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EDUCATIONAL SIMULATION IN PRACTICE: A TEACHING EXPERIENCE USING A FLIGHT SIMULATOR

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Abstract

The use of appropriate Educational Simulation systems (software and hardware for learning purposes) may contribute to the application of the “Learning by Doing” (LbD) paradigm in classroom, thus helping the students to assimilate the theoretical concepts of a subject and acquire certain pre-defined competencies in a more didactical way. The main objective of this work is to conduct a teaching experience using a flight simulation environment so that the students of Aeronautical Management degree can assume the role of an aircraft pilot, in order to allow the students understanding the basic processes of the air navigation and observe how the new technologies can transform and improve these processes. This is especially helpful in classroom to teach the contents of the Single European Sky ATM Research (SESAR) programme, a European project that introduces a new Air Traffic Management (ATM) paradigm based on several relevant technological and procedural changes that will affect the entire air transportation system in the short and medium term. During and after the execution of several activities with a flight simulator in the classroom, both the performance and satisfaction level of the students regarding the teaching experience have been assessed through four different assessment methods, i.e., objective test, execution test, observation techniques and attitude-opinion survey.

Keywords – Teaching experience, Educational Simulation, Flight simulation, Learning by doing, Competencies.

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1 INTRODUCTION

Educational Simulation (ES) is a term that refers to a variety of selectively representational and interactive environments that can represent or imitate the behaviour of any real system or phenomenon (either physical or social) at the time that provides with an adequate framework to perform highly effective learning experiences. The main goal of an ES is to promote the learning by discovery and to enhance the skills involved in the study of a certain system/phenomenon of interest. ES provides to students with the opportunity to interact, reflect and learn, so, they actively participate in the educational process (Aldrich, 2005; Valverde, 2010).

According to Aldrich (2005), the success of any educational experience through simulations depends on the proper configuration of the following three elements: the Simulation component, the Pedagogical component and the Game component. See Fig. 1.

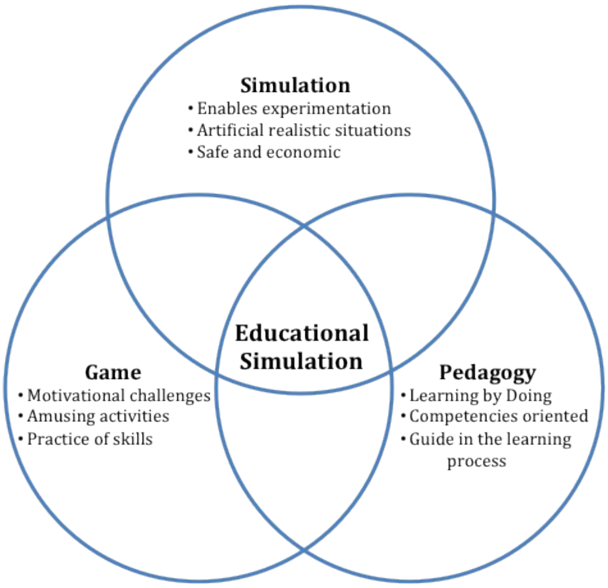

Figure 1. Educational Simulation components

With regards to the Simulation component, it allows recreating and representing the real world in different circumstances and with different levels of abstraction and realism. More precisely, the term Simulation in this paper refers to the "process of designing a model of a real system and carry out experiences with it, with the purpose of understand the system behaviour and evaluate new strategies –within the limits imposed by a criterion or a set of them- for the operation of the system." (Shannon & Johannes, 1976). Some of the main features of any type of simulation are:

- Useful for making decisions.
- Enables to evaluate and/or predict potential future solutions in today's present.
- Enables to optimize the system behaviour (if the system can be modified, e.g., a factory plant).
- Offers a safe and economical method for training operators.
- Enables to explore situations where actual experimentation might be dangerous, problematic, expensive or directly impossible.

Therefore, the Simulation component in a learning experience allows taking people to a time or place that they are unable or unlikely to experience directly, thus encouraging the learning within artificial situations that can be fully adapted to enhance the learning experience. In addition, the above features can be usually complemented with the capability of the simulators to represent and connect huge amounts of information through multimedia, such as high-definition video and high-fidelity surrounding sound (Alessi & Trollip, 1991; Gibbons & Fairweather, 1998), which altogether add an extra value to the ES and makes the learning experience more attractive to the students.

Regarding the Pedagogical component, one important feature of an ES experience is the opportunity to apply the Learning by Doing (LbD) concept in classroom. Note that according to Martínez (2003), "It is a misconception that people learn by listening or reading and validate your knowledge through an examination (where his memory is measured but never his understanding). People learn by doing, making mistakes and reflecting on how to solve problems, usually with the help of someone more experienced".

Within the European Higher Education Area (EHEA) paradigm the university students not only learn knowledge in classroom, they must also acquire the general competencies that they will need when transferred to the labour market after completing their studies (EHEA, 1999). In this context, the term competency means, as defined by Echevarría (2001), the ability to discriminate the information that is important to cope with a certain situation/problem and the ability to use this information to face with it. Note that the concept of competency is sometimes referred as skill in the Anglo-Saxon context (Bonsón, 2009); in this paper the word skill is used with the meaning of methodological capability to apply the technical knowledge to specific real situations. In this sense, who possesses professional competency is who has the necessary knowledge, skills and attitudes to exercise their own work, to solve problems creatively and with independency, and that is able to contribute to their work environment and work organization (Lasnier, 2000; Biggs, 2005; Tardiff, 2006). Therefore, since the development and assessment of competencies should be performed in realistic environments (Lussier & Allaire, 2004; Airasian, 2001), the ES can contribute (through a LbD approach) to the design of new activities that guide to the students towards the improvement of their professional competencies as required for their expected future positions.

Finally, the Game component of an ES experience motivates the student during the learning process through amusing activities that indirectly provide benefits. Note that in a game situation the player engages in a lose/win situation that requires the practice of knowledge, skills and techniques (i.e., competencies) that are either already acquired or in the process of being acquired. Practice is said to facilitate knowledge acquisition (Biggs & Moore, 1993).

