determine which actions fit the pedagogical approach of choice and select those that do. The result of this step is a pedagogical profile for the activity driven from the appropriateness of each tool or resource. In turn, resources determine if a particular action suits both the activity's outcomes and its pedagogical approach.

In order to perform Step 4, actions are mapped against the three axes of a 3D lattice, according to [9]:

- **Individual – Social:** learning is considered mainly an individual experience or achieved through interaction with others.
- **Reflective – Non-reflective:** learning comes from conscious elaboration about experience, or through drill and practice.
- **Information – Experience:** learning depends on using the available sources of information, or on direct experience and activity.

The MISTELA learning platform

The MISTELA learning platform was conceived as an online solution for MIS cognitive skills learning, exploiting MIS surgical videos at the core of the learning process [17]. The platform is built using Moodle, an open source solution widely extended in academic circles. MISTELA integrates an external media server where digital collections of MIS videos can be stored and retrieved, and an authoring tool (AMELIE) where the didactic potential of raw videos can be augmented by adding dynamic layers of information and clips [18].

Demonstrator course

Design of the course on Nissen fundoplication was led by a panel of surgical experts and course designers from Jesús Usón Minimally Invasive Surgery Centre (Cáceres, Spain), Leiden University Medical Centre (Leiden, The Netherlands) and St. Olav's Hospital (Trondheim, Norway). Course designers were asked to follow the pedagogical model, while at the same time sticking to their pedagogical approach of choice.

The design of the demonstration course followed Kolb's Experiential learning model, relying on the augmented qualities and interactivity of video demonstrators to facilitate the learning experience, the tests and feedback to help reflective observation, and the assignments and discussions to enable abstract conceptualization of the procedures reviewed [19]. The design followed the appropriate steps of the model:

Step 1: Activity

The course was structured according to five knowledge domains: anatomy, equipment and instruments, indications and contraindications, procedural steps, and complications. Based on them, a list of MIS learning outcomes and indicators of performance was defined, several of which were selected suitable for the demonstrator course (Table 1).

Step 2: Context

Instructional design changes substantially depending on the context of learning. For example, a course designed to facilitate collaborative learning may not meet the needs of students with a tight schedule or working on night shifts at the hospital, because they would find it difficult to engage in synchronous discussions or teamwork. Likewise, a course with limited opportunities or inappropriate tools for communication could frustrate the efforts of a tutor who relies on conversation as a learning facilitator.

One critical point was defining the required prior knowledge for the course. The course is mainly oriented to surgical residents. Nissen fundoplication is commonly taught in MIS surgical training programmes. However, in Spain, it is taught early on in MIS specialization courses, while other countries such as Norway consider it a more advanced procedure with several approaches. This was acknowledged as a potential limitation outside the scope of the panel, and the course was implemented focusing on a standard approach to the surgical intervention [15].

Time constraints involved in the course were also considered. Learning resources should consider the effective time learners will spend in a course. It has

Table 1. General MIS learning outcomes and indicators of performance. *: selected learning outcomes for the demonstrator course on Nissen Fundoplication.

