# A FLEXIBLE INFRASTRUCTURE FOR P-LEARNING: A FIRST APPLICATION IN THE FIELD OF PROFESSIONAL TRAINING

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Abstract: With the availability of nomadic computing, and its new interaction user devices connected through wireless networks, it is obvious that the traditional way of delivering e-Learning will be changed. This paper is focused on a new mode called pervasive learning which relies on the potential of new IT infrastructures able to provide dynamic adaptations of information contents and services according to various contexts. Using our previous experiences in the design and implementation of multi-channel accesses to services (mobile-Commerce or e-Learning) we are designing a new infrastructure, based on a Multi-Agent Systems, which satisfies our requirements for future p-Learning systems. Its potential is illustrated through a dedicated scenario of uses drawn from needs founded in the field of learning on demand, in the framework of a shop, contextualized for several seller situations and professional activities. The dedicated system, called a Personal Training Assistant, is supported, in interaction with a Smartspace, through our infrastructure.

## 1 INTRODUCTION

With the rapid dissemination and uses of mobile wireless devices, there is an opportunity to enlarge, or to modify, the scope and the nature of the traditional e-Learning modes of education. This is particularly required by the organizations that are rapidly evolving, under the pressure of their users and of their markets, whatever the users are students, clients, citizens or members of a community. Recent surveys, such as those conducted by (Woodill, 2006), show also that new socio-technological approaches of the Web, the WEB2.0 umbrella; will have a great impact on the way we will consider exchanges of information and co-production of knowledge in the future. So we can assume, from a research perspective, that the features of the e-Learning will be more open, but also more complex, in order to incorporate all these social and technological changes, into a co-evolving process, occurring between the technological pushes and the real needs of the stakeholders.

Using our previous experiences in the design, development, deployment of e-Learning services and technological platforms, both from the research or real operational perspectives, and also our experiences in research on multi-channel computer applications in the field of e-Commerce and mobile-Commerce, we have start a new research program focused on the design and experimentation of new infrastructure for pervasive learning mode. This is done in the framework of an important collaboration in a large regional consortium, between Universities and several big companies from the retail industry, and from the e-Commerce and the direct marketing fields, sets to forecast and master evolutions of these fields. Our present research project is deeply rooted in the new domains of computer sciences whatever they are called "Ubiquitous Computing", "Context-Aware Computing", "Pervasive Computing" or even "Ambient Intelligence". But it takes also seriously in consideration the particular needs from these companies, and their application domains, for the continuous training of their employees and, if possible jointly, of their clients and affiliates. This will be illustrated by a specific scenario of use, simplified here, that we have kept for presentation in this paper, among several others that we are investigating actually.



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# 2 FROM E-LEARNING TO P-LEARNING

## 2.1 Mobile Learning is more than e-Learning Adaptation to Mobile Phone

At a first look it seems that mobile-Learning (or m-Learning) is just an adaptation of the e-Learning systems to accesses through wireless networks, increasing the accessibility (from the learner location) and the "reachability" (to the learner location). There is already a strong research interest in the world for this new domain. It appears that m-learning is, first, not a mode phenomenon, and second, that it goes beyond traditional e-Learning systems. Several research projects (Attewell, 2005) have shown that in spite of the current limitation of the mobile devices put in the users' hands (i.e. a basic GSM phone), it is possible to envision new learning activities, less focused on rich document interactions, but more communication oriented, in the spirit of the CSCL mode of education. The novelty in uses of wireless networks and mobile user devices is the possibility to take into account the singular context of the learner/user, for example depending of his/her location. m-Learning is learning that can take place anytime, anywhere with the help of a mobile computer device. The device must be capable of presenting learning content, in a context sensitive way, and providing wireless two-way communication between teacher(s) and student(s). This is why m-Learning is different from e-Learning due to its ubiquitous nature. However previous researches have shown that to be effective the user device must satisfy some requirements: *Highly portable, Individual, Unobtrusive, Available anywhere, Adaptable to the context of learning and the learner's evolving skills and knowledge, Persistent, Useful, Intuitive to use by people with no previous experience of the technology* (Sharples, 2003).

The researches on m-Learning have taken two directions:

- The design of systems based on wireless LAN (WiFi or Bluetooth) that organize the learning physical space, classroom, theatre, campus, in order to supplement the mobile user devices, in general Personal Digital Assistant, with fixed devices located close to the users. This is a case of what it is called "SmartSpace", where there is an automatic detection of the user location and of the proximity services. For example the PDA can be used in conjunction with a large intelligent electronic whiteboard in a theatre during a lecture.