In this paper an ES case study is introduced in which a teaching experience has been performed based on the use of a flight simulator. The targets of this experience have been the students of Bachelor in Aeronautical Management, within the subject of Technologies and Procedures for Air Traffic Control and Navigation (note, however, that the same or similar exercises can be adapted to other fields of study, e.g., Aeronautical Engineering). One of the difficulties of this subject is that it introduces several new Air Traffic Management (ATM) concepts that are currently under development in the context of the Single European Sky (SESAR Consortium, 2007) and that are difficult for the students to understand in deep only from the point of view of theoretical explanations. For instance, the SESAR ATM paradigm requires the use of 4D trajectories, i.e., precise execution of a flight trajectory in the three dimensions and time. The students should note during the course that the precise 4D navigation is not affordable in practice for humans (i.e., it requires high levels of automation in all the control and navigation processes), and the best way to allow them observing that fact is through a practical flight activity (i.e., learning by doing) in which they adopt the role of a pilot. After the experience, the students have been questioned with a knowledge evaluation exam and a satisfaction survey requesting their opinion.

The paper is structured as follows. Section 2 outlines the design process of the teaching experience and activities proposed to the students taking into account the competencies that the student should acquire and the relationship with the contents of the subject. In addition, the last subsection of the section 2 shows how the teaching experience has been executed and assessed, whereas Section 3 explains the results obtained after the assessment. Finally, Section 4 reads the conclusions.

2 PLANNING AND DESIGN OF A TEACHING EXPERIENCE THAT USE A FLIGHT SIMULATOR

The planning and design of the teaching experience have been divided in the definition of objectives, methodology applied and assessment methods.

2.1 Definition of the objectives

The main goal of the teaching experience proposed here is to guide the students in the process of acquiring a set of specific and transversal competencies that have been previously defined in the context of the subject "Technologies and Procedures for Air Traffic Control and Navigation", a subject in which the students are introduced to the current and future technologies and procedures used in aviation. Some of the contents of this subject are difficult to be understood in deep only through theoretical explanations, e.g., how the students can understand the difficulties of performing a precise 4D navigation if they have not experienced the difficulties of the –much more easier– 2D and 3D navigation? Therefore, the purpose of the learning activities proposed in this paper is to allow the students to play the role of a pilot by means of a flight simulator, so they can understand the basic principles of the air navigation, experience the most common tasks performed by pilots and to observe how the new technologies can facilitate and transform such processes.

Some of the pursued competencies that the students should acquire in the context of the subject (specifically related to the Navigation sub-topic of the subject) have been identified in Table 1, together with the identification of the specific objectives related to each of the competencies that the students should be able to perform after the teaching experience. The description of these specific performance objectives can be found in Table 2.

Competency identifier	Competency	Typology	Competency components	Objectives
C1	*Deep understanding of all the processes involved in the air transportation system*	*Specific*	*Knowledge*	*O1*
			Skills	
			Attitudes	*O2*
C2	*Deep understanding of the reasoning, abilities and worries of flight pilots*	*Specific*	*Knowledge*	*O3*
			Skills	*O4*
			Attitudes	*O5*
C3	*Capability to detect improvement areas at any process of the air transportation system*	*Specific*	*Knowledge*	*O6*
			Skills	
			Attitudes	*O7*
C4	*Capability to identify new potential technologies and procedures that may improve the command and/or navigation of a flight*	*Specific*	*Knowledge*	*O8*
			Skills	*O9*
			Attitudes	*O10*
C5	*Capability to have an open, tolerant and adaptive thinking*	*Transversal*	*Knowledge*	
			Skills	*O11*
			Attitudes	*O12*
C6	*Capability to make good decisions in different situations*	*Transversal*	*Knowledge*	*O13*
			Skills	*O14*
			Attitudes	*O15*

Table 1. Competencies and relationship with the teaching experience objectives

Objective identifier	Specific performance objectives
O1	*The student knows the concepts and complexities related to the control and navigation of an aircraft during a flight*
O2	*The student has enhanced interest for the contents of the subject*
O3	*The student knows the different types of instrumentation on-board to command an aircraft*
O4	*The student have basic abilities for the commanding and navigation of an aircraft*
O5	*The student is able to have enhanced empathy towards the pilots and knows the feelings related to flying*
O6	*The student understand the tasks required for the commanding and navigation of an aircraft as a particular process within the complex air transportation system and thus is able of evaluating the impact of any technological or procedural change that may improve or worsen the command and navigation of an aircraft*
O7	*The student is able to perform critical thinking with regards aeronautical technologies and procedures*
O8	*The student knows the historical evolution of the technologies and procedures used in the commanding and navigation of aircraft and is able to evaluate their impact in the flight processes*
O9	*The student can manipulate the different technologies and instrumentation on-board and can follow basic flight procedures*
O10	*The student is able to perform critical thinking with regards aeronautical technologies and procedures*

Objective identifier	***Specific performance objectives***
O11	*The student is able of adapting rapidly to a new environment (in this case, a cockpit) while processes a lot of information and puts in practice his/her psychomotor coordination skills*
O12	*The student is able to have enhanced empathy towards the actors of any working position (in this case, the pilot's working position)*
O13	*The student has good knowledge about the context in which the decision-making is performed (in this case, the knowledge of C1, C2, C3 and C4)*
O14	*The student is able to identify how a decision may affect to, or may be affected by, different aspects of the same problem (in this case, how a decision may affect to or may be affected by the processes conducted by the pilot or the navigation systems of an aircraft)*
O15	*The student is able to feel self-confident during the decision making process and also is able to have enhanced empathy towards the main affected actors (in this case, the pilots)*

Table 2. Performance objectives of the teaching experience

2.2 Methodology

To reach the pursued goals, a set of activities have been designed for the students, following the approach proposed by (Boix & Armisen, 2008) and summarized in Figure 2, in which the main characters, teachers and students, must interact with each other so that the second can learn and acquire the due competencies necessary to become a good professional.

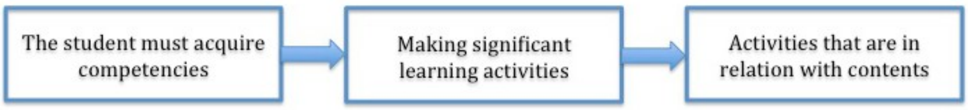

Figure 2. Methodology for the design of learning activities oriented to competencies

These learning activities have included the usage of an ES platform (i.e., a flight simulator) so the students can acquire the pursued competencies by means of a LbD approach. Therefore, the three ES components (i.e., Pedagogical, Game and Simulation) have been set in the following three sequential steps for the effective performance of the teaching experience.