Code	Learning outcome	Proficiency indicator	Error indicator
Knowledge of anatomy			
C1*	List anatomical structures involved in the procedure	All anatomical structures listed	Miss any number of critical anatomical structures involved in the procedure
C2*	Identify anatomical structures which are fully visible/partially visible/can only be seen if an organ or anatomical structure is moved away in the surgical field	Identify all visible/partially visible/ uncovered anatomical structures that are relevant for the procedure	Miss a number of critical visible anatomical structures
C3	Locate anatomical structures which are behind the surgical scene	Locate critical anatomical structures that are behind the surgical scene	Fail to locate critical anatomical structures that are behind the surgical scene
C4	Identify anatomical variations in the surgical field	Recognize all anatomical variations present in the case anatomy	Fail to recognize non-critical anatomical variations
C5	Identify lesions in anatomical structures, based on the colour, texture or size.	Recognize pathological anatomy in anatomical relationships	Fail to recognize severe lesions in the anatomical structures
C6	Identify differences in an animal anatomical model in comparison to a human when performing the procedure on living animal	Identify all differences between the human and animal anatomy	Unable to identify differences between the human and animal anatomy
Knowledge of equipment and instruments			
C7*	List the equipment required to perform the procedure	List all equipment necessary to perform the procedure	Miss any equipment necessary to perform the procedure
C8*	Locate the connections between the different elements	Connect correctly all the equipment	Unable to set connections between the different elements of the equipment
C9*	Manage equipment at a user level (turn on, turn off, change configuration …)	Advance independent use of the equipment	Dependent use of the equipment
C10*	Recognize the different types of tools that are necessary to perform the procedure	Recognize types of tools that are necessary to perform the procedure	Unable to recognize the types of tools that are necessary to perform the procedure
C11*	Recognize the functioning of each tool (open, lock, movement of the tooltip …)	Recognize the advanced function of tools	Unable to recognize the function of tools
C12	Select the most suitable sutures for the procedure (size, type and needle)	Select most suitable sutures	Select a wrong suture
Knowledge of indications, contraindications and procedural steps			
C13*	Identify indications to perform the procedure	Identify all indications for the procedure	Fail to recognize most relevant indications for the procedure
C14*	Identify contraindications to perform the procedure	Identify all contraindications for the procedure	Fail to recognize most relevant contraindications for the procedure
C15*	Select patient position to perform the procedure	Select the best patient position	Select a wrong patient position
C16*	Place the equipment in the operating room	Place elements in the most suitable position	Place elements in an unfeasible position
C17*	Place each member of the surgical team within the operating room, including main surgeon, assistant, scrub nurse and anaesthetist	Place people in the most suitable position	Place people in an unfeasible position
C18*	List the standard points were trocars are placed for a specific procedure	Place all trocars in the most suitable positions	Place any trocar in a wrong position
C19*	Associate which tools are usually inserted through each trocar for a specific procedure	Select the most suitable trocar for each tool	Select a wrong trocar for any tool
C20*	List the steps required to perform the procedure	List all steps to perform the procedure	Miss a critical step to perform the procure
C21*	Identify the most suitable surgical plane for a specific procedure	Identify the most suitable surgical plane	Define the surgical plane through critical organs, anatomical structures or vascular structures
Knowledge and treatment of complications			
C22*	List the most common complications that might occur during the procedure	Identify all common complications	Fail to mention/identify complication
C23*	List causes of the most common complications that might occur during the procedure	Identify most common causes	Fail to identify the cause of the complication
C24	Identify possible risks that may lead to complications during the procedure	Identify all possible risks	Fail to identify one or more risks
C25	Identify a complication	Successfully identify the complication	Fail to identify the complication
C26	Suggest a suitable treatment to common complications that might occur during a procedure	Successfully solve the complication	Fail to solve the complications

been shown that duration of an online course is directly related to abandonment rates [20]. The time required to complete a course should therefore be carefully dimensioned.

Step 3: Actions

Potential actions for the course and their mapping against MISTELA's available tools and resources are presented in Table 2. Having the right tools and

Table 2. Mapping of actions against the available resources in MISTELA. For ease of reference actions are categorized into learning, assessment and social interaction/communication actions.