- The design of specific portals, for regular Learning Management Systems, LMS, that are able to support mobile communication and devices on GSM type of networks in Europe. This means gateways for SMS supports, sometimes the support of the WAP, or I-Mode standards, for browsing information. But until now there are no true multi-channel accesses to these LMS, in the way already explored in the field of m-Commerce. Even worse we have already demonstrated that Learning Objects standards, such as SCORM compliant ones, can limit the potential of a dynamic adaptation of the learning contents to the diversity of channels (X3, 2006). Similarly, the potential of the multimodality is not used in m-Learning, for example using the potential of coupling voice and WAP interaction, thanks to standards such as VoiceXML and X+V, and the proposal for a true multimodal and device independence Web in the future, by the W3C consortium.

## 2.2 Emergence of the Pervasive Learning Mode

In the last years a new concept has appeared to translate the potential of Ubiquitous or Pervasive Computing in education. This new way to use technologies to support the learning processes has been called either "Ubiquitous-Learning" (or u-Learning) (Jones, Jo, 2004), or Pervasive-Learning. (Keil-Slawick et al., 2005). In this proposal we have adopted p-Learning to name this new field of research. As for m-Learning, most of the authors mention that p-Learning goes farther than uses of new technologies provided by recent research in pervasive computing to support e-Learning traditional views, but that it enlarges also the view of the learning process itself. For example for (Bomsdorf, 2005): "***Ubiquitous learning*** *is the next step in performing e-Learning…. Furthermore, it enables seamless combination of virtual environments and physical space".* And she gives the main characteristics of u-Learning in terms of: Permanency, Accessibility, Immediacy, Interactivity, Situating of Instructional Activities, and Adaptability. It means than context sensitive learning environments, learning material semantics, are not necessary locked to the geographical location of the learner, but depend of other kinds of contexts such as his/her present role into the professional activities and work, the history of the past learning phases, the technological contexts (characteristic of the present channels that can be used) and, in the future, even the affective state of the learner. In

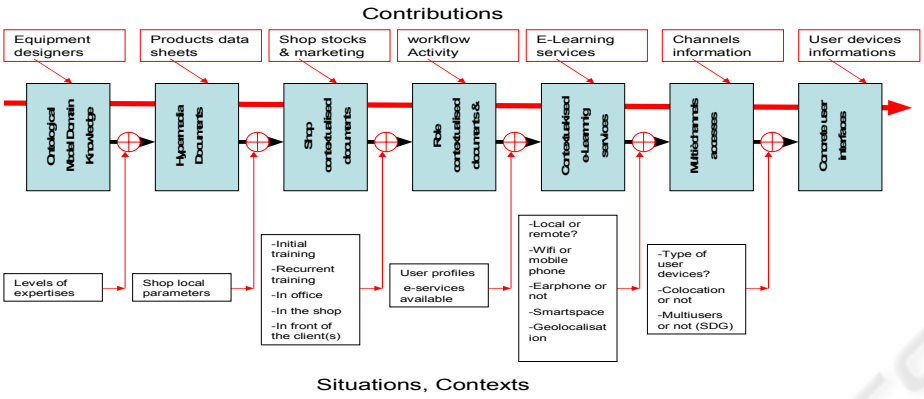


Figure 1: Chain of contextualized transformation for the scenario Personal Training Assistant.

accordance with Bomsdorf, we state that the central problem is about dynamic adaptation of the learning materials and activities proposed for several kinds of contexts. We also share the reflection done by (Syvänen et al., 2005) when they said "*The combination of context and adaptivity…can also prioritize communication channels, encourage cooperation, and adjust information modalities*".

It is the challenges that we want to support into the open intermediation infrastructure we are designing in our present project. And for that purpose we will reuse also previous researches that we have conducted in the field of multi-channel e-Commerce (Chevrin et al., 2005a).

# 3 NEW NEEDS AND NEW LEARNING SCENARIOS FOR EVOLVING ORGANISATIONS

## 3.1 Some General Hypotheses for the Design of Future p-Learning Infrastructures

Just to summarize we want to put emphasis on some of our main hypotheses, which result of our previous investigations and experiences in the field of e-Learning, or in the field of the mobile-Commerce:

H1: New learning modes, in this case, the p-Learning mode, and new organization approaches will appear that enlarge or modify the traditional e-Learning mode. This is especially true due to the ubiquitous nature of the interaction with the learner on the one hand, and in the other hand to the new needs of the organization for the training of both, and jointly, of their employees, clients, providers and partners in accordance with the related organizational workflows. There is also a tremendous potential for some learning environments and contents that are more or less auto-produced by the learners themselves, in collaboration with others pedagogical agents (human or synthetic one). This leaves place for a better involvement and an active participation of the person to his/her learning and collaborating process;