2.2.1 Pedagogical component

First, the relationship between the contents of the subject and the specific performance objectives and competencies has been established (i.e., Pedagogical component of ES). Table 3 identifies some of the contents of the subject of Technologies and Procedures for Air Traffic Control and Navigation and puts them in relation with the competencies and objectives pursued. These objectives have been sorted in the table attending to the component (i.e., knowledge, skills or attitudes) of the related competencies.

Subject identifier	*Subject content*	*Competency components*	*Competencies related*	*Objectives related*
SC1	*Concepts, procedures and technologies applied to the air navigation*	*Knowledge*	*C1, C2, C3, C4, C6*	*O1, O3, O6, O8, O13*
		Skills	*C6*	*O14*
		Attitudes	*C1, C3, C4, C6*	*O2, O6, O9, O14*
SC2	*Instrumentation available on-board for the navigation and control of an aircraft*	*Knowledge*	*C1, C2, C3, C4, C6*	*O1, O3, O6, O8, O13*
		Skills	*C2, C4, C6*	*O4, O9, O14*
		Attitudes	*C1, C3, C4, C6*	*O2, O6, O10, O15*
SC3	*Practical use of cockpit instruments and navigation procedures*	*Knowledge*	*C1, C3, C6*	*O1, O6, O13*
		Skills	*C2, C4, C5, C6*	*O4, O9, O11, O14*
		Attitudes	*C1, C2, C3, C4, C5, C6*	*O2, O5, O7, O10, O12, O15*
SC4	*Practical understanding of the multiple tasks and difficulties arisen at the pilot's working position*	*Knowledge*	*C1, C2, C3, C6*	*O1, O3, O6, O13*
		Skills	*C5, C6*	*O11, O14*
		Attitudes	*C1, C2, C3, C4, C5, C6*	*O2, O5, O7, O10, O12, O15*
SC5	*Deeper and practical understanding about the difficulties of executing 4D trajectories (SESAR context)*	*Knowledge*	*C1, C2, C3, C4, C6*	*O1, O3, O6, O8, O13*
		Skills	*C2, C4, C5, C6*	*O4, O9, O11, O14*
		Attitudes	*C1, C2, C3, C4, C5, C6*	*O2, O5, O7, O10, O12, O15*

Table 3. Subject Contents and their relationship with the competencies and objectives

2.2.2 Game component

After the definition of the Pedagogical component, the activities to be executed by the students in classroom have been developed (i.e., Game component of ES). The idea is to design some exercises that make use of a flight simulator so that the students can adopt the role of a pilot and thus assimilate in practice the theoretical concepts seen in class and improve their skills while at the same time they can enjoy of the learning process, thus generating positive attitudes towards the subject and the concepts learnt. Attending to the Pedagogical component stated in Table 3, i.e., competencies to be acquired and their relation with the subject's contents, the following activities have been designed:

- Piloting experience. Initially, during the first contact with the flight simulator, the activities must be driven to allow the students to get used to the controls and manoeuvrability of the aircraft when it is airborne. The first activity requires the student flying straight while maintaining constant altitude and also maintaining constant other certain flight parameters. Later, when the students can stabilize the aircraft, they can start to manoeuvre the aircraft, performing some controlled turns and changing the flight level by ascending and descending the aircraft with a controlled vertical speed. These exercises are not trivial for beginners and they present different levels of difficulty depending on the aircraft type used (in general, the bigger the aircraft the more difficult its stabilization during the flight).
- Air navigation, from theory to practice. This activity aims at showing the historical evolution of the air navigation, a problem that involves two unknowns, i.e., which is the current position of the aircraft and how to reach a desired destination in the most optimal way possible. In the first place, the students are requested to use charts and visual references to know where they are while still commanding the airborne aircraft (as pilots traditionally did in the past and still sometimes do). Later they are introduced to the radio-navigation instruments available on-board: ADF (Automatic Direction Finder), which makes use of the ground navigation aid called NDB (Non Directional Beacon), and VOR/DME (Very High Frequency Omnidirectional Range/Distance Measure Equipment); see Martínez and Belda (2000). Such exercise allows the students to have a more practical view of the navigation concepts seen in the theoretical classes, and also having a better "in situ" understanding of how these

technologies actually help the pilots in their tasks, specially during severe climatologic conditions (e.g., dense fog or severe thunderstorm, among others), which are also introduced in the exercises.

- Modern technologies for flight control and navigation. Once the students have understood (and lived) the difficulties related to the control and navigation of an aircraft, they are introduced to the most modern technologies developed to aid pilots in those complex tasks. In particular, they are able to manage a navigational system that use Global Navigation Satellite Systems technologies (i.e., GNSS, which include GPS, Galileo and GLONASS satellite constellations), that combined with the radio-navigation and inertial systems altogether provide to the pilots with higher accuracy of the flight tracking information, with more interdependency with respect to the ground radio-navigation aids and with an improved displaying of the information and pilot-system interaction. Finally, the students are able to activate and configure different types of autopilots, thus observing how easy it turns the execution of the same tasks that they previously did manually with difficulties in the above activities (note that some of the current autopilots are able to land an aircraft with very little/almost null intervention of the pilot). After that, the students are more sensitive to understand the complexity and value of the incoming 4D navigation systems, which are currently being under development introducing even higher levels of automation to enable a future air traffic management system (i.e., SESAR) which aims at being more precise, safer and efficient than the current one.

Table 4 shows the relationship among the activities and each of the contents and objectives related. Note that the three activities designed are related directly or indirectly with all the subject contents and thus will all the performance objectives. It occurs because all these contents are unavoidably present during the three flight simulation activities. However, the sequence order of these activities allows introducing more subject contents and extra milestones difficulty in a progressive way, and until all the subject contents are fully –and consciously– managed by the students.

Activity identifier	*Activity*	*Contents directly related*	*Contents indirectly related*	*Objectives related*
A1	*Piloting experience*	*SC2, SC3, SC4*	*SC1, SC5*	*All* *(directly or indirectly)*
A2	*Air navigation, from theory to practice*	*SC1, SC2, SC3, SC4*	*SC5*	*All* *(directly or indirectly)*
A3	*Modern technologies for flight control and navigation*	*SC1, SC2, SC3, SC4, SC5*		*All* *(directly)*

Table 4. Activities and their relationship with the subject contents and objectives

2.2.3 Simulator component

As a third step, the components to install a functional flight simulator have been chosen and configured (i.e., Simulator component of ES). Note that the diversity of software and hardware components available nowadays to perform a flight simulation for training purposes is huge (Aguado & Ruiz, 2013) and that many different components have been designed to set up different kind of Flight Simulation Training Devices (FSTDs) in order to provide to the users with different functionalities, qualities and with different levels of realism (EASA, 2008). Thus, the selection of the most appropriate combination of software and hardware for the purposes of the teaching experience must take into account the actual needs to perform the activities in the classroom.