Learning actions	Resource support
Reading text documents	✓✓✓
Watching videos	✓✓✓
Using augmented videos	✓✓✓
Interacting with 3D models	✓
Watching images (photos/image studies)	✓✓✓
Watching illustrations	✓✓✓
Using the course searching engine	✓✓✓
Reading/editing wikis	✓✓✓
Watching live streaming courses	✓
Watching recorded lectures	✓✓
Listening to podcasts/recordings	✓
Participating in interactive scenario-based task with automated feedback	✗
Participating in interactive scenario-based task with no feedback at all	✗
Performing case-based tasks with personalized feedback and orientation from an expert	✗
Performing equipment handling tasks	✓
Performing patient diagnosis tasks	✓✓
Performing postoperative follow-up tasks	✓✓
Participating in group discussions	✓✓✓
Participating in collaborative role playing	✓✓✓
Performing group assignments	✓✓
Participating in discussion boards	✓✓✓
Sharing content	✓✓
Messaging with other users	✓✓✓
Participating in chat groups	✓✓✓
Writing/reading in comments' sections	✓✓
Assessment actions	
Carrying out essay questions	✓✓✓
Carrying out projects	✓✓✓
Carrying out case studies	✓✓✓
Carrying out assignments	✓✓✓
Answering textual Multiple choice questions MCQ	✓✓✓
Answering MCQ supported with video/images	✓✓✓
Answering MCQ supported with interactive video/images	✓
Answering sorting questions based on text statements	✓✓
Answering sorting questions based on images	✓✓
Answering textual questions	✓✓✓
Answering questions about an image/video	✓✓✓
Selecting the correct image/video in a sequence	✓✓✓
Locating an anatomical structure	✓✓✓
Locating a specific surgical instrument	✓✓✓
Indicating a specific instrument manoeuvre/trajectory	✓✓✓
Selecting the correct image/video	✓✓✓
Choosing word/phrases from a list	✓✓✓
Writing open options	✓✓✓
Matching text – text statements	✓✓✓
Matching text – image statements	✓✓✓
Matching text – video statements	✓✓✓
Matching image – image statements	✗
Matching image – video statements	✗
Matching video – video statements	✗
Dragging fragments of text to complete statements	✗
Filling in the missing parts of the image with a selection of possible images	✓✓
Performing questions with combinations of text – image	✓✓
Answering comprehension questions (answers present in the revised activity)	✓✓✓
Answering reflection questions (answers not presented before)	✓✓✓
Answering questions concerning prior knowledge (answers based on something learners should know about)	✓✓✓
Interaction and communication actions	
Seeking guideline provision	✗
Seeking feedback provision	✗
Seeking online help	✗
Synchronous (participating in online chat sessions)	✓✓✓
Asynchronous (participating in mailing lists)	✓✓✓
Asynchronous (participating in discussion boards)	✓✓✓
Participating in teacher mediated boards (one moderator)	✓✓✓
Participating in community mediated boards (all moderators)	✓✓✓
Organizing the teamwork	✓✓✓
Synthesizing ideas from others	✓✓✓
Peer reviewing	✓✓✓
Participating in student-2-student sessions	✓✓✓
Participating in student-2-tutor sessions	✓✓✓
Participating in tutor-2-tutor sessions	✓✓✓
Participating in group sessions (with tutor)	✓✓✓
Participating in groups sessions (without tutor)	✓✓✓

✓✓✓: Action fully supported; ✓✓: Action partially supported; ✓: Action not supported directly; might be implemented using alternative routes (e.g., plugins); ✗: Action not supported.

Table 3. Final selection of actions and corresponding resources available to enable them.

No	Action	Category	MISTELA resources
1	Reading text documents	LEARNING	Glossary/Lesson/Text file/Embedded text
2	Watching videos	LEARNING	Embedded videos
3	Watching augmented videos	LEARNING	AMELIE augmented videos and clips
4	Watching images (photos/image studies)	LEARNING	Image files/Embedded image/Lessons
5	Taking a lesson	LEARNING	Lessons
6	Using search engines	LEARNING	Moodle engine
7	Sending private messages to other users	INTERACTION & COMMUNICATION	Messenger
8	Participating in discussion boards	INTERACTION & COMMUNICATION	Forum
9	Giving opinion on course contents	INTERACTION & COMMUNICATION	Forum
10	Sharing videos/texts	INTERACTION & COMMUNICATION	Glossary/Tasks
11	Answering multiple choice questions	ASSESSMENT	Quiz
12	Answering sorting questions	ASSESSMENT	Quiz
13	Answering matching questions	ASSESSMENT	Quiz
14	Answering T/F questions	ASSESSMENT	Quiz
15	Answering embedded questions	ASSESSMENT	Quiz

