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Using a serious game to complement CPR instruction in a nurse faculty

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ABSTRACT

Cardiopulmonary resuscitation (CPR) is a first aid key survival technique used to stimulate breathing and keep blood flowing to the heart. Its effective administration can significantly increase the chances of survival for victims of cardiac arrest. LISSA is a serious game designed to complement CPR teaching and also to refresh CPR skills in an enjoyable way. The game presents an emergency situation in a 3D virtual environment and the player has to save the victim applying the CPR actions. In this paper, we describe LISSA and its evaluation in a population composed of 109 nursing undergraduate students enrolled in the Nursing degree of our university. To evaluate LISSA we performed a randomized controlled trial that compares the classical teaching methodology, composed of self-directed learning for theory plus laboratory sessions with a mannequin for practice, with the one that uses LISSA after self-directed learning for theory and before laboratory sessions with a mannequin. From our evaluation we observed that students using LISSA (Group 2 and 3) gave significantly better learning acquisition scores than those following traditional classes (Group 1). To evaluate the differences between students of these groups we performed a paired samples *t*-test between Group 1 and 2 ($\mu_1 = 35, 67$, $\mu_2 = 47, 50$ and $p < 0.05$) and between students of Group 1 and 3 ($\mu_1 = 35, 67$, $\mu_3 = 50, 58$ and $p < 0.05$). From these tests we observed that there are significant differences in both cases. We also evaluated student performance of main steps of CPR protocol. Students that use LISSA performed better than the ones that did not use it.

1. Introduction

In last years, there has been a rapid growth of serious games in educational contexts [1,2]. Two main factors have motivated this change. On the one hand, the new teaching and learning paradigm where the learner becomes the center of the process, and practice takes an important role. On the other hand, the capacity of serious games to capture students attention and engage them in the exposed content by providing virtual environments to practice [3,4]. In medical context, the use of serious games started forty years ago. First, with the introduction of role-playing techniques and mannequins, and more recently with digital games [5,6]. Several studies showed that students prefer a serious-game based approach than the

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traditional one, even though the obtained scores were similar in both approaches [7–10]. The well-acceptance of this new teaching approach has led serious games to be an emerging focus of research and development.

Unfortunately, the design and creation of video games is costly in terms of time and effort, mainly due to the graphical interface that require and the narrative that is needed to support them. Three years ago, we started to develop LISSA, that stands for LIfe Support Simulation Activities, a serious game to teach and learn cardiopulmonary resuscitation skills [11]. Cardiopulmonary resuscitation (CPR) is an emergency lifesaving procedure that is done when someone's breathing or heartbeat has stopped. The procedure combines rescue breathing to provide oxygen to the lungs and chest compressions to keep oxygen-rich blood flowing until the heartbeat and breathing can be restored. Permanent brain damage or death can occur within minutes if blood flow stops. Therefore, it is very important that blood flow and breathing be continued until trained medical help arrives [12]. Since 1960, when Kouwenhoven et al. published an article stating that anyone, anywhere, could perform CPR, providing CPR has become an essential competency not only for expert but also for laypersons.

To teach CPR, different learning strategies have been proposed such as classical teaching strategies with mannequins, interactive videos and 3D simulation scenarios [13–16]. Below, we review some of them. On the one hand, there are video training applications such as Save-a-life [17], an interactive on-line video simulation that tests the player knowledge of helping someone suffering from sudden cardiac arrest; and CPR Choking [18], an application that provides instant information on how to perform CPR and how to aid a choking victim. On the other hand, there are handheld device applications such as CPR Game [19], a cardiac arrest simulator on iOS platform focused on advanced CPR training; iResus [20], an application for smart phone, designed to improve the performance of an advanced life support provider in a simulated emergency situation; iCPR [21,22], an iPhone application designed for both lay persons and healthcare professionals able to detect the rate of chest compressions performance by using the built-in accelerometer; M-AID [23], a first aid application for mobile phones that uses yes or no questions to judge an on-going situation giving to the user detailed instructions of how to proceed; CPR simulator [17], a set of CPR exercises including adult, child and infant CPR simulator that runs through the CPR sequence and Viva!CPR [24], a smartphone application from the Italian Resuscitation Council addressed to children and young adults to provide real time feedback on chest compression quality. Other applications are the Mini-Virtual Reality Enhanced Mannequin (Mini-VREM) [25] which is a CPR feedback device with motion detection technology including Kinect, sensor and software specifically designed to analyze chest compression performance and provide real-time feedback in a simulation training setting; AED Challenge [26], an application that provides online automated external defibrillation and CPR skill practice and testing with realistic scenarios; First-Aid game [28], a video game addressed to middle and high school students based on a low-cost software simulation with photo-realistic scenarios and simple interactions to introduce the theory of basic life support and the correct performance of its procedures; and LIFESAVER [16] a simulator proposed by the UK Resuscitation Council that fuses interactivity with live-action film. In the serious games context, some games for CPR training are JUST VR System [14] an immersive virtual reality situation training system for non-professional health emergency operators; MicroSim Pre-hospital [13] designed for pre-hospital training on emergency medical services, and Staying alive [27], an online 3D simulator which provides a learning experience of saving a virtual patient from cardiac arrest in 4 min; Relive [24] a first person 3D adventure where the player faces different rescue situations and can test the quality of his CPR, directly; Viva!Game [29], a Web-based serious game designed to create awareness on cardiac arrest and cardiopulmonary resuscitation [24]; and HeartRun [31], a mobile simulation game to train resuscitation and targeted at giving school children an understanding of CPR and getting them to take action.

