# ePULab
## *An Adaptive e-Learning Tool for Pressure Ulcer Evaluation*

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Abstract: Pressure ulcers (PrU) are considered as one of the most challenging problems that Nursing professionals have to deal with in their daily practice. Nowadays, the education on PrUs is manly based on traditional lecturing, seminars and face-to-face instruction, sometimes with the support of photographs of wounds being used as teaching material. This traditional educational methodology suffers from some important limitations, which could affect the efficacy of the learning process. This current study has been designed to introduce information and communication technologies (ICT) in the education on PrU for undergraduate students, with the main objective of evaluating the advantages an disadvantages of using ICT, by comparing the learning results obtained from using an e-learning tool with those from a traditional teaching methodology. In order to meet this major objective, a web-based learning system named *ePULab* has been designed and developed as an adaptive e-learning tool for the autonomous acquisition of knowledge on PrU evaluation. In this article, the ePULab software is described in details and the general results from an experimental educational validation study are also presented and analysed.

## 1 INTRODUCTION

The European Pressure Ulcer Advisory Panel (EPUAP) defines a pressure ulcer (PU) as an area of localized damage to the skin and underlying tissue caused by pressure, shear, friction and or a combination of these (European Pressure Ulcer Advisory Panel (EPUAP), 1999; Gawlitta et al., 2007). The pressure ulcers (PrU) are considered as one of the most challenging problems for Nursing professionals in their daily practice, whatever is the assistance speciality they are working on. The PrU care usually suffers from a high variability and uncertainty in decision-making tasks carried out by nurses, not only when dealing with prevention strategies but also when considering the evaluation of the wound and the pharmacological treatment to be administered (Demarre et al., 2011; Revello and Fields, 2012). All these aspects are on the basis of the interests that Nursing professionals pursue when they are proposed to enrol an education activity to improve their skills in PrU evaluation and wound care-taking. On the other hand, getting a better education on PrU diagnosis and treatment, not only by professionals but also by undergraduate students, could become the most effective strategy to reduce the use of pharmacological products with non-yet-demonstrated benefits, and also to homogenize the clinical interventions and increase the efficiency of decision-making protocols for PrUs.

Nowadays, the education on PrUs for undergraduate students is mainly based on traditional on-campus learning, with face-to-face classes and the common use of real PrU photographs as teaching aid. The most frequent educational objectives are usually focused on two main aspects: 1) to facilitate the comprehension of the risk factors related to PrU incidence and prevention; and 2) to provide the students with the necessary knowledge to identify accurately and classify correctly each one of the different types of wounds, on the basis of the four classical PrU evolution stages proposed in USA in 1989 by the NPUAP (*National Pressure Ulcer Advisory Panel*), and adapted with minor changes in 1.999 by the EPUAP (*The European Pressure Ulcer Advisory Panel*) in Europe (Defloor and Schoonhoven, 2004). Furthermore, that theoretical education is usually complemented with other practical activities, which the students can carry out when attending the practical clinical sessions in which

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they are able to observe PrU wounds in a real clinical context and try the therapeutic criteria they learned at the classroom. Nevertheless, this traditional education suffers from some important limitations that could compromise the efficacy of the learning process: on one hand, in traditional education schemes the students behave usually as passive subjects during their learning process, as the classical teaching methodology is difficult to arouse their motivation and interest; on the other hand, a high variability in the learning process is generated during the clinical sessions, so that it is not possible to control the entire educational environment —its final configuration depends on the eventual existence or absence of PrU wounds in the clinical unit in which each student is temporary practising, as well as on the offer of opportunities for the student to get involved in the care of the existing PrUs of that clinical unit. Having all these aspects into account, it is not possible to guarantee that all the students can observe and care PrUs and, furthermore, the number of PrUs that each student can observe is limited and different to that of their classmates; finally different evolution stages and high variable treatments could be found by each student when dealing with the PrUs of patients in the clinical unit they are involved in during their practical sessions. To conclude, the traditional education on PrUs makes difficult to homogenize the acquisition of knowledge and practice by the undergraduate students, while it does not guarantee yet the learning of the same concepts and the enjoyment of the same education opportunities on PrUs evaluation. This fact could also determine the subsequent variability of the PrU care carried out by the Nursing professionals when the join finally the Health system. Moreover, the continuing education on PrUs of these Nursing professionals usually suffers from the same limitations as the undergraduate education above, as it is difficult to arouse the motivation and participation of these Health workers in their own education on PrU diagnosis and treatment.

