The impact of innovation in medical and nursing training: a Hospital Information System for Students accessible through mobile devices

Filippo Cacace, Maria Cinque, Michele Crudele, Giulio Iannello, Marco Venditti
Università Campus Bio-Medico di Roma
Via E. Longoni 83 - 00155 Roma - Italy
Emails: {*f.cacace; m.cinque; m.crudele; g.iannello; m.venditti*}*@unicampus.it*

Abstract

In the HISS (Hospital Information System for Students) project, run by Campus Bio-Medico University of Rome, students of Medicine, Nursing and Dietetics practising in the wards were trained to use handheld devices connected through a WLAN to record patients' data. Beside learning this new technology and applying it for freely accessing teaching resources from any place in the Campus, the students were able to design new user interfaces for accomplishing daily tasks. The work done by Dietetics students was a good basis for the development and implementation of a real solution in the University Hospital.

Keywords: mobile training, ubiquitous computing, adaptive user interface, impact of innovation

1. Introduction

Learning on the job has always been considered a basic methodology for medical related professions. An important part of the teaching is accomplished in the wards, while visiting patients. The typical way of memorizing what is said or done by the teachers, nurses or physicians is to take a written note on an exercise book. This leads to unstructured data and makes it difficult to rapidly access specific information. Post-production is usually needed to reorganize the notes in a practical way for easy recovery of any part of it.

In Campus Bio-Medico University of Rome we introduced at the beginning of 2003 wireless networks and portable devices starting a number of projects for assessing the use of this technology. One of them emphasizes the utilization of handheld computers (palm and tablet PC's) for training Medicine, Nursing and Dietetics students: HP Applied Mobile Technology Solutions in Learning Environments - 2003 Grant Initiative financed the project. It was the only Italian project in a list of forty worldwide ones. It was presented in HP Labs at Palo Alto, California in September 2003 by one of the authors to all other institutions that received a grant.

We installed wireless devices so that from every room of all the wards a connection could be set to a separate LAN, different from the Hospital Information System one, for security reasons. Each student participating in the project, during training sessions was equipped with a wireless LAN enabled HP iPAQ 5500 capable of fingerprint authentication. Some of them, especially the teachers (nurses and physicians) used a HP Tablet PC.

Attention was paid to feedback: a system for collecting comments, bug notices, proposals and other information from the users, was set up. Experienced tutors closely followed the monitoring activity so that quantitative data were integrated with qualitative evaluations directly gathered from observation of students and teachers activity.

We had many goals: first of all we wanted to teach our students the new technologies they will encounter in the future while working in hospitals. We also aimed at giving them a better tool for learning the medical topics they were dealing with in the wards. We wanted them to define the user interface for medical applications on handheld computers; this goal had a predicted positive effect: instead of involving in the interface design actual nurses and physicians, always busy in their daily tasks (and whose time is costly), we used feedback from the students for developing new approaches in view of a real operational Hospital Information System for handheld computers.

From the learning point of view we were interested in examining whether the students using handheld computers were achieving better results in their examinations. We soon realized that this last goal was to complex to accomplish because too many factors are involved in the learning phase and comparing groups with and without handhelds requires many students and an enormous amount of data.

2. Project development

2.1. A task oriented solution

Our first chore was to convert the written note into an Electronic Patient Record (EPR) suitable for handheld computers. We developed the structure and contents of EPR studying some existing models like Ward-in-Hand (Ancona *et al.* 2000) and Bedside Florence (Policlinico Gemelli 2002) and addressing the specific needs of our 120 beds University Hospital. We held periodical meetings with teachers, tutors, physicians, nurses and dieticians in charge of their departments. We also followed the daily hospital activity of the three main groups of actors: physicians, nurses and dieticians. We concentrated on the tasks that may require a mobile device: we selected all the information that they usually write at the bedside, therefore excluding other longer data, for example the patient's entrance and exit letter which can be better written on a desktop computer. Furthermore, we based our analysis on the existing paper models in order to reduce the impact of innovation and achieve a higher acceptance degree by both teachers and students.