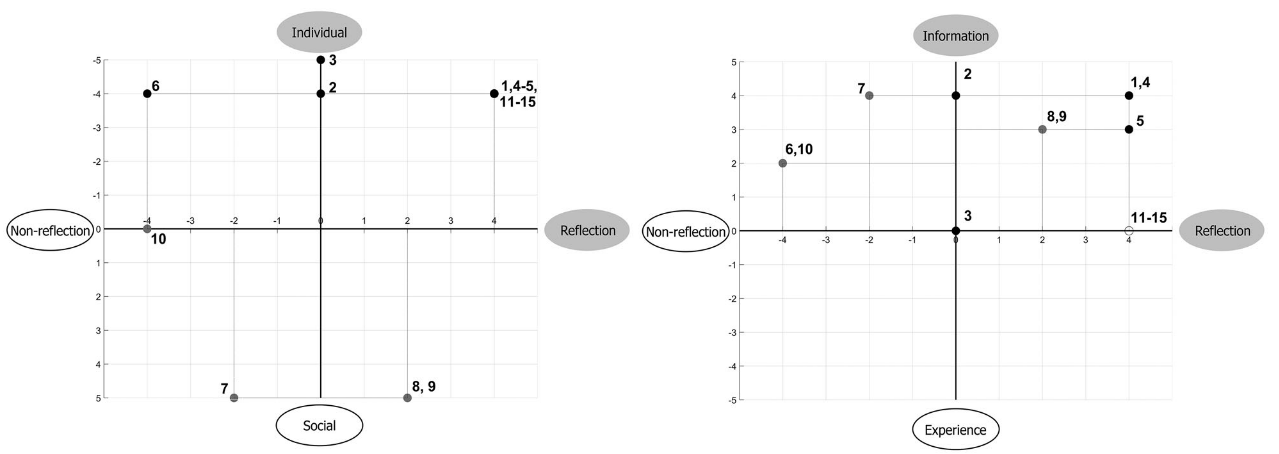

Figure 1. Mapping of the 15 actions (listed in Table 3) against the 3D framework. Left: Reflection–Non Reflection vs. Individual–Social. Right: Reflection–Non Reflection vs. Information–Experience. Black dots: learning actions. Dark grey dots: Interaction and communication actions. White dots; assessment actions. Shaded tones indicate how actions lean towards the Information, Individual and Reflection poles.

resources for the identified actions is critical for a course's success and, therefore, a predesigned set of tools such as those that a customised platform may provide are an advantage as long as they fit the pedagogical approach. One can look for additional external tools once he/she is certain (through the mapping) that available options are not covering the pedagogical needs.

Step 4: Coordinating actions

Fifteen actions were identified suitable and mapped according to the pedagogical approach sought for the course (Table 3). Designers were asked to reflect upon the orientation they wanted to give to the course and chose actions situated in their area of preference in the 3D framework's dimensions according to their views about how training is most effective, and useful for eventually reaching the learning outcomes, structuring them according to the expected progression and scaffolding.

The pedagogical profile of the different actions is shown in Figure 1. Actions close to the Information and Reflection poles are in line with e-learning approaches that include exposure to accurate, varied and context-aligned examples and use cases; and require some degree of elaboration from students, who are provided with related and significant feedback [21–23]. Personal work stands in the Individual pole, although interaction among peers and with tutors is facilitated as a way of building and confronting mental models of the tasks, with related actions approaching the Social pole.

The final learning activity is outlined in Table 4. It consists of five modules, following the domains identified in Step 1. The course was implemented in the MISTELA learning platform. A raw video recording of a complete Nissen fundoplication was augmented and clipped by course designers and included as part

Table 4. Nissen fundoplication course: learning outcomes, course outline and structure.

Learning outcomes	Course outline	Action	Resource	Structure overview
Module 1. Anatomy				
C1, C2	1.1 Human Anatomy	1, 4, 10	–Embedded image –Glossary	1.1.1. Abdominal oesophagus 1.1.2. Central tendinous 1.1.3. Oesophagus Etc.
	1.2 Quiz	11–15	–Quiz	–
	1.3 Discussion forum	8, 9	–Forum	–
Module 2. Equipment and instruments				
C7, C8, C9, C10, C11	2.1 Equipment	1, 4, 5	–Lesson –Embedded image & text	2.1.1. Laparoscopic tower. 2.1.2. Accessory equipment. 2.1.3. Use of the laparoscopic tower.
	2.2 Instruments	1, 4, 5	–Lesson –Embedded image & text	2.2.1. Laparoscopic access instruments. 2.2.2. Dissection and cut instruments. 2.2.3. Gripping instruments. 2.2.4. Retractor instruments. 2.2.5. Aspiration and irrigation instruments. 2.2.6. Extraction instruments.
	2.3 Quiz	11–15	–Quiz	–
	2.4 Discussion forum	8, 9	–Forum	–
Module 3. Indications and contraindications				
C13, C14, C15, C16, C17, C18, C19, C21	3.1 Indications	1, 4, 5	–Lesson –Embedded image & text	3.1. Indications for laparoscopic Nissen fundoplication
	3.2 Contraindications	1, 4, 5	–Lesson –Embedded image & text	3.2. Contraindications for laparoscopic Nissen fundoplication
	3.3 Quiz	11–15	–Quiz	–
	3.4 Discussion forum	8, 9	–Forum	–
Module 4. Steps of the procedure				
C15, C16, C17, C18, C19, C20, C21	4.1 Pre-operative	1, 4, 5	–Lesson –Embedded image & text	4.1.1. Patient position 4.1.2. Position of the surgical team and equipment 4.1.3. Insertion of Veres needle 4.1.4. Methods to check if needle is properly placed 4.1.5. Positions of trocars in regular/obese patients
	4.2 Protocol	1–5	–Lesson –Embedded image & text –Augmented video	4.2.1. Opening the pars flaccida 4.2.2. Opening the pars densa 4.2.3. Opening the phrenoesophageal membrane 4.2.4. Sectioning the gastrosplenic ligament 4.2.5. Creation of the retroesophageal window 4.2.6. Sectioning the gastrosplenic ligament 4.2.7. Confirming that there is ample space for passage through the valve 4.2.8. Closing the diaphragm pillars 4.2.9. Constructing the valve
	4.3 Quiz	11–15	–Quiz	–
	4.4 Discussion forum	8, 9	–Forum	–
Module 5. Complications				
C22, C23	5.1 Complications	1, 4, 5	–Lesson –Embedded image & text	5.1.1. Wrap herniation 5.1.2. Pneumothorax 5.1.3. Perforation Etc.
	5.2 Quiz	11–15	–Quiz	–
	5.3 Discussion forum	8, 9	–Forum	–