Different studies assessed CPR instruction and results indicate that CPR skills decay within three to six months after initial training [30,32,33]. Therefore, as important as teaching CPR is the development of techniques to refresh and maintain CPR knowledge and skills. In this context, serious games can be suitable tools to tackle this problem since they can be used not only to complement CPR instruction but also to present new situations in order to refresh the protocol knowledge [34]. In this paper, we describe and evaluate the use of LISSA as a tool to complement CPR teaching in the Nurse Faculty of our university.

2. Material and methods

2.1. The serious game

2.1.1. Game description

LISSA is a serious game designed to complement CPR teaching and also to refresh CPR skills in an enjoyable way. Its target audience are students of CPR courses that require methods to carry out practice and complement mannequins instructions and also people that has CPR knowledge and require methods to refresh this knowledge. The game storyline turns around an emergency situation represented in a 3D virtual environment with the victim, the helper, and all the auxiliary tools that may require the emergency (see Fig. 1(a)). The game starts presenting the emergency situation with a description of the victim and the situation. The player takes the role of the helper and his mission is saving the victim applying the CPR actions in the correct way to obtain the maximum score. Incorrect actions and time delays are penalized decreasing player score and in the worst case leading to the victim death. One of the critical scenes of the game is when the player has to perform the CPR maneuver. The player has to place helper hands on the correct thorax position and perform compressions following the correct rhythm and the correct depth. After 30 compressions, the helper has to perform two rescue breaths in a ratio of 30 compressions and 2 ventilations. In the current version of the game chest compressions and ventilations are done via keyboard. The interfaces used to show on-line the player performance are shown in Fig. 1(c). These actions can be also done via Kinect [36], however for our experiments this option is not suitable since it requires several Kinect devices for the

(a) Main menu (b) CPR maneuver interfaces (c) Performance report

Fig. 1 – Two screenshots of the game and the performance report.

students. The game is over when one of the next situations is given: the victim recovers, the victim dies, or the ambulance arrives. In all the cases, it appears a final report with all actions performed by the helper (see Fig. 1(c)). In this way, students and teachers can analyze correct and incorrect actions.

Since LISSA is used to complement CPR courses, each player is assigned to a group of students with a supervising teacher. The user can play under teacher supervision or not. In the supervised mode all player actions are registered in the LISSA database and are followed by the teacher to provide advise. In the non-supervised mode the player compete with the students of his group to obtain one of the three best scores. LISSA registers time and score of the three best marks.