For instance, some of the FSTDs are used to train pilots (civilian and military) in the commanding of different kinds of aircraft under different circumstances, thus requiring software and hardware able to represent the aircraft dynamics and the boundary conditions of real operations with maximum realism (Sánchez, 2012). In such cases, it might be recommendable to use a Full Flight Simulator (FSS), which is a perfect replica of a certain aircraft cockpit that includes full realistic motion and maximum quality and realism in the sound and video recreated. Of course the price and the complexity of both the software and the hardware is very high as well as the difficulty to operate the flights, which altogether suppose a level of realism that must be considered “excessive” for the purposes of this teaching experience.

Nonetheless, since the target of the experience is inducing the students to feel like walking in the pilot’s shoes, the appropriate flight simulator must still include an acceptable level of realism for the representation of the flight dynamics under different weather conditions and also include a minimum cockpit representation to allow the practice of the most common procedural aspects (and for which a maximum level of realism in the simulations is not required). This kind of flight simulator is referred in EASA (2008) as a Basic Instrument Training Device (BITD), which are much more cheaper than FSSs, easier to set up and also easier to command, thus being ideal for the purposes of this teaching experience.

Furthermore, there are others requirements that are also important to design and set up the flight simulator platform. In particular, the system must be useful for different purposes, including (but not limited to) the teaching experience proposed that should allow the users reaching the learning goals through the experimentation of the role of a pilot, it must be efficient, meaning that it should allow the users reaching the goals defined and the role experimentation of a pilot with the minimum (economic) resources, it must be easy to use and ergonomic in order to allow a fast learning curve for its usage, and it must have a reasonable cost (including installation) with regards to the academic objectives pursued. Finally, the system must be reliable, i.e., the probability of failure or error must be the lowest possible; robust, so it can stand the test of the time and the usage by different users (in particular, students); and polyvalent, in order to can be used for different kind of teaching and research activities.

After a comprehensive analysis of the market options, and taken into account all the above requirements, the software chosen to perform the flight simulations has been the Microsoft Flight Simulator X, whereas the hardware components have been a medium-power computer (Intel i5 CPU with 4GB of RAM and with a dedicated graphical card featuring HDMI out), a 24 inches high-resolution flat screen, and the specific flight simulator component “Saitek Pro Flight System”, which is composed by a yoke and throttles that are robust, ergonomic, easy-to-install and present a good quality-price relationship. Rudder pedals have not been found to be necessary for the purpose of this teaching experience, although their introduction could be considered to increase the realism during the practice of the flight exercises. See Figure 3.

Figure 3. Flight simulator cockpit view (Yoke and throttle). Flight instruments are software-simulated thus enabling different cockpits and views, e.g.: Cessna 172 (left), Boeing 737 (right)

2.3 Assessment methods for the teaching experience

The evaluation of competencies requires the alignment and combination of different types of assessment methods, due to the different nature of the components that compose the competencies, i.e., knowledge, skills and attitudes (Yániz & Villardón, 2006; McDonald, Boud, Francis & Ginczi, 2000). This approach is often referred as Authentic Assessment (De Miguel, 2005; Herrington & Herrington, 1998). In order to evaluate this teaching experience and the degree of achievement of the goals pursued (Tables 1 and 2), four different assessment methods have been considered: an objective test of knowledge, an execution test, observation techniques, and an attitude and opinion survey. Each assessment method is further explained in the following subsections, and Table 5 shows which of the objectives have been evaluated with each of the assessment methods.

Assessment method	O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	O13	O14	O15
Objective test	X		X			X		X					X	X	
Execution test	X			X		X			X		X		X		
Observation techniques		X			X						X	X			X
Attitude and opinion survey		X					X			X				X	X

Table 5. Assessment methods and objectives assessed

2.3.1 Objective test

A short objective test has been prepared and filled by the students in order to evaluate whether they have assimilated and learnt the concepts explained during the flight simulation activity, i.e., to evaluate the knowledge component of competencies C1, C2, C3, C4 and C6 (also the skills component of C6 is evaluated). The test is a multiple-choice test with five questions and four possible answers each (only one is correct). The test can be seen found in the following table 6.

Question	Statement
1	*The flight basic instruments which provide altitude indication and heading to the pilot, are respectively:* *a. Altimeter and Attitude indicator (Artificial horizon).* *b. Altimeter and Vertical speed indicator (Variometer).* *c. Altimeter and Heading indicator (Directional gyro).* *d. Airspeed indicator and Heading indicator (Directional gyro).*
2	*What does Air Navigation mean?* *a. The science and technology that aims to determine the height of an airplane relative to the ground and maintain exactly the desired route.* *b. The science and technology that aims to determine the position of an aircraft relative to the surface of the earth and accurately maintaining the desired path.* *c. The science and technology that aims to determine the position of an airplane.* *d. The science and technology that aims to keep exactly the desired route of an airplane relative to the surface of the earth.*
3	*Two of the some radio navigation aids that provide information to the pilots for carrying out a safe flight under adverse meteorological conditions (fog, thunderstorms, blizzard, etc.), are:* *a. Airspeed indicator and VOR/DME.* *b. ADF and VOR/DME.* *c. ADF and HSI.* *d. VOR/DME and Variometer.*
4	*What system will allow to airplanes to being totally independent from the ground stations?* *a. GPS navigation system.* *b. Galileo navigation system.* *c. GLONASS navigation system.* *d. All the above.*
5	*A satellite-based navigation system will allows…* *a. Airspace "optimization".* *b. Cost reduction.* *c. Reduced flight time.* *d. All the above.*

Table 6. Knowledge test

In order to asses the effectiveness of the teaching experience to enhance the knowledge of the students the test has been requested to the students six weeks after the flight simulation experience without previous notification (the test has been used to assess the teaching experience only, thus it did not count to pass the course).

2.3.2 Execution test

The execution test has been prepared with a set of milestones to be accomplished by the students during the flight simulation as a way to assess the skill component of the competencies C2, C4 and C5, and also the knowledge component of the competencies C1, C3 and C6. The flight instructor (i.e., the teacher) has been guiding and assessing the correct achievement of the milestones during the execution of the activities seen in Table 4. In addition, the flight instructor has been giving the necessary information at each precise moment of the activity, in order to facilitate to the students interiorizing the knowledge, skills and techniques, and attitudes pursued. See Fig. 4.