With the aforementioned problems, this current study has been designed to introduce the information and communication technologies (ICT) in the education on PrUs for undergraduate students, and evaluate its advantages by comparing the results from this e-learning strategy with those obtained with traditional teaching methods. Many studies have appeared in the last decade which show the impact of ICT on Nursing education (see (Bloomfield et al., 2008) and (Ainsley and Brown, 2009) as two conclusive reviews on this particular subject). However, although the methods based on e-learning have gained an increasing popularity in the last few years and become effective strategies constituted as a real alternative to traditional teaching tools, some authors have recently pointed to the necessity of improving the validity of the studies which evaluate the effectiveness of e-learning tools, advancing by this way to the optimization of the methodological design of those studies (Bloomfield et al., 2008).

## 2 ePULab E-LEARNING TOOL

The design of the ePULab (*educational-Pressure Ulcer Laboratory*) software has been focused on the registering of PrU photographs, their automatic segmentation, the computer-assisted labelling of all the tissues present in the PrU images by using artificial vision techniques (Veredas et al., 2010), and the collaborative work for mutual evaluation of PrUs done by Nursing professionals and other clinical experts. On one hand, the specification the ePULab system includes the design of some modules to manage the different educational levels of the students. These modules adapt the educational level of the system to the learning necessities of each student during their evolutionary learning cycle. On the other hand, the design of the ePULab system has been oriented to allow the monitoring of the progresses made by the students, while giving also support to the teachers to analyse the learning objectives that their students achieve, therefore making possible the subsequent generation of reports and statistics on the progresses and marks obtained by the students. The ePULab system allows the users to have both an on-line or an off-line learning, therefore making the time consumed by the learning process more flexible and adaptable.

### 2.1 ePULab Teacher's Interface

The so-called *teacher's interface* (Figure 1) allows the lecturer to insert new PrU cases in the system, as well as edit their clinical information —which includes the possibility of uploading PrU photographs and their image segmentation maps— and all the relevant information about the PrU evaluation: local features such as classification, PUSH (*Pressure Ulcer Scale for Healing*) index, presence of infection signs or smell, state of the surrounding skin, depth, presence of cavitation, amount of exudate existing in the wound, etc.; treatment information such as dressing type and treatment, handling of bacterial load, position changes to be provided, support devices used by the patient, etc.; and patient's general information on their health state, such as patient's Pfeiffer and Braden indexes, patient's sex and age, informal carer's in-

terest, education and motivation, patient's nutritional status, etc.

The login page of the teacher's interface allows them to have access to the system by using an authenticated connection which counts on the SSL encrypting protocol, with a `https` URL, to get a secure connection to the data. The design of the login page is similar for both interfaces, i.e. the teacher's one and the student's one, although those two separated interfaces are independent and located at different URLs.

Once a user with *teacher profile* has been granted access to the system, an operating interface is shown, which consists of several frames with specific functionality. The main page of this teacher's interface is structured in three different sections (figure 1):

- The *list of PrUs*: it is located in the upper left frame (Figure 1) and consists of the list of all the PrUs available in the system. From this frame, the information on the evaluation of each PrU is accessible for edition and query.
- The *list of training/evaluation tests* for students: it is located in the lower left frame of the teacher's interface (Figure 1), and allows the user with *teacher profile* to create and edit *training/evaluation tests*, i.e. a set of PrU cases that have been evaluated by the teacher and grouped together to be available to the students for their practice on PrU evaluation (by using the ePULab student's interface). Consequently, these training/evaluation tests have to be designed by the teacher with two main objectives: to allow their students the learning of the principles of PrU diagnosis and treatment (at three different complexity levels that the teacher is able to select), and to evaluate and monitor the progresses that their students achieve during their learning phases.
- The *central frame* of the interface, in which the forms, fields, panels and data of each PrUs stored in the system are shown for query or edition (Figure 1). These data consist of information on the evaluation of each PrU, which includes photographs, local information on the wound, general information on the patient's health state, information on the treatments and Nursing clinical interventions on the wound, informal carer's data, etc. On the other hand, this central panel is also used to manage all the information regarding the creation, query and edition of training/evaluation tests for the students.