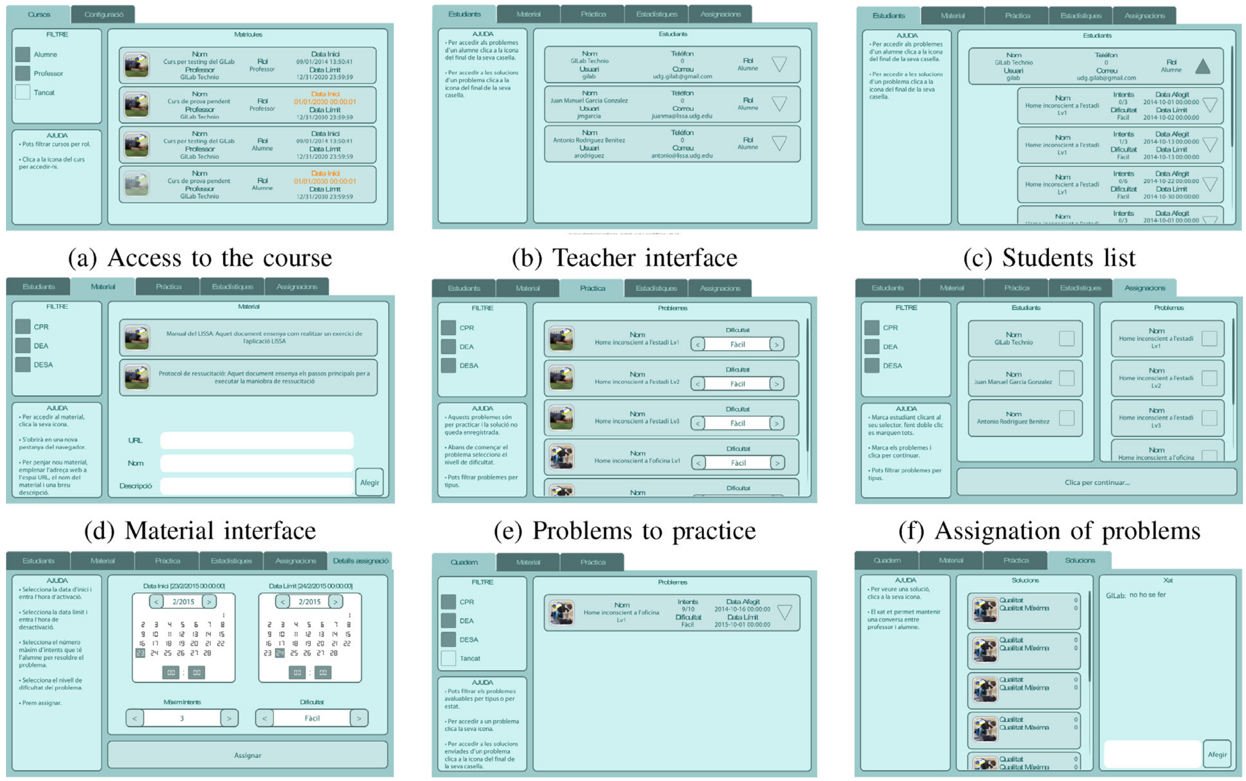
2.1.2. E-learning functionalities

LISSA supports two user profiles, teachers and learners, and provides different e-learning functionalities for each one (see Fig. 2). To describe these functionalities we are going to consider the emergency situation as a problem to be solved and the player actions as the solution to the problem. In our framework the learner is assigned to a course supervised by a teacher (see Fig. 2(a) and (b)). This teacher creates a workbook for each student and assigns problems to this workbook. Problems are selected from a common repository. Before assigning a problem the teacher fixes the deadline, the number of solutions that a student can propose, and the level of difficulty that determines the penalty of errors on the final score (see Fig. 2(e)–(g)). The teacher can also attach material to the course which can be consulted by the student (see Fig. 2(d)). When the learner enters into the game he accesses to a course (see Fig. 2(a) and (e)). In the course he can access to the workbook, the course material or the practice space (see Fig. 2(e)). In this last case, he can solve problems but the proposed solutions are not stored in the LISSA database, the students works in the non-teacher supervised mode. If he enters into the workbook he can select a problem and the proposed solution is stored in the database as well as the performance report. This report can be consulted by the teacher at any time. In this way, teacher can track all students work (see Fig. 2(c)). In addition, there is a chat to connect student and teacher (see Fig. 2(i)). This is only available in the teacher-supervised mode.

2.1.3. Architecture and implementation details

LISSA follows a client-server architecture composed of a set of systems and modules that have been implemented using different programming languages, environments, tools and data communication strategies. In Fig. 3 we present the general view of this architecture and below we describe it.

- The *Login System* is used to access LISSA. To enter LISSA the user requires a userID and a Password, both assigned by the LISSA administrator. Since LISSA is used as a complement to CPR courses we considered two accessing modes. The first one accesses LISSA directly using the *Online Web module* which has been implemented in `html` and `Webplayer`. In this mode, the userID and Password are codified and registered in the LISSA database and the Password can only be decoded using stored information related to the user and a private key. The second mode accesses LISSA via another application such as Moodle. This last option is required in centers that have their own learning management system and want to control students with their own system. The *External Login module* allows this integration and users can enter LISSA with the external password. To support this feature, we register user information in the LISSA database and when the external application sends a login request, a `PHP` compares request information with the stored one and controls via a session system that only correct users can enter into LISSA. The Login System also includes a *Local Administrator Web module* which is local for security purposes. This module has been implemented in `Qt` and is used to efficiently manage the database providing functionalities to create problems, create and remove users, add users from `CSV` files or modify passwords, amongst others. For security purposes when a new user is created the system automatically sends one e-mail with accessing information.
- The *Application System* contains the Simulation and e-Learning modules. The *Simulation module* creates the 3D scenarios that reproduce the emergency situation and controls all the actions performed by the user. To create the scene we modeled the CPR flowchart as a state machine where each state corresponds to one step of the flowchart and the transitions between states to the protocol procedures. The user actions performed on the menu (see bottom part of Fig. 1(a)) trigger the transitions. For instance, in the first state of the machine we present a victim lying on the floor and the helper next to him. If the player selects the correct action from the menu the corresponding animation will be triggered. In this case, if he selects *Check perimeter option*, the animation where we can see the helper turning