The flight simulation activities have been performed with two students per machine, one of the students of each group has been commanding and navigating the aircraft for a while, whereas the other has been observing and helping as a co-pilot (they have exchanged positions during the activity).

Figure 4. The teacher has guided and assessed the correct execution of the activities

2.3.3 Observation techniques

The introduction of observation techniques is an interesting assessment method considering that the evaluation of some of the competency components pursued in this teaching experience, in particular the attitudes, are difficult to evaluate with objective or execution tests, such as the level of interest of the student in relation with the contents of the subject, the understanding of the feelings of a pilot during a flight or the level of self-confidence of the student towards the pilot's working position (i.e., competencies C1, C2, C5 and C6). Therefore, these competency components have been partially evaluated through some observation techniques applied during the execution of the flight simulation exercises (the skill component of C5, i.e., ability to rapidly adapt to a new situation has been also evaluated through observation). In particular, the teacher has been aware about the comments spontaneously verbalized by the students in order to find traces that reveal the presence and/or development of the pursued attitudes. When the students have not spontaneously made such comments (or reactions) the teacher has requested the feedback about the current feelings, opinion and expectative in order to perform the assessment.

2.3.4 Attitude and opinion survey

Finally, the same 38 students that did the exercises of the teaching experience have been also requested to fill a short survey in order to assess some of their attitudes (in particular the attitude components of C1, C3, C4 and C6) and also their opinions towards the flight simulator activity and their elements. The complete survey with 16 questions can be found in the following table 7. The rating scale for the survey has been defined as follows: 1 = Strongly disagree or very low rating; 2 = Disagree or low rating; 3 = Neutral; 4 = Agree or high rating; 5 = Strongly agree or very high rating.

Items/questions to evaluate
1. The Flight Simulation (FS) activity has helped to me to understand the subject's concepts better.
2. The FS activity has increased my interest for the subject.
3. The theoretical content of the activity is well structured.
4. The theoretical part is suitably integrated with the practice part.
5. FS practice has helped to me to learn new things.
6. I have found interesting the FS activity.
7. The FS software has been useful for doing the activity.
8. The FS hardware (yoke and throttles) has been useful for doing the activity.
9. Value the degree of difficulty of the exercises performed.
10. Value your level of satisfaction with the activity.
11. Extra time is necessary to develop the activity better.
12. After doing the FS activity I have increased my general knowledge regarding the subject.
13. The teacher/instructor of the FS activity has expressed with clarity.
14. The teacher has used useful examples to explain the subject.
15. The teacher has shown enthusiasm for the subject.
16. Do you think that is necessary more content as seen in this activity in the Aeronautical Management Degree?

Table 7. Attitude and opinion survey

3 RESULTS

The following subsections provide the results obtained for each of the assessment methods.

3.1 Objective test

The objective test has been answered by 38 of a total of 40 students that performed the Flight Simulation activity. The results obtained show that the 92,11% of the students (i.e., 35 students) have successfully passed the test, while only 3 students have failed the test with a mark of 2 out of 5 (three questions answered correctly have been considered the threshold to pass the exam). The most frequent marks have been "3" and the "4" with a number of students of 13 and 20 respectively. Only three of them have got the maximum punctuation, a mark of 5.

The results can be analysed question by question. The first query has been answered correctly by 28 of the 38 students, which means a success rate of 73,68%. The number of students that have answered correctly the next second, third and fourth questions have been 22, 15 and 34 respectively, and its corresponding success rates are 57,89%, 39,47% and 89,47%. The fifth and last question has been answered correctly by 37 of 38 students, which means a success rate of 97,37%.

Note that it was expected from the beginning that the second and third questions were the most difficult to answer, since these queries show ambiguous answers due to the use of acronyms in the third and due to the use of tricky definitions in the second. Nevertheless, the second question was expected to be the most failed question and not the third one as finally occurred.

It is important to point out that this test has been requested to the students six weeks after the flight simulation experience and they were not informed that the test was going to be requested (the test has been used to assess the teaching experience only, thus it did not count to pass the course).

The same test has been requested to other two control groups in order to contrast the test results with other students that have not carried out the learning experience, thus assessing the effectiveness of the teaching experience. The first of these control groups has been formed with students that are not related to Aeronautical Management studies. This group has been referred as Group X: Non-AM. The second control group has been composed with students of Aeronautical Management that have still not taken the course of Technologies and Procedures for Air Traffic Control and Navigation and thus they have not learnt from the teaching experience presented here. This group has been referred as Group Y: AM pre-experience. Finally, the group that has been learning with the teaching experience and that after has been evaluated is referred as Group Z: AM post-experience. Table 8 shows for these three groups the statistical summary of the test results.

Statistical parameters	*Group X: Non-AM students*	*Group Y: AM Pre-experience*	*Group Z: AM Post-experience*
Sample size, n_x	$n_x = 39$	$n_y = 41$	$n_z = 38$
Sample mean, $\overline{X}$	$\overline{X} = 1.8462$	$\overline{y} = 2.4878$	$\overline{Z} = 3.5789$
Sample variance, S_x^2	$S_x^2 = 1.0810$	$S_y^2 = 1.2061$	$S_z^2 = 0.5747$
Proportion of passing marks, $\hat{p}_x$	$\hat{p}_x = 28.21\%$	$\hat{p}_y = 53.66\%$	$\hat{p}_z = 92.11\%$