of the course. The rest of the contents were created directly using MISTELA's Moodle resources. The reader may find a general overview of the course in the supplemental video provided with this study.

Content validation

Content validation was carried out to measure the impact of the pedagogical model on the quality and accuracy of the actual contents' design and structure according to the learning outcomes of the course. Thirteen external surgical experts (five from Spain, three from The Netherlands, two from Norway, two from United Kingdom, and one from Turkey) reviewed and assessed the adequacy of the course to meet learning outcomes using a 5-point Likert scale subjective questionnaire (1: strongly disagree – 5: strongly agree). All experts had background in general surgery and experience in MIS. Three had five to ten years of experience in MIS, and the other ten had >10 years of experience in MIS. Moreover, all experts had experience in designing training curricula and/or contents, as well as in teaching surgical skills and/or acting as a mentor: three had <5 years of teaching experience, three had five to ten years of teaching experience, and seven had >10 years of teaching experience.

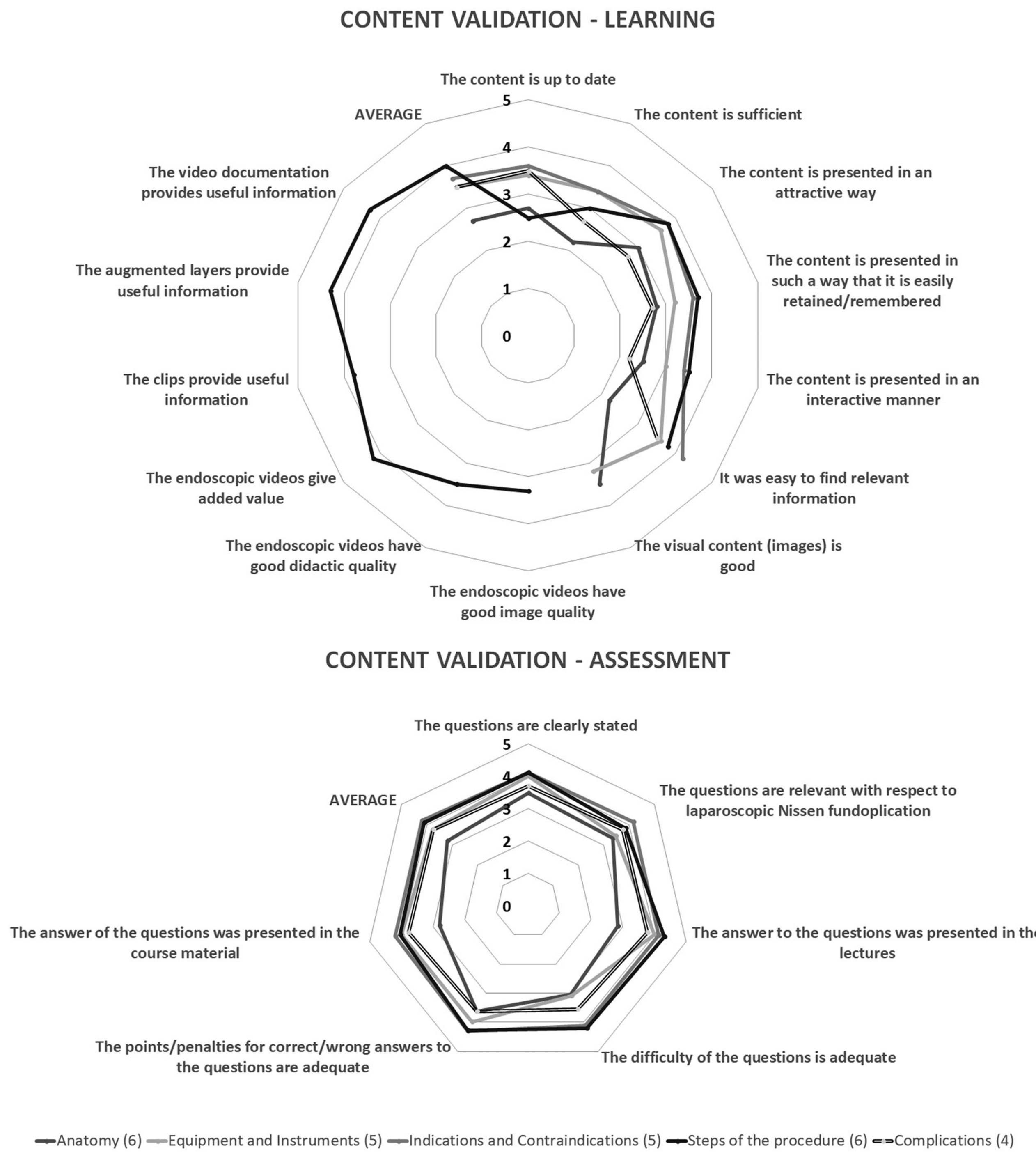

Figure 2. Content validation results, according to modules. Top: questions related to learning. Not all questions pertained all modules. Bottom: questions related to assessment. Numbers in brackets besides a module reflect the final number of reviewers for said module.

Results

Content validation results are presented in Figure 2. Due to experts' time constrains, we had to limit the amount of content to evaluate per participant to two out of five modules. The proposed distribution of the modules was done such that four to six experts validated each module.

Most experts agreed on the suitability of content structuring (three experts disagreed; five agreed; five strongly agreed). All experts agreed that the course provides means to assess the intended learning outcomes (12 agreed; one strongly agreed).

In average, the weakest module was found to be 'Anatomy' (2.7/5 learning, 3.2/5 assessment). The main reason given was the lack of advanced, specific content about the Nissen procedure and pathological anatomy. 'Indications and Contraindications' (3.7/5 learning, 4.2/5 assessment) and 'Steps of the Procedure' were correctly described and obtained the highest scores (4/5 learning, 4.1/5 assessment).