(a) Access to the course (b) Teacher interface (c) Students list (d) Material interface (e) Problems to practice (f) Assignation of problems (g) Setting assignation parameters (h) Student interface (i) Student's solutions

Fig. 2 – Some of the teacher and learner interfaces.

the head from one side to the other will be triggered. If an incorrect option is selected it will appear a message saying that the selected option is not correct. Once a correct action is done we go to the next state. Time and score are properly updated according to user actions (see top part of Fig. 1(a)). In addition, all the actions, correct and incorrect, are recorded to create a final report that appears when the game is over (see Fig. 1(c)). This module has been implemented in Unity3D. To improve performance, we create a unique scenario and load models dynamically according to

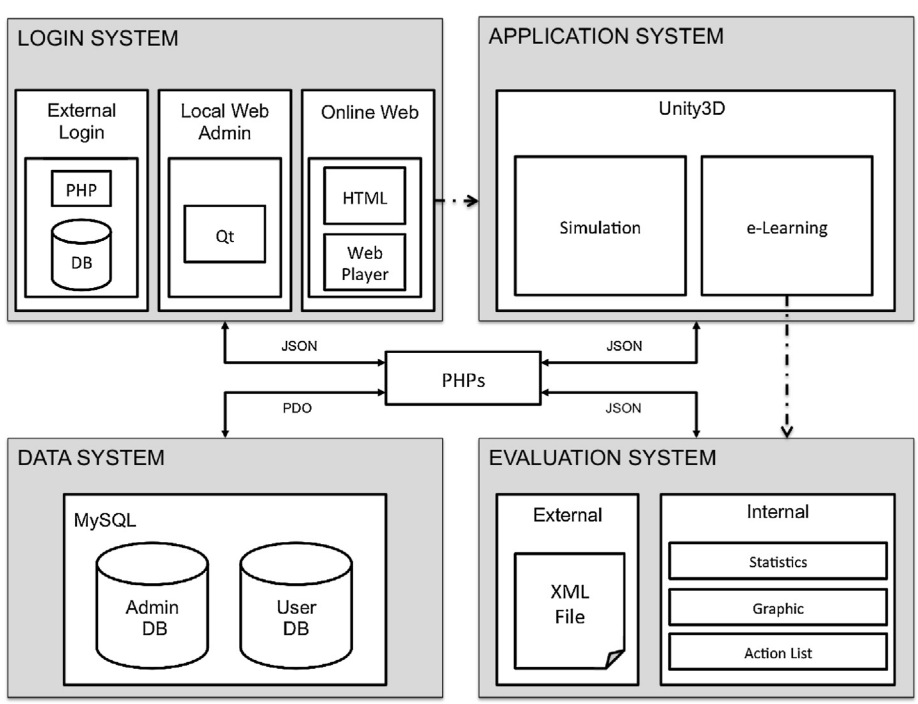


Fig. 3 – LISSA software architecture (see main text for details).

the step of the CPR flowchart that has to be represented. The states of the machine are independent and they have no information about other states. This makes the creation or modification of new situations easier since it has no effect on the other states. Focusing on the score, this is modified according to the level of difficulty of the problem. When the game starts the player has the maximum score and according to performed actions he can lose or gain points. He loses points when incorrect actions are done or when he spends more time than the given one. Penalties can be low, medium or high and loosed points vary according to this classification. In the same way bonus are obtained if actions are correctly performed. The levels of difficulty of the problems determine how these penalties and bonus have to be applied. Special attention is given to the rhythm of CPR maneuver.

The *e-Learning module* provides all teacher and student functionalities to assign exercises, material, etc. This module maintains the different interfaces that have been implemented in `Unity3D`. Interfaces have been programmed with tabs that change the page content. Teachers can see courses, students, assign problems to the students, assign material, check students solutions and communicate with the student, amongst others. Students can see material, the assigned problems and also their performance reports (see Fig. 2). In addition, there is a practice option that can be used both by teachers and students to practice with the different problems and computer with other students.