2.2. An adaptive users' interface

After designing the actors and the use cases, the main problem was content adaptation depending on mobile devices features and the frequent changes in the interface definition. We were aware that the development process in writing the software had to be adaptive, because the students would discover new solutions and redefine the structure many times.

Since we were not bound to real production and we had no strict deadlines, we were free to try different solutions (on-line and off-line; XML and RDBM; access trough WLAN, GPRS, UMTS; interface adaptation for pocket and desktop PC's). Eventually we based our system on ASP.NET, C#, XML and SQL server. The web-based application, accessible through a wireless LAN, included both generic and specific data entry masks. By using XML we built thirty different masks simply combining a few tags: <Section>, <Title>, <Voice>, <VoiceName>, <Value> for the different structural parts; <SmallText>, <MediumText> and <BroadText> for data input; <Drop> corresponding to the object DropDownList in ASP.NET and <Check> corresponding to CheckBoxList in ASP.NET (see figure 1).

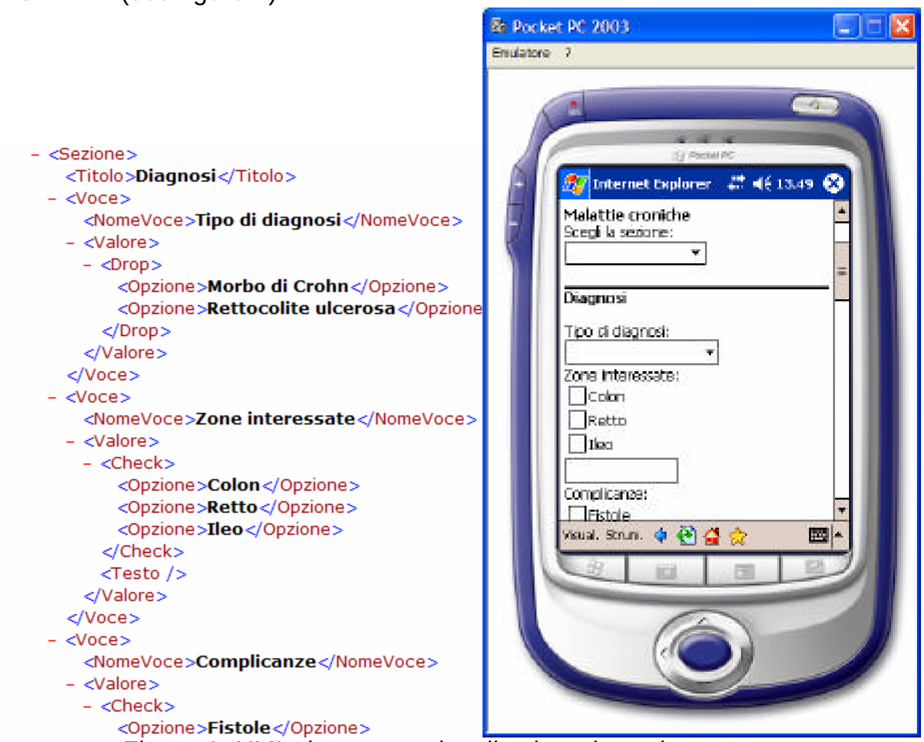

Figure 1. XML data entry visualized on the palm computer

The possibility to rapidly change the contents through a XML schema, without varying the code, allowed us to improve, day by day, the application: for example, in ten days of work with the physicians the anamnesis module changed four times and the general examination five times.

Besides contents adaptation, we carefully studied the way to present them to the users. The design involved ergonomic and technical factors. The interface, very simple at the beginning, was enriched thanks to users' feedback. The main innovations concerned: multiple sections masks to avoid too long HTML pages; substitution of text boxes with drop down lists or check lists of options; distinction between frequently and less used options; text boxes of different size (short, medium and large) at the end of the lists to insert additional information (values, observations, descriptions); different modules to modify or read the recorded information; automatic view of the clinical information requested by a specific department. In the final state of implementation there are three ways of collecting information from a patient: write into a free text box; search a (complete or partial) string in the database; answer a multiple sections mask with drop down lists, check lists or text boxes based on XML schema.