Table 8. Statistical summary of the three group samples

Hypothesis test id	*H_0*	*H_1*	*Contrast statistic*	*p-value*	*Result ($\alpha = 0.03$)*
HT1	$P_y - P_x \leq 0$	$P_y > P_x$	$Z=\frac{\hat{p}_y-\hat{p}_x}{\sqrt{\hat{p}_0(1-\hat{p}_0)(\frac{n_y+n_x}{n_y . n_x})}}=2.3116$ $\hat{p}_0=\frac{n_x . \hat{p}_x+n_y . \hat{p}_y}{n_x+n_y}$	0.0104	$H_1 : P_y > P_x$
HT2	$P_z - P_y \leq 0$	$P_z > P_y$	$Z=\frac{\hat{p}_z-\hat{p}_y}{\sqrt{\hat{p}_0(1-\hat{p}_0)(\frac{n_z+n_y}{n_z . n_y})}}=3.8090$ $\hat{p}_0=\frac{n_z . \hat{p}_z+n_y . \hat{p}_y}{n_z+n_y}$	0.0001	$H_1 : P_z > P_y$
HT3	$P_z - P_x \leq 0$	$P_z > P_x$	$Z=\frac{\hat{p}_z-\hat{p}_x}{\sqrt{\hat{p}_0(1-\hat{p}_0)(\frac{n_z+n_x}{n_z . n_x})}}=5.7163$ $\hat{p}_0=\frac{n_z . \hat{p}_z+n_x . \hat{p}_x}{n_z+n_x}$	0.0000	$H_1 : P_z > P_x$
HT4	$\mu_y - \mu_x \leq 0$	$\mu_y > \mu_x$	$Z=\frac{\overline{y}-\overline{x}}{\sqrt{\frac{S_y^2}{n_y}+\frac{S_x^2}{n_x}}}=2.6844$	0.0036	$H_1 : \mu_y > \mu_x$
HT5	$\mu_z - \mu_y \leq 0$	$\mu_z > \mu_y$	$Z=\frac{\overline{z}-\overline{y}}{\sqrt{\frac{S_z^2}{n_z}+\frac{S_y^2}{n_y}}}=5.1702$	0.0000	$H_1 : \mu_z > \mu_y$

Hypothesis test id	H_0	H_1	*Contrast statistic*	*p-value*	*Result* ($\alpha = 0.03$)
HT6	$\mu_z - \mu_x \leq 0$	$\mu_z > \mu_x$	$Z = \frac{\bar{z} - \bar{x}}{\sqrt{\frac{S_z^2}{n_z} + \frac{S_x^2}{n_x}}} = 8.3718$	*0.0000*	$H_1 : \mu_z > \mu_x$
HT7	$\sigma_y = \sigma_x$	$\sigma_y \neq \sigma_x$	$F = \frac{S_y^2}{S_x^2} = 1.1158$	*0.3682*	$H_0 : \sigma_y = \sigma_x$
HT8	$\sigma_z \leq \sigma_y$	$\sigma_z > \sigma_y$	$F = \frac{S_y^2}{S_z^2} = 2.0987$	*0.0124*	$H_1 : \sigma_z > \sigma_y$
HT9	$\sigma_z \leq \sigma_x$	$\sigma_z > \sigma_x$	$F = \frac{S_x^2}{S_z^2} = 1.8810$	*0.0286*	$H_1 : \sigma_z > \sigma_x$

Table 9. Hypothesis tests comparing the results of the three groups

According to Table 8 important differences can be observed between the performances of the three groups. Table 9 shows the statistical results for different hypothesis tests (Newbold, 2001) that make comparisons among the three groups with regards to the proportion of students that have passed the exam (i.e., *HT1*, *HT2* and *HT3*), the average number of correct answers (i.e., *HT4*, *HT5* and *HT6*), and the variance that describes the variability of correct answers within each group (i.e., *HT7*, *HT8* and *HT8*).

The *p*-values that have been calculated indicate that all the null hypotheses, H_0, can be rejected with a significance level of $\alpha = 0.03$, thus having strong statistical confidence in the rejection of the hypothesis (97% of confidence), except in the case of *HT7* that should be accepted even for much higher significance levels (up to $\alpha = 0.6882$). The null hypothesis, H_0, can be rejected in favour of the alternative hypothesis H_1 for any value of the contrast statistic higher than the significance level α and with a confidence level of $\gamma = (1 - \alpha)\cdot 100\%$. The *p*-value of the contrast can be interpreted as the critical significance level value such that if $\alpha \geq$ *p-value* the null hypothesis H_0 can be rejected (with a confidence level of $\gamma = (1 - \alpha)\cdot 100\%$) and if $\alpha <$ *p-value* cannot (in such a case it is often said that H_0 is "accepted"). In the cases shown in Table 9 all the null hypotheses can be rejected with a significance level $\alpha = 0.03$ and with a confidence level of 97% (they some of them can be rejected even for higher confidence levels), except in the case *HT7* in which H_0 cannot be rejected with such level of confidence (thus it should be accepted).

These results mean that there is strong statistical evidence that confirm the differences among the three groups. Only a 28.21% of the students of Group X have successfully passed the exam, whereas a 53.66% of the students of Group Y have done so. This result suggests that all the students of Aeronautical Management already had previous knowledge about some of the concepts questioned in the test. Nevertheless, the fact that the 92.11% of the students that have taken the teaching experience have passed the test, together with the fact that the average number of correct answers, $\bar{z}$, is significantly higher than $\bar{x}$ and $\bar{y}$, suggests that the teaching experience has positively enhanced the knowledge of the Group Z students. In addition, another finding that should be remarked is that the variability of the groups X and Y, i.e., S_x^2 and S_y^2, are statistically equal, while the variability of Group Z, S_z^2, is significantly smaller. This fact suggests that after the teaching experience the knowledge of the students has converged (i.e., the knowledge seems to have been unified among all the students) while the number of questions correctly answered "by-chance" seems to have been reduced. Figure 5 summarizes these results in a graphical manner.

The high success rate of the students passing the exam indicates that objectives O1, O3, O6, O8, O13 and O14 have been successfully achieved and as a consequence the competencies related have been enhanced.

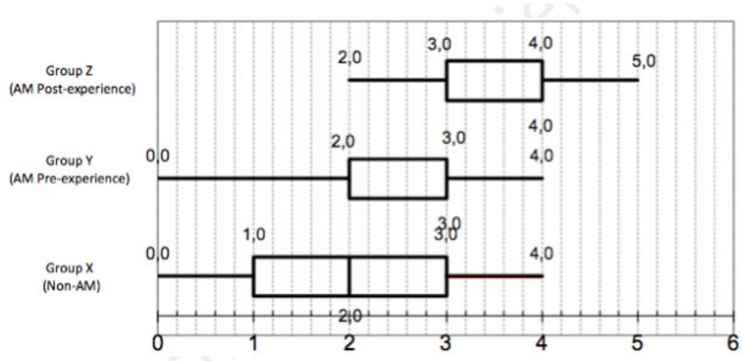

Figure 5. Box diagram with the statistical results of the three compared groups

3.2 Execution test

During the teaching experience all the students have been able to follow all the exercises proposed, although with high heterogeneity with regards to the levels of precision during the execution of the manoeuvres (i.e., some of the students were already used to manage flight simulators whereas for other it was their very first contact). Therefore, the successful execution of the exercises designed indicates the consecution of the objectives O1, O4, O6, O9, O11 and O13.