- The *Data System* maintains the administrator information related to courses, students and problems and also the user information such as students workbooks, problems, solutions, reports, etc. These modules have been implemented in `MySQL`. Administrator and user information are stored independently to preserve the system security. In addition, each user only accesses to his information and only the administrator has the information of all the users. To communicate with the database we used the `PDO` extension of `PHP` which improves system robustness to possible attacks. Moreover, we do not allow external requests but only from applications that are in our own server.
- The *Evaluation System* is composed of two different modules implemented in `Unity3D`. The *external module* is used to export course scores in a `xml` format which is very common in applications that exchange data. This module is used when the user wants to analyze data from an external application. The *internal module* provides functionalities to obtain statistics, or generate graphics and the actions list that will appear in the final report. All data about user actions is stored in the system database and we have implemented different functions to evaluate this data such as maximum score, minimum score, or number of attempts. In the statistics module we have implemented functions to obtain information on-line. All statistics are computed in the server and only relevant information required to show the results is send. The graphic module creates the graphics to illustrate CPR maneuver, it shows one plot for the compressions and another for the ventilations (see bottom of Fig. 1(b)). Graphics information is stored in a compressed way in the database and is downloaded only when it is necessary. The last module shows the list of actions performed by the player. Described systems are connected via `PHP` using `JSON` and `PDO` as it is illustrated in Fig. 3.

2.2. *Study participants*

The population of our testing scenario was composed of 109 nursing undergraduate students enrolled in the Nursing degree of our university. The undergraduate nursing program consists of four years with a spring and fall semester each year. Basic CPR skills are taught in the second year, in the subject of Performance in Emergencies. CPR is introduced at the beginning of the semester. Teachers provide students the European Resuscitation Council (ERC) [37] guidelines and a set of tests that have to be solved via Moodle. A self-directed learning methodology is used to acquire these contents. Students have to solve different tests sequentially. A test can be solved only when the previous one has been correctly solved. After theoretical teaching is completed, students are separated into small groups and continue their studies in the simulation laboratory under lecturer supervision.

2.3. *Laboratory setting*

The laboratory is equipped with a Resusci Anne Simulator, by Laerdal Medical Incorporation from Norway. This mannequin is a full-size patient simulator anatomically realistic with a host of features available for multiple learning objectives including: high quality airway management with a BVM and Supra-glottic airway devices; spontaneous breathing, ECG and live defibrillation; blood pressure; voice, lung and heart sounds for basic simulation training and Quality CPR (QCPR) feedback on the SimPad to measure and improve CPR performance. The laboratory is also equipped with a Laerdal AED Trainer 2 which provides a variety of simulations, or training scripts, to help responders become familiar with the automatic external defibrillator (AED) and allow them to demonstrate the basic skills necessary to use the AED in an emergency. In addition, there is the Laerdal PC SkillReporting System in compliance with Guidelines 2010 which is used in combination of the AED Trainer 2 and AED Resusci Anne.

2.4. *Assessment of student performance*

Each student is examined individually. The student enters in the laboratory and the teacher describes him the scenario. A victim has suddenly fallen down and is laying on the floor. The student has 1 min to explore the laboratory and then he starts the exercise. The teacher remains in the laboratory in front of a computer where he has loaded a rubric with the 15 items presented in Table 1 and the Laerdal Resusci Anne Wireless Skillreporter Software that analyzes the CPR maneuver. To define the rubric we follow the protocol defined by the ERC [37]. Below we describe the steps of the protocol and the related item from the rubric. When there is a victim lying on the floor, we have to proceed as follows. (i) Check perimeter to make sure the situation is safe (evaluated in ITEM 1). (ii) Check the victim for a response by gently shaking his shoulders and asking loudly if he is all right (evaluated in ITEM 2). (iii-a) If the victim responds, leave him in the position in

Table 1 – Items used to assess CPR laboratory sessions.

	RCP protocol	Evaluated skill
1	Check Perimeter	Make sure that you, the victim and any bystanders are safe
2	Check conscious	Check the victim for a response, gently shake his shoulders and ask loudly: Are you all right?
3	Ask for help	If victim does not respond shout for help
4	Open airway	Turn the victim onto his back and then open the airway using head; tilt and chin lift;
5	Check breath (position)	Check if the victim is breathing
6	Check breath (time)	Check breath during 10 s
7	Call Emergencies	If victim is not breathing call 112
8	Use AED	Correct AED use
9	Place electrodes	Check electrodes are placed in the correct position
10	Desfibrilation before 1′	First defibrillation is applied before 1 min
11	30 Compressions	The maneuver starts correctly
12	Correct rythm compressions	Compressions are performed correctly
13	Hands placement	Hands are placed correctly
14	Correct ventilations	Ventilations are done in the correct way
15	Correct sequence	The applied sequence is correct