The fields in the forms for PrU evaluation are classified in three different levels (Figure 1): *beginner*, *intermediate* and *advanced*. When a training/evaluation test is presented to a student for the first time, all the diagnosis and treatment questions corresponding to the *beginner* level are set up. The student can then interact with the system by reading the on-line tutorials and contextual information, and answering the proposed questions on tissue identification, diagnosis and treatment. The student also can monitor their progresses, as well as consult and edit their answers to the proposed questions. Once the number of correct answers from an user with *student profile* has risen above an established threshold (which is previously configured by the teacher when they designed the training/evaluation test), the student's level increases and they get the *intermediate* level. This new level would include more complex questions on PrU diagnosis and treatment, which were previously configured by the teacher by using their own interface. Similarly, the *advanced* level could be get by the students once a new learning threshold is reached.

## 2.2 ePULab Student's Interface

The student's interface (Figure 2) is located at a URL that is different from that used for the teacher's interface (section 2.1). Nevertheless, the login page to access to the system by an authenticated connection (with user/password login) is similar to that used by the teachers. As in the case of the teacher's interface, the student's interface is also provided with the SSL encrypting protocol to get a secure access to all the specific functionality that the students are supplied with.

Once a user with *student profile* has been granted access to ePULab, a welcome page is displayed, which consists of a list of training/evaluation tests that a teacher would have left available for their students. The student is then able to choose a particular training test to start with the evaluation questions of all the PrU cases that it consists of. With this purpose, the student can select a training test by clicking on it; from that moment on, the student will get all the contextual information necessary to the effective understanding of each one of the PrU cases that the test is grouping together as established by the teacher when they designed the test. For each PrU, the student is able to read its contextual information and navigate through the sequential evaluation phases by answering the different diagnosis and treatment questions that the system poses. During this training process, the student can also get all the necessary feedback about their progresses and check their responses to the different questions on PrU evaluation.

When a user with *student profile* gets access to the system for the first time, they start at a *beginner* level, so that they only have to answer those question on

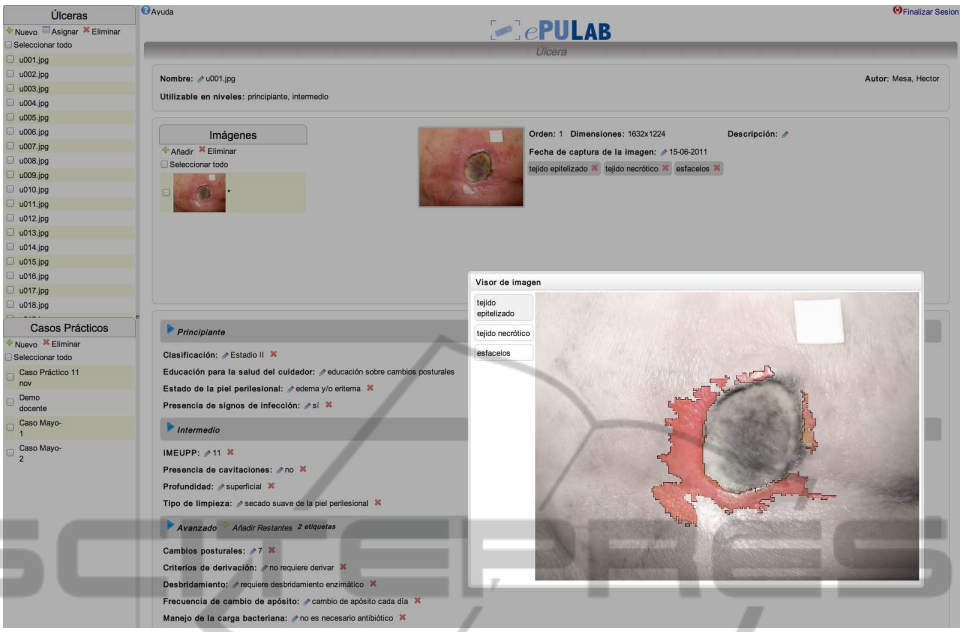


Figure 1: A screenshot of the teacher's interface, which shows the list of available PrUs and training tests for the students, as well as the central frame for visualization, query and edition of data from PrU evaluations. (The text in the image is in Spanish).