Suggested improvements focused on adapting the theory for different European countries. Most experts indicated that the course presented a 'classical way' of performing Nissen fundoplication. It was proposed to include information on alternative approaches in order to trigger discussions on the techniques and to learn which/when different techniques should/should not be used. Experts believe that such a way of addressing the content would allow the resident to make better choices when performing real operations, as the choices would be based on advantages and disadvantages of the techniques.

Discussion

This work showcases how a general-purpose e-learning framework can be accommodated to the needs of MIS training. One of the most important prerequisites sought was to provide flexibility to course designers in their task of planning learning activities. In this sense, the 3D pedagogy framework is progressive and considers different learning perspectives, making explicit how any given one is foregrounded in different activities, along with the effective use of different tools and resources to support it. Course designers can find their pedagogical orientation supported, no matter if they are eclectic in their choice of actions or even if they do not have an explicit pedagogical basis for their course design; moreover, the model forces them to become aware of it.

This study provides a preliminary insight on the quality of instructional design when informed by the pedagogical model, as a necessary first step prior to handing down the content to students. The number of experts was considered a limitation (due to availability and time constraints); however, the geographical distribution of the sample allowed us to consider different approaches to surgical training in different countries. Nevertheless, we are fully aware that learning effectiveness and course dimensioning requires further validation with actual learners, preferably in the form of randomized controlled trials to compare courses structured according to the model with other methods of learning design [7]. Validation should also consider the impact on learning climate, measuring aspects such as self-perception on acquired competences, overall training satisfaction or quality of life [24]. Moreover, results focus on one specific course and, thus, further validation is required to generalise them. As part of our ongoing work, we are currently working on the definition of new courses and studies with learners from the different countries, including new sites such as Romania and Hungary. These studies will incorporate measures to enable comparisons between learning methodologies, as well as self-reports that might give insight to issues that were not considered in the design phases [7].