which you find him, provided there is no further danger; try to find out what is wrong with him and get help if needed (This case is not considered in the practice). (iii-b) If he does not respond, shout for help (evaluated in ITEM 3), turn the victim onto his back and then open the airway using head; tilt and chin lift; place your hand on his forehead and gently tilt his head back; with your fingertips under the point of the victims chin, lift the chin to open the airway (evaluated in ITEM 4). (iv) Keeping the airway open, look, listen and feel for breathing (evaluated in ITEM 5) during 10 s (evaluated in ITEM 6). (v-a) If he is breathing normally, turn him into the recovery position and send or go for help (call 112 or local emergency number for an ambulance) and continue to assess that breathing remains normal (This case is not considered in the practice). (v-b) If the breathing is not normal or absent send someone for help and to find and bring an automatic external defibrillator (AED) if available; or if you are on your own, use your mobile phone to alert the ambulance service. Leave the victim only when there is no other option (evaluated in ITEM 7). (vi) Start chest compression and rescue breaths in a ratio of 30:2. This manoeuver is the key step of the protocol. To perform compression you must place vertically above the victims chest and press down on the sternum at least 5 cm (but not exceeding 6 cm); after each compression, release all the pressure on the chest without losing contact between your hands and the sternum; repeat at a rate of at least 100 compression per minute but not exceeding 120. After 30 compressions open the airway

Fig. 4 – SkillReporting System output used to assess performance of CPR maneuver.

again and perform two rescue breaths, blowing steadily into the mouth while watching for the chest to rise, taking about 1 s as in normal breathing. Continue with chest compressions and rescue breathes in a ratio of 30:2 and stop to recheck the victim only if he starts to wake up: to move, opens eyes and to breathe normally. Otherwise, do not interrupt resuscitation (evaluated in ITEM 11,12,13,14). (vii) If the victim recovers put in the lateral security position. This protocol varies when the AED arrives. In our case we have an AED in the laboratory. In ITEM 8, 9 and 10 we evaluate if the student switch on the AED and attach the electrode pads on the victims bare chest. Since CPR and AED discharges are combined we evaluate that the correct sequence is applied (evaluated in ITEM 15). To evaluate the compressions and ventilation rhythm and performance we use the data from the Laerdal software. In Fig. 4 we illustrate a report from SkillReporting System that after the completion of the scenario by the student provides a graphical and numeric performance summary to compare individual student performance against guideline recommendations.

According to student performance the teacher answers rubric items with yes or no. When the practice is finished yes is coded as 1 and no as 0 achieving a maximum of 15 points per student that will be transformed to a 0–100 scale. The obtained score is used as a final mark.

2.5. *LISSA use*

To compare educational efficacy of LISSA with that obtained from the traditional one we randomly divided students in groups that had between 13 and 15 students. 42 students corresponding to groups, A, B and C, received the classical teaching approach without LISSA. The other groups, from D to H used the LISSA software before laboratory sessions. These students had an on-line LISSA tutorial and no teacher instruction was given. Each student had assigned six problems of different levels of difficulty (one easy, three medium, two difficult). The student could access the problems one week before the laboratory session of his group started. He had to solve the problems before the session. From the 67 students, 51 solved all the problems and 16 more than 50% but not all of them.

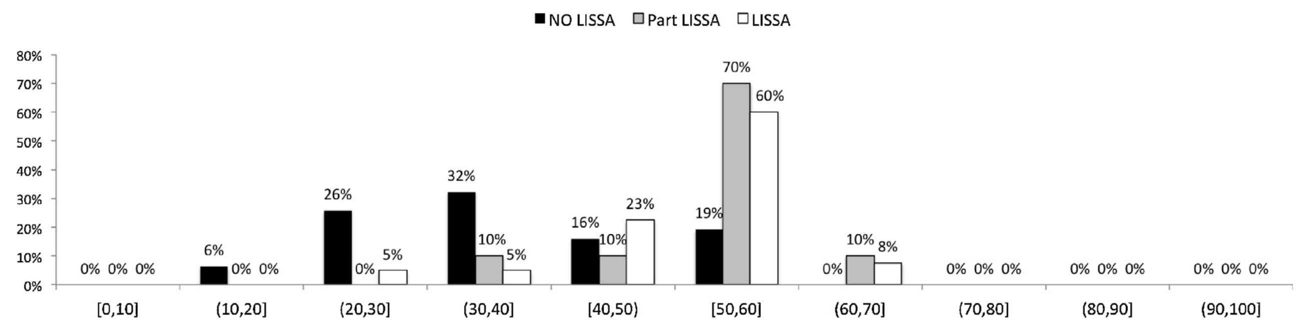


Fig. 5 – Number of students of each group for each score range.

3. Results

We assigned a score between 0 and 100 to each student according to the evaluated items presented in Table 1. To present the scores we considered three different groups: students that did not use LISSA (Group 1), students that used LISSA and solved all assigned problems (Group 2), and students that used LISSA and solved more than 50% of problems but not all of them (Group 3). For each group we considered the number of students that have a score between 0 and 10, 10 and 20, 20 and 30, and so on, until 90 and 100. The obtained results are shown in Fig. 5. Note that the best results are obtained by students that used LISSA. To evaluate the differences between students that used LISSA with respect the ones that did not use we performed a paired samples *t*-test, first between Group 1 and 2 ($\mu_1 = 35.67$, $\mu_2 = 47.50$ and $p < 0.05$) and second, between students of Group 1 and 3 ($\mu_1 = 35.67$, $\mu_3 = 50.58$ and $p < 0.05$). From these tests we observed that there are significant differences in both cases. We also performed a paired samples t-test between Group 2 and 3 ($\mu_2 = 47.50$, $\mu_3 = 50.58$ and $p > 0.34$). In this case, there are no significant differences between these groups. For this reason, we are going to consider Group 2 and 3 as a unique group, the LISSA students.