Our next goals will be: full adaptation capability and context awareness, that is the content server could transparently deliver information in a format suitable for a specific device and user; standardization of the recorded clinical information, beginning from the classification of pathologies – which is now based on the Italian version of ICD9-CM – in order to apply HL7. We are aware that the final implementation of any record system must be based on tasks and attitudes in the particular healthcare environment (Rossi Mori *et al*. 2000).

2.3. Ubiquitous access

To improve network performance and availability, we tested HISS access through heterogeneous networks. Our approach was based on the emerging Mobile IPv6 protocol, that provides the following benefits: management of mobility at the network layer, allowing network applications to be unaware of changes in the network; easiness of use and configuration so that the user does not need to change anything moving from local to geographic wireless networks.

Our Mobile IPv6 enabled clients can now seamlessly access HISS through both wireless access points and GPRS or UMTS VPN's without changing the session or re-logging. A network interface monitoring module in the client device traces the signal level of wireless interfaces, as well as the presence of wired connections, and triggers the handoffs from one interface to the other when needed. In order to minimize changes to the existing hospital network and to allow access to IPv4 hosts, we developed a NAPT-PT (Network Address Port Translation + Protocol Translation, according to RFC 2766) IPv6-IPv4 transition mechanism that translates IPv6 packets into IPv4 packets and vice versa. This allows a transparent communication between IPv6 nodes (mobile clients of the HISS environment) and the IPv4 nodes (legacy platforms of the Hospital Information System). The main benefit of this approach is simplicity: the mechanism is easy to configure, since clients need only to use a DNS server that supports IPv6 addresses.

We also evaluated transport protocols performance during handoffs among heterogeneous networks as well as usability (user perception of network performance in real cases, geographical access to HISS for patients follow-up at their homes, etc.). We implemented so far the mobile access on tablet PC's running Linux, since Windows Mobile does not yet completely support all mobility protocols. In the future we plan to extend it to other operating systems, devices and interconnection technologies (e.g. Bluetooth).

2.4. Formal training and informal education

We monitored students using palm devices during their training in the hospital, which is a quite different activity from the one in a classroom. As previously stated we did not monitor their improvement in learning, but we analyzed how they managed the new devices and which effects this training produced on the activities done in the hospital.

Since the system is not a mere simulation, but a database with real cases, access to the data was restricted to students and their teachers, following strictly the Italian privacy regulations. At first the students were trained to convert paper recordings into electronic recordings, starting from data retrieved from the actual Hospital Information System. In the second phase they operated directly at the bedside, while admitting patients.

We tried different ways of collecting data (on-line and off-line) and we used many iPAQ 5500 and some Symbol PPT 2800. We recorded that users tend to prefer a smaller device, with colour display, to a faster one (usability seems more important than performance). The comparison between off-line and on-line activity offered interesting results. In the off-line case, the software on the handheld required synchronization with a desktop PC. Thus, the “back office” work was much harder. But from the point of view of the users, the off-line solution avoided all the problems related with network performance. Therefore we envisage a new scheme for the future: data is saved off-line anywhere and automatically synchronized as soon as the device is on an active cell.

Besides the modules created for the project, which were accessible on-line, the students learned to use all the software installed on the iPAQ (including recording vocal notes) and other trial applications (Handbase, Medical Pocket PC) which were selected and installed by Bioengineering students. We also acquired pocket PC versions of medicine manuals, like Washington or Harrison therapy manuals. A specific database with drugs principles and prescriptions was commissioned to an external firm and was personalized according to the users' needs. These resources were very useful not only for the students, but also for their teachers: it was an application of continuing medical education.

In the last years we have been producing streaming video based lessons for nurses in order to give them access to University level resources and the capability of reaching the “laurea” level (Campus Bio-Medico was the first Italian University to establish a University level course for nurses). We later adapted these videos in order to stream them on handheld computers so that a nurse in a ward, during a relatively calm period (such as a night turn) can easily access the video on demand library of lessons. Campus Bio-Medico University has also produced video based tutorials for the VAKHUM project, funded by the European Commission, dealing with 3D kinematics of the human bones (Van Sint Jan *et al.* 2003).