Our current challenge is to accommodate the model for online learning of technical skills, incorporating simulators to the resource portfolio in a new version of the MISTELA platform. Simulators are currently used to train technical skills at basic and intermediate levels and can be effective in the diagnosis of surgical skills [25,26]. Their use will typically involve deliberate, repetitive practice drills to achieve progressive automation of accurate movement patterns [27]. The 3D model could accommodate those actions mapped towards the Individual, Non-reflective and Experience poles, so any limitations may come from the actual provision of tools and resources that exploit deliberate practice of technical skills within an online learning environment.

The ultimate challenge is making the model known to the wider MIS community. As we have seen, the way techniques are performed in Europe differ from country to country, even from hospital to hospital. There are also different guidelines for when patients are operated upon, and different skills are taught during the surgical curriculum, making it difficult to standardize learning in Europe. Whilst our model does not negate any approach, it does provide a common framework to structure learning, accommodating to different learning approaches and strategies. Its integration as part of the practices, procedures and policies of training organizations may impact positively on their learning climate [24]. Together with a powerful e-learning tool, it could be used to foster a common approach to teaching-learning MIS skills across Europe. Thus, we are currently working on strengthening the bonds with clinical associations and new partners both in academy and industry to ensure that the efforts of standardization of MIS learning reach all involved stakeholders and can one day become a reality in Europe. This requires that those responsible for MIS training start developing training plans with explicit, rather than assumed, pedagogical foundations. Only if sound instructional design is acknowledged as a necessary part of training development will the deployment of a common pedagogical model be possible.

Acknowledgements

The authors thank all staff from the Jesús Usón Minimally Invasive Surgery Centre, Leiden University Medical Centre and St. Olav's Hospital participating in the course panel.

Declaration of interest

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

Funding

This work has been carried out under project MISTELA [528125-LLP-1-2012-1-UK-LEONARDO-LMP]. This project has been funded with support from the European Commission. This communication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

ORCID

Ignacio Oropesa http://orcid.org/0000-0003-4560-285X
David Gutiérrez http://orcid.org/0000-0001-6433-8922
Luisa F. Sánchez-Peralta http://orcid.org/0000-0002-7630-353X
Cecilie Våpenstad http://orcid.org/0000-0002-9167-5593
Patricia Sánchez-González http://orcid.org/0000-0001-9871-0884
José B. Pagador http://orcid.org/0000-0002-4382-5075
Thomas Langø http://orcid.org/0000-0002-2824-6120
Francisco M. Sánchez-Margallo http://orcid.org/0000-0003-2138-988X
Jenny Dankelman http://orcid.org/0000-0003-3951-2129
Enrique J. Gómez http://orcid.org/0000-0001-6998-1407