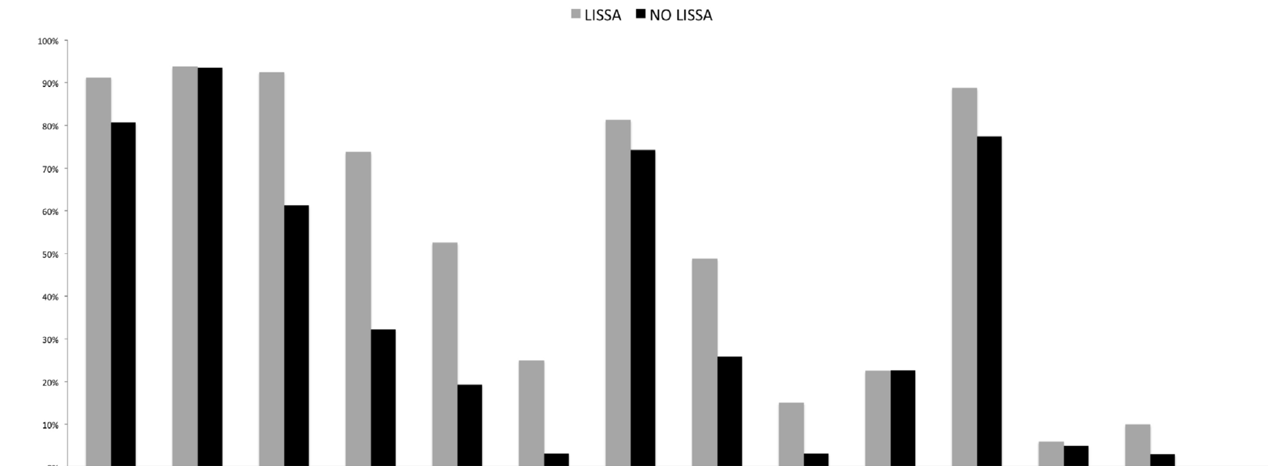
We also evaluated one by one the different items related with the CPR protocol. The obtained results are shown in Fig. 6. We can observe that in all the cases the better results are obtained by the students that used LISSA. More than 90% of students performed *Check perimeter*, *Check conscious* and *Ask for help* correctly. More than 70% of students that used LISSA performed *Open airway* correctly while from the others only a 32% did it. *Check breath position* and *Check breathing for a maximum 10 s* were two of the more poorly performed actions, although in all the cases it was better performed by the students that used LISSA. To improve performance of these actions as future work we will introduce a timer in the LISSA scene that forces the student to spend 10 s observing the victim. In addition we will improve the action to show how to perform head; tilt and chin lift and also the correct position to control breath. The next evaluated action, *Call emergencies*, is better performed by LISSA students. With respect to *DEA use* and *Electrodes placement*, LISSA students performed better although the obtained results are very poor if compared with other actions. The % of student that started defibrillation before 1 min from discovery of unconsciousness is the same for both groups of students. This is an important parameter since patients who revived CPR before 2 min significantly increased survival [35]. For this reason, we will improve the time icon of the game to make student conscious of the importance of acting rapidly and starting chest compressions early to increase survival after cardiac arrest.

The worst results are obtained in the actions related with compressions and ventilations maneuver (*Correct compressions*, *Hands placement* and *Correct ventilations*). In these cases none of the groups performed well. However, these results do not surprise us since no practice delivering was given. Moreover, using the computer it is very difficult to simulate the correct performance of these actions, we reproduce the rhythm of the compressions but the depth is difficult to be reproduced in a realistic way. To overcome these limitations we are working on the development of an external device to assess rhythm and depth. Similarly, ventilations are difficult to simulate via keyboard.

From this first evaluation we conclude that the game is a good complement to theory since the obtained results are better than if only theory is considered. The game helps student to retain the actions of the protocol. However, it is difficult using only the game to teach how to perform the main maneuvers of the protocol, compressions and ventilations. We consider LISSA not as a substitute of laboratory sessions but as complement to improve theory concepts and laboratory performance.