3. Users' feedback on wireless training

The evaluation methodology was based on users' observations, interviews with them, questionnaires filled by students and their tutors. Furthermore, we tried to monitor the users' feedback using categories created by Everett Rogers, a theorist who spent over thirty years studying the diffusion of innovations, from qwerty keyboards to new agricultural methods in developing countries. According to Rogers (1995), the characteristics of an innovation, as perceived by the members of a social system, determine its rate of adoption. Five attributes of innovations are: (1) relative advantage; (2) compatibility; (3) complexity; (4) trialability; (5) observability.

Interesting results came from a test submitted to all the first year dietetics students. The students were asked to indicate the main advantages and drawbacks of using a pocket PC instead of a paper questionnaire. The majority of them indicated two main advantages: a) speed in finding the answers; b) time spared in the transcription of data from paper to PC. Usability was also indicated as one of the criteria of preference of a handheld: the palm computer does not need a stand and it is not “uncomfortable” (not heavy to carry in comparison to a normal PC). Furthermore 80% of the interviewed students think that the presence of a keyboard would not help them in data entry. The three main requirements of innovation acceptation (advantage, compatibility and acceptable complexity) were therefore fulfilled. The other two indicators – trialability (the degree to which an innovation may be experimented on a limited basis before making an adoption/rejection decision) and observability (the degree to which the results of an innovation are visible to others) – were considered less important by the students interviewed.

As to nursing students, great importance was given to the “relative advantage” factor. In the first phase only 60% of them felt to be advantaged by the use of PDA's. Since the attitude of some tutors towards the HISS project was negative, the students' feelings were biased. In this case we had to work on the tutors to achieve good results with the students. Only when the tutors began to perceive the innovation as being better than the activity it superseded (writing on a piece of paper and then rewriting it on a PC, or deliver it to the physicians), they motivated the students to use the new system.

A crucial indicator for PDA acceptance was “accuracy”. We demonstrated to the tutors that students using handheld devices for data entry in structured masks were more accurate than those writing on a blank piece of paper; the first ones noticed more things (having different questions to answer) and were more precise.

The most critical approach was by Medicine students. The complexity of the tasks and the different approach in data entry contributed to a very low degree of acceptance of the new technology. Therefore, after an ineffective extensive phase (all the students in all the wards), we tried an intensive approach. A pilot project started in the departments that had shown a more positive attitude during the first phase: general surgery and cardiology. All the medical staffs were involved, not only the students and their tutors. This phase showed that the presence of a leading figure is a key element for the acceptance of innovation: the fact that the directors of both departments were keen on using the devices motivated all the staff.

4. Conclusions

The HISS project, which was carried out in our University Campus during the academic year 2003-2004, achieved the following goals: enhancing the hospital level of technology by improving the accessibility to the information system at different levels (students, nurses, physicians) through mobile technologies; improve teaching and learning in the wards through a faster access to clinical data; designing new interfaces for small devices for collecting and examining data at the bedside; a deeper comprehension of security issues; analysis of geographical mobility needs; performance evaluation.

The iPAQ's were used by 110 students (of different departments), recording data concerning more than 1500 patients to accomplish 30 different tasks. The Medicine students entered 495 records; the Nursing students 243; the Dietetics students 193 while their tutors 919.

The positive effects of the project went beyond our expectations. Two companion projects started, following the enthusiasm of some members of the staff: the first one, for the surgery department physicians, has changed completely the way of rapid data entry at bedside, which was previously done on a sheet placed on a wooden tablet. The second one, carried out in collaboration with the Campus Information System software developers, is carrying out the complete conversion of all dieticians' activities (such as bedside-kitchen communication) to an electronic version.

We feel that other institutions may benefit from our experience by being encouraged to use their students as generators of specifications for real world software applications.

Besides being the acronym of a system for students, HISS became a powerful metaphor: the 'hiss' – i.e. the whisper, the buzz – spread itself and involved more people and more tasks than expected.

More information about the HISS project is available at http://research.unicampus.it/HISS

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