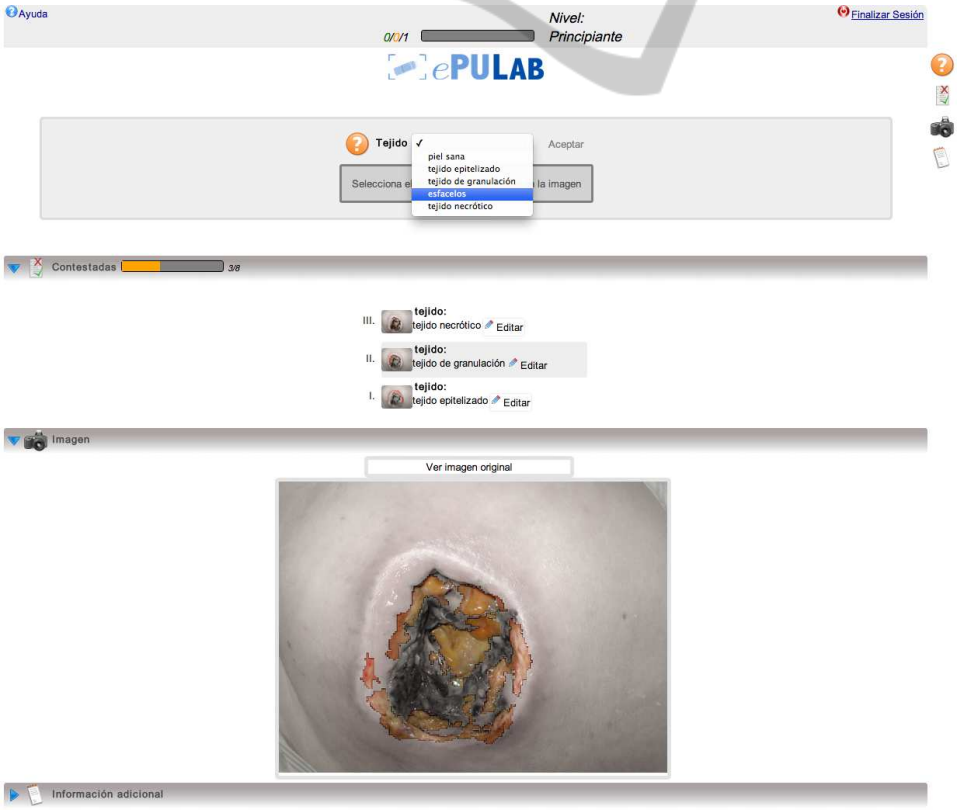


Figure 2: A screenshot of the student's interface, which shows the section of tissue identification on a particular case of PrU evaluation. (The text in the image is in Spanish).

PrU evaluation that are included in that initial level, such us tissue identification (Figure 2), PrU classification, Health education for the informal carer, state of the surrounding skin and presence of infection signs. As the student is making progresses for the questions in the beginner level and finally reaches an established threshold, they go forward to the intermediate level and, subsequently, to the advanced level. In each one of these levels, the student has to answer all the question on PrU evaluation corresponding to that level and the lower ones. Some questions included in the intermediate levels are: wound depth, presence of cavitation, PUSH index, or cleaning types necessary for the hygiene of the wound. The advanced questions include some treatment issues such as the necessity of debridement, dressing type, handling of bacterial load, number of position changes, etc. In all moment, the student is able to query the contextual information that the teacher has included for each PrU in the training test. That information involves additional comments and observations on the wound, such as the amount of exudate, the location of the wound, the patient's sex and age, the wound area, etc. Furthermore, a complete set of on-line tutorials on PrU diagnosis and treatment are available to be looked up by the students.

One of the most important sections that each student has to go through when evaluating each one of the PrUs included in a training/evaluation case is the identification of all the significant tissues present in the PrU image. In Figure 2 one of the PrU tissues proposed for classification is shown, as it is displayed on the student's interface. The ePULab software supplies the user with a PrU image-viewer which allows the student to display the original PrU image and navigate friendly through the different tissues previously segmented in the image (Figure 2). The image segmentation maps, as well as the classification of the tissues, are provided by the teacher when they insert a new PrU case in the teacher's interface. Those segmentation maps can be manually or automatically generated by using the image processing tools designed and implemented by this same research group as a result of previous projects (see (Veredas et al., 2010) for a complete review of these techniques and results).