At the end of the experiment, students filled a questionnaire in order to evaluate their experience and the benefits they obtained from LISSA. The 5 statements presented in Fig. 7 were rated on a five-point Likert scale: 1 = full agreement, 2 = partial agreement, 3 = indifference, 4 = partial disagreement, 5 = full disagreement. The majority of students consider that LISSA improved their knowledge and skills relevant for laboratory CPR practice. They consider LISSA user-friendly and easy to use. In addition, they prefer to use LISSA working individually and not in group.

The questionnaire also included two open questions. Below, we give a brief summary of the obtained responses. Students feel more motivated to solve problems using LISSA. They consider as the main advantage the immediate feedback provided by the platform. This feature motivates them to practice. From the teacher point of view, they consider that LISSA provides gains with respect to the classical teaching methodology. The main benefits include speed, consistency



	Check Perimeter	Check conscious	Ask for help	Open airway	Check breath (position)	Check breath (time)	Call Emergencies	Use DEA	Place electrodes	Desfibri.<1'	30 compres.	Correct compres.	Hands placement	Correct ventilations
LISSA	91%	94%	93%	74%	53%	25%	81%	49%	15%	23%	89%	6%	10%	0%
NO LISSA	81%	94%	61%	32%	19%	3%	74%	26%	3%	23%	77%	5%	3%	0%

Fig. 6 – Obtained results for each evaluated item.

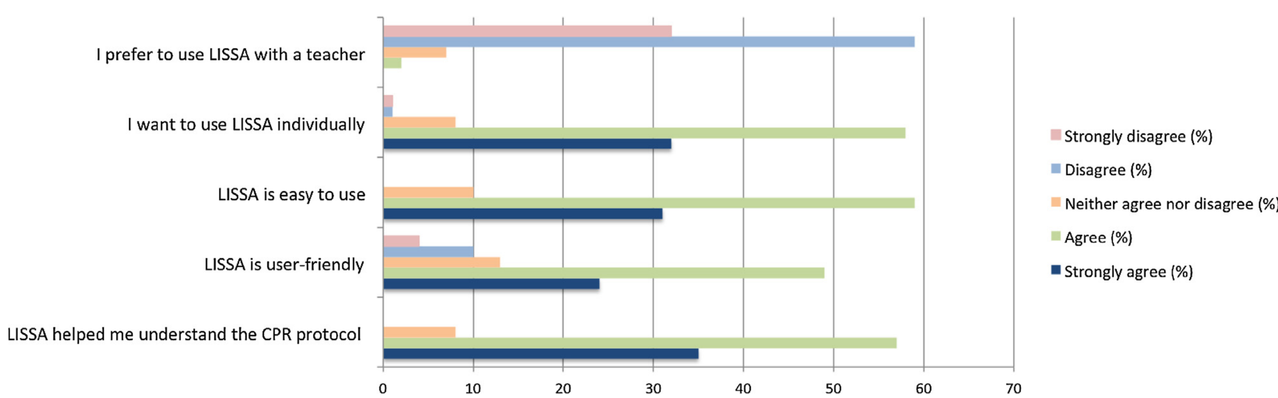


Fig. 7 – Results from the end-course questionnaire.

and availability 24 h per day. The tool can support a variety of problems. The possibility to reuse information and problems for different activities is considered an important feature too. They also highlight that LISSA offers a system for the continuous assessment of the students progress. They can retrieve statistics on different aspects of the problems. This information can be collected before a theory, problem or laboratory session, and can be used to guide the new session. In addition, teachers consider that LISSA makes personalized attention to the student easier. Time required to correct problems is reduced considerably since the system provides an automatic correction technique. They can track student work and send messages to them enhancing the student–teacher relationship. Teachers considered LISSA user-friendly and easy to use.

4. Conclusions and future work

Currently, CPR training in nurse education follows the traditional model consisting of a theoretical introduction and individual manikin-based procedural training. Different virtual techniques can be used for theoretical introduction but there are few virtual methods for practice. The main limitation of current approaches is that they only consider some parts of the CPR protocol, especially the CPR maneuver. In this article, we have evaluated the use of LISSA, a serious game that considers all the steps of the CPR flowchart. We have analyzed the impact of using LISSA after theory introduction and before laboratory practice. The obtained results show that students that practice with LISSA performed better in the laboratory sessions than students that only read theory material. We also observed that some actions that are not clear enough in the game can lead to some misconception in practice sessions. For instance, when checking for victims breath students spent less time than the 10 required seconds. This type of errors requires a better representation of some steps of the CPR protocol. However, from the results we can conclude that LISSA use improves students knowledge and skills on CPR. In addition, students consider that LISSA helps them to learn.

Our future work will be centered in the design of new scenarios and the introduction of new characters into the game.

In addition, we want to test LISSA as a tool to refresh CPR knowledge since CPR skills decay within three to six months after initial training. We plan to test LISSA with experimented people on CPR.

Conflict of interest

There are no conflicts of interests.

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