3.3 Observation techniques

In general, all the students have shown high levels of concentration during the activities and explanations whereas they seemed to enjoy the experience as expected (see Fig. 6). This fact, together with the verbal feedback obtained, suggests that the objective O2 has been achieved (i.e., the students showed interest for the subject) and thus the competency related, i.e., C1, has been successfully enhanced for most of the students.

During the execution of the activities, many students spontaneously verbalized some attitude changes regarding the pilot working position, with sentences such as “I did not know that the process of flying required to be so calmed down, whereas the speed of the flight is so fast”. The identification of this kind of sentences during the execution allows stating that the student can now understand in a deeper way the tasks, feelings and logical thinking of the pilots (objectives O5, O12 and O15). When the students did not spontaneously express their feelings, the teacher directly requested their opinion and thinking. All the students, except the ones with previous experience in flight piloting, admitted a deeper understanding of the feelings, reasoning and worries related to the pilot’s working position after the simulation experience.

At the beginning of the exercises some of the students were notably anxious by the fact of being in the working position of a pilot by their very first time, a feeling that was emphasised by the fact that they had to process a lot of new information, had to learn very fast how to manipulate the command and navigation instruments and at the same time they had to coordinate all the actions required to accomplish the milestones of the activities. After some minutes of (guided) practice, it was observed that all the students were able to adapt to the new situation while most of them showed higher levels of self-confidence than at the beginning of the activities. These observations suggest that objectives O11 and O15 have also been achieved successfully.

Figure 6. The students presented high levels of concentration

3.4 Attitude and opinion survey

To facilitate the assessment of the attitudes and opinions generated by the teaching experience, the questions of the survey can be re-grouped an analysed in groups of related meanings.

Questions 7, 8 and 14 are fairly illustrative of the satisfaction levels regarding the Simulation component of the teaching experience (see Fig. 7). In particular, questions 7 and 8 show that most of the students found the flight simulation system (both hardware and software) to be highly appropriate for the purposes of the activities. Specifically, the 97% of the students agreed or strongly agreed with the question 7 and the 89% with question 8, whereas the rest remained neutral. Question 14 shows that the major part of the students has considered useful the ability of the flight simulation system to recreate realistic scenarios that were used for educational purposes. Specifically, the 82% of the students agreed or strongly agreed, whereas only a 5% disagreed and the rest remained neutral.

Note that to answer these questions (i.e., 7, 8 and 14) the students have needed to analyse which of the aeronautical technologies available in the cockpit have been used during the exercises, and then determine the levels of realism provided by the simulation components in relation to the activities proposed during the teaching experience. The high levels of satisfaction obtained in these items suggest that the students must have taken into account the usefulness of abstracting some of the instruments and procedures required in real flight executions (the simulation components are part of a Basic Instrument Training Device and thus they are relatively simplistic and austere) in order to ease a basic training of the commanding and navigation skills. Such (most likely) reasoning indicates that the students are now able to perform critical thinking with regards the aeronautical technologies present in the cockpit, and thus the objectives O7 and O10 (i.e., critical thinking) can be considered as achieved. Under the same arguments, also the objective 14 (i.e., ability to identify how a decision may affect or may be affected by the pilot or the cockpit instrumentation) should be considered as successfully observed.

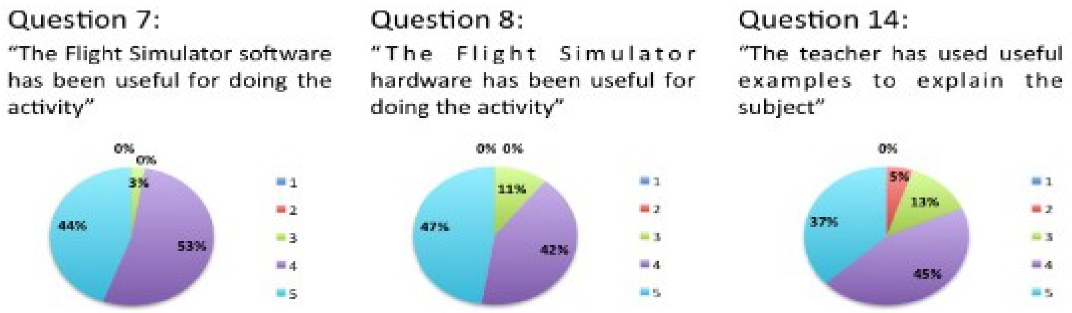

Figure 7. Survey questions related to the Simulation component

Questions 2, 6 and 9 illustrate the evaluation with respect the Game component of the teaching experience (see Fig. 8). In particular, question 6 shows that most of the students have found the activity to be interesting (90% agreed or strongly agreed), while question 2 shows that students have increased their interest on the subject due to such activity (82% agreed or strongly agreed). These results are directly related with the successful consecution of objective O2 and confirm the assessment done through observation of attitudes during the execution of the activities. Question 9 shows that the difficulty of the flight simulation exercises has been considered adequate in average: the 53% considered neutral/medium difficulty, the 24% considered the exercises to be difficult (although no one found them very difficult), and the 23% considered the exercises to be easy or very easy (note that some of the students were familiar to flight simulators whereas for some of them this activity was their very first contact). Note that the perception of the difficulty is a direct reflex of the self-confidence levels regarding the flight navigation activities performed. The fact that the levels of difficulty perceived are well balanced in average suggests that the competences related to objective O15 (i.e., ability to feel self-confident in the context of flight commanding and navigation) have been achieved.