References

[1] Oropesa I, Sánchez-González P, Lamata P, et al. Methods and tools for objective assessment of psychomotor skills in laparoscopic surgery. J Surg Res. 2011;171:e81–e85.
[2] Moorthy K, Munz Y, Sarker S, et al. Objective assessment of technical skills in surgery. BMJ. 2003;327:1032–1037.
[3] Schreuder HWR, Oei G, Maas M, et al. Implementation of simulation in surgical practice: Minimally invasive surgery has taken the lead: the Dutch experience. Med Teach. 2011;33:105–115.
[4] Dankelman J, Chmarra MK, Verdaasdonk EGG, et al. Fundamental aspects of learning minimally invasive surgical skills. Minim Invasive Ther Allied Technol. 2005;14:247–256.
[5] Wood TC, Raison N, Haldar S, et al. Training tools for nontechnical skills for surgeons – a systematic review. J Surg Educ. 2017;74:548–578.
[6] Madani A, Vassiliou MC, Watanabe Y, et al. What are the principles that guide behaviors in the operating room?: creating a framework to define and measure performance. Ann Surg. 2017;265:255–267.
[7] Maertens H, Madani A, Landry T, et al. Systematic review of e-learning for surgical training. Br J Surg. 2016;103:1428–1437.
[8] García-Cabrero B, Hoover ML, Lajoie SP, et al. Design of a learning-centered online environment: a cognitive apprenticeship approach. Educ Tech Res Dev. 2018;66:813–835.
[9] Conole G, Dyke M, Oliver M, et al. Mapping pedagogy and tools for effective learning design. Comput. Educ. 2004;43:17–33.
[10] Ferhatoglu MF, Kartal A, Filiz Aİ, et al. Comparison of new era's education platforms, YouTube® and WebSurg®, in sleeve gastrectomy. Obes Surg. 2019;29:3472–3477.
[11] Can U, Narter F. Are the video surgery platforms useful and preferable for urologist? South Clin Istanbul Eurasia. 2018;30:33–37.
[12] Gagné RM, Wager WW, Golas K, et al. Principles of instructional design. 5th ed. Belmont (CA): Thomson/Wadsworth; 2005.
[13] Honebein PC. Seven goals for the design of constructivist learning environments. In Wilson B, editor. Constructivist learning environments: case studies in instructional design. New York: Educational Technology; 1996. p. 11–24.
[14] Carr-Chellman A, Duchastel P. The ideal online course. Br J Educ Technol. 2000;31:229–241.
[15] Fuchs KH, Babic B, Breithaupt W, et al.; European Association of Endoscopic Surgery (EAES). EAES recommendations for the management of gastroesophageal reflux disease. Surg Endosc. 2014;28:1753–1773.
[16] Kuutti K. Activity theory as a potential framework for human-computer interaction research. In: Nardi B, editor. Context and consciousness: activity theory and human computer interaction. Cambridge: MIT Press; 1995. p. 17–44.

[17] Oropesa I, Chmarra MK, Vapenstad C, et al. A pedagogically-supported TEL solution for learning nontechnical minimally invasive surgical skills across Europe. In: Campos RJ, Caminal Magrans P, Giraldo Giraldo BF, et al., editors. Proceedings of the XXXII Congress of the Spanish Society of Biomedical Engineering. Vol. 704. Barcelona (Spain): Spanish Society of Biomedical Engineering; 2014. p. 1–4. Available from: http://seib.org.es/descarga/comunicaciones-caseib-2014/

[18] Sanchez-Gonzalez P, Oropesa I, Garcia-Novoa J, et al. AMELIE: Authoring Multimedia-Enhanced Learning Interactive Environment for medical contents. Stud Heal Technol Inf. 2013;190:68–70.

[19] Kolb D. Experiential learning: Experience as the source of learning and development. J Organ Behav. 1984;8:359–360.

[20] Romero M, Usart M. The time factor in MOOCS time-on-task, interaction temporal patterns, and time perspectives in a MOOC. In: Zvacek S, Restivo MT, Uhomoibhi JO, et al., editors. Proceedings of the 6th International Conference on Computer Supported Education. Setubal (Portugal): SciTePress; 2014. p. 53–62.

[21] Salas E, Tannenbaum SI, Kraiger K, et al. The science of training and development in organizations: what matters in practice. Psychol Sci Public Interest. 2012;13:74–101.

[22] Smith SM, Vela E. Environmental context-dependent memory: a review and meta-analysis. Psychon Bull Rev. 2001;8:203–220.

[23] Quilici JL, Mayer RE. Role of examples in how students learn to categorize statistics word problems. J Educ Psychol. 1996;88:144–161.

[24] Sartori E, Ghezzi F, Cromi A, et al.; Italian Society of Gynecology and Obstetrics (SIGO). Learning climate and quality of Italian training courses in gynecology and obstetrics. Eur J Obstet Gynecol Reprod Biol. 2019;241:13–18.

[25] Mansoor SM, Våpenstad C, Mårvik R, et al. Construct validity of eoSim – a low-cost and portable laparoscopic simulator. Minim Invasive Ther Allied Technol. 2019.

[26] Vitale SG, Caruso S, Vitagliano A, et al. The value of virtual reality simulators in hysteroscopy and training capacity: a systematic review. Minim Invasive Ther Allied Technol. 2019.

[27] Nesbitt CI, Birdi N, Mafeld S, et al. The role of simulation in the development of endovascular surgical skills. Perspect Med Educ. 2016;5:8–14.