# 3 DESIGN OF A VALIDATION STUDY FOR ePULab

In order to count with an initial validation of the ePULab tool as an effective adaptive e-learning software on PrU diagnosis and treatment, we have designed an analytical and experimental study of educational research by configuring a randomized trial with a non-concurrent control group. The main objective of this study is to compare the educational efficacy of the ePULab software with that obtained from the traditional on-campus face-to-face instruction of Nursing undergraduate students.

The population of the study was composed of 73 Nursing undergraduate students enrolled in the Nursing degree in the *Escuela Universitaria de Enfermería* of the *Provincial Council of Málaga*, Spain. This population sample was divided into two different groups: an *experimental/intervention* group, which used the ePULab software for e-learning education on PrU; and a *control* group, which received an on-campus education on PrU evaluation and treatment.

The variables measured in the *a priori* knowledge questionnaire (pre-test), as well as in the acquired knowledge questionnaire (post-test), are the same for both groups of the population (experimental and control group), and are based on the observation of a PrU image that is printed on a paper and projected on a screen in the classroom at the same time. On the basis of that PrU image, which was always the same for both groups of students, we evaluated the following aspects: the student's ability to classify the wound; the student's ability to evaluate the characteristics of the peri-ulcer skin; the student's faculty to detect infection signs in the wound; and the degree of correctness in the choice of the type of dressing necessary for the wound healing. On the other hand, there has been also designed a question in both the pre- and post-tests to evaluate the student's skill to determine which Nursing care interventions are appropriate for that wound in the image. Finally, the last issues in the questionnaires were designed to measure the student's ability to identify the different significant tissues present in the wound image.

## 3.1 General Validation Results

The results from the global scores obtained by the students in the experimental and control groups, for both the pre- and post- tests (questionnaires), are shown in Figure 3, wherein the boxplots show the different distribution of the total scores from the pre- and post-questionnaires: while no differences were found between the experimental group and control group for the pre-test (*a priori* knowledge), significant differences between the two groups were observed for the post-test (acquired knowledge) however. The total score from the tests ranged from 0 to 22 points and was obtained from the summation of all the scores from the items included in the different categories of the questionnaires. By observing the results shown

in Figure 3, we can first highlight the comparability of the initial knowledge conditions of both groups, with an averaged total score of 8.23 (standard deviation 1.23) for the control group, and 8.27 for the experimental group (standard deviation 1.39). Nevertheless, although the results from the post-tests reveal the effectiveness of both education strategies (as an increase in the averaged total scores can be observed for both groups of students), the averaged total score from the experimental group (15.85) is significantly higher ($p < 0.01$, t-test) than that obtained from the control group (11.6), giving a higher efficacy of the educational scheme based on the use of the ePULab e-learning tool than that of the traditional on-campus approach.

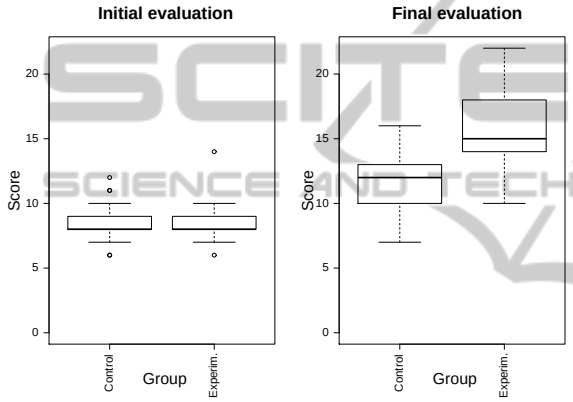


Figure 3: Boxplots of the total score (range [0, 22]) from the items in the pre- and post- questionnaires for the control group (with an educational approach based on a traditional on-campus teaching) and the experimental group (with an educational strategy based on the use of the ePULab e-learning tool for PrU evaluation).

## 4 CONCLUSIONS

In the previous sections, we have presented a new adaptive e-learning tool, namely ePULab, which was specifically designed for education on PrU evaluation. The main characteristics of the ePULab software have been exposed in detail, and the design of an experimental study to measure the efficacy of ePULab as an effective educational tool has been also presented. The general results obtained from this study show how knowledge acquisition on PrU evaluation is significantly higher for those students who used the ePULab tool, compared to the students who received a traditional on-campus instruction. These results reveal the validity of the ePULab e-learning tool as a very effective instrument for the learning on PrU evaluation and treatment, as well as for the efficient acquisition of skills for those processes of a high significance in Nursing daily practice.

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