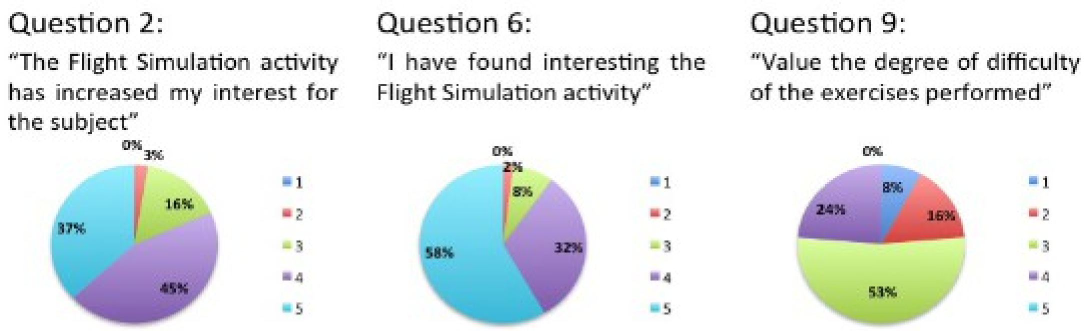

Figure 8. Survey questions related to the Game component

Regarding the Pedagogical component, the questions 1, 5 and 12 allows stating that the students have perceived the activity as valuable from the point of view of the learning process (see Fig. 9). Note that in questions 1 and 5 more than 75% of the students recognized that the activity has contributed or strongly contributed to their learning process, whereas in question 12 (that refers to the amount of knowledge acquired in relation to all the contents of the subject) this percentage has diminished up to 63%. This could be attributed to the fact that the flight simulation activity represents no more than 5% of the concepts seen in the subject during the entire course. In any case, these results contribute to reinforce that the objective O1, O2, O14 and O15 have been achieved.

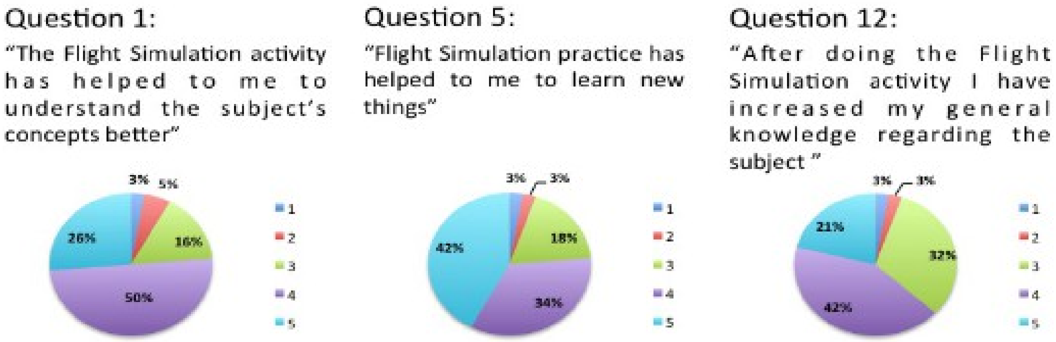

Figure 9. Survey questions related to the Pedagogical component

Finally, questions 10, 11 and 16 allow evaluating the perception of the students with regards to the ES activity as a whole (see Fig. 10). In particular, question 10 directly asks for the levels of satisfaction, and again more than 75% of the students have agreed that the activity has been satisfactory or highly satisfactory, whereas only a 6% disagreed (no one strongly disagreed) and the rest remained neutral. Questions 11 and 16 illustrate that students demand for extra activities similar to the ones presented in this paper. Specifically, a 79% agreed or strongly agreed to question 11 and an 82% agreed or strongly agreed to question 12. To be remarked that the 69% of the students strongly agreed with the idea that this kind of Educational Simulation activities should be also introduced in other subjects of the degree (only a 5% disagree to such idea and no one strongly disagreed).

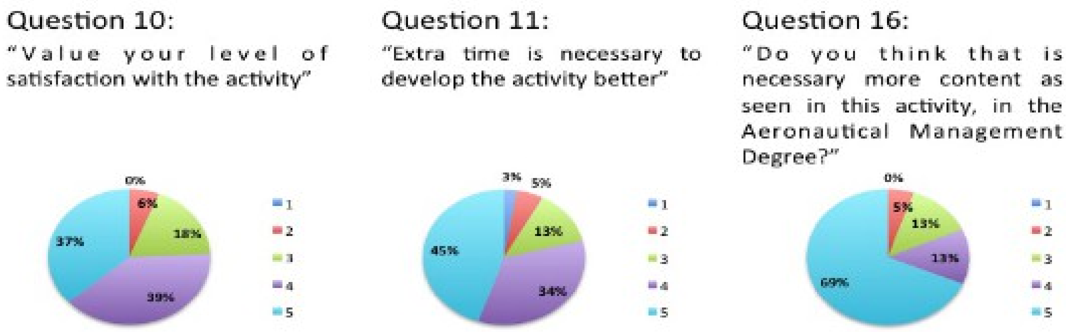

Figure 10. Survey questions related to the Educational Simulation activity as a whole

4 CONCLUSIONS

A Learning-by-Doing teaching experience that has made use of an Educational Simulation system has been performed and presented in this paper. Specifically, a basic flight simulation environment has been set up, which has allowed the students experimenting and conducting some of the most common tasks of an aircraft pilot. The activity has been designed for students of the degree on Aeronautical Management in order to improve their competencies in the field of the air transportation, specifically providing them with a clearer picture about the most important processes that are involved in the commanding and navigation of an aircraft (including the pilot's logical reasoning), as well as increasing their ability to understand and detect potential areas of improvement based on the use of the new technologies and higher levels of automation. Such capabilities may contribute in turn to improve the decision-making competencies of the students in their future professional working positions related to the air transportation market.

The acquisition by part of the students of some of the pursued competencies (knowledge, skills and attitudes related to aircraft commanding and navigation) has been successfully observed and assessed during the execution of the activities. In addition, after the execution of the teaching experience it has been evaluated with an objective test and an attitude and opinion survey, both filled by 38 students six weeks later and without any previous announcement (i.e., surprise exam). After analysing the results of the different assessment methods used (i.e., objective test, execution test, observation techniques and attitude survey) it can be argued that the teaching experience has been a success in terms of the objectives pursued.

The results have indicated that the students have learned and assimilated the pursued concepts of flight commanding and navigation with a very high success rate, i.e., the 92,11% of students have passed the surprise exam while all the students succeed in the execution test and in the evaluation of attitudes. Furthermore, according to the results of the opinion survey, it can be stated that the acquisition of the software and hardware products used for the flight simulation experience has been a wise decision. Finally, the levels of satisfaction with regards to the Educational Simulation experience have been also very high, showing that most of the students have enjoyed the experience while they admit that these activities have contributed to their learning process; congruently, they express a demand for extra similar Educational Simulation activities as part of their university studies.

As seen, Educational Simulation can provide to teachers with an interesting framework to perform highly effective learning experiences, in particular enabling the development of Learning-by-Doing activities that can facilitate the learning process of the students and also the acquisition of competencies that otherwise might be difficult to achieve.

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