H2: There are various "contexts" that need to be considered for a real p-Learning system, some are independent of the domain of application such as technological, physical contexts, and some are specific to the learning process and to the present status of the learner (worker or client). An effort must be put on the way to "contextualize" a pedagogical scenario and to support an easy development of the deployment of the infrastructure needed for these p-Learning settings;

H3: The first generation of technological e-Learning platforms, the LMS, are not suitable for the development of p-Learning, Learning on Demand across the value-chains, and in the context of future agile and virtual organizations. The future will be a collection of dedicated learning and other e-Services, some provided outside the concerned organization, similar to the Application Service Provider model;

H4: The first investigations about mobile-Learning have shown that the mobile phone user platform can be useful if proper adaptation of both the learning material and of the learning activities is done. The rise of the Smartphone, supporting universal roaming (from GSM to Wifi and local Internet accesses for example) and different communication medium, from Voice, Podcasting, WAP, Web 2.0, Rich Media, to Digital TV, should be a booster for the new learning environments;

H5: Importance of the dynamic adaptations of materials, e-Services and activities for learning, and

of the delivery systems and their channels or modalities mobilized for the user interaction, in a great diversity of contexts and of rules and strategies of transformation, that maintain nevertheless the pedagogical and didactical intentions.

### 3.2 An Example of Rich Generic Scenario with the Associated Transformation Chain

In the framework of our present project to design a p-Learning infrastructure we have partnerships with companies in the field of retail, ranging from small retail shops to hypermarkets and huge online stores. The following generic scenario is extracted from the needs in matter of p-Learning coming from one of these partners. However it will be simplified here for reasons of clarity and of confidentiality.

The main aim is to develop a Personal Training Assistant (PTA) for sellers working in the field of Hifi/Video equipments. This domain is becoming complex due to the rapid changes in the underlying technologies with the appearance of High Definition TV, sophisticated home video, media-centers, Terrestrial and satellites digital TV… So an effort for continuous education of the sellers is needed in order to maintain quality of the relations with the clients and his/her efficiency. The main idea is to use hand held computer, which can be used for several others purposes also (stocks management for example), in order to support both the learning and the coaching of the seller/learner in various contexts. It could be for example a Personal Assistant connected to the information infrastructure of the shop. Because the development of such a training system is costly, it is envisioned that the cost will be shared by a cooperation across, not only all the shops of the distributor, but also across the value chain. This means that the learning contents and activities start from general and more abstract levels, not contextualized, are transformed through a chain of transformation, in order to generated, mostly at run-time, a dedicated, contextualized support for a particular seller/learner interaction situation. It must be noted that the whole system has also intents to be adapted automatically to the training of the potential clients, in order to facilitate her/his choice of particular set of equipments, or for after a purchase for its operations.

Figure 1 shows that many transformations must be supported in order to deliver a pertinent learning or coaching support to a particular user that can be mobile, across the shop and connected through wireless networks. Various situations (or contexts) can be handled by the system depending of the place, work activities, presence of the potential clients or not, etc. Several sources on contribution feed the chain with knowledge and contents. It must be noted that the other e-Learning services such as tutoring, assessment, access to dedicated forum, management of the learning curriculum, are introduced on the fly, depending of the situations and needs. Transformations will be done at run-time following rules and inferences about knowledge modeling at design time.

There are two main situations for the seller/learner:

- The seller, or client, is outside the shop counters: seller in the back office or storage areas, client at home or another places;
- The seller is in middle of his/her department, alone or in front of potential client with the possibility to use resources from the Smart Space surrounding them.

We can precise here the second situation which is richer in terms of interactions and importance of contexts. In this situation, from the learning perspective, the seller used the mobile information system for both revising his/her knowledge about products and selling characteristics or as a coach to help him/her, in front of the potential client, in the selling process especially in the selection/decision phase. For this purpose he/she is equipped with a new Ultra Mobile Personal Computer (UMPC) such as the Q1 of Samsung, operating with WindowsXP OS system and having a WiFi connection to the shop network, and a Bluetooth to an earphone or eventually to the mobile client's phone (in order to download information). From the earphone the seller can receive calls from the call-centre of the shop or enterprise, and computer generated voice message with the help of the VoiceXML standard. Future investigations will also support multimodal interaction both using the digital pen or the touch screen of the personal assistant and the microphone included in the Bluetooth earphone. There are two main variants:

- One where the seller is also equipped with a portable of a code-bar of RFID tag reader. This enables the potential for real objects, such as the product (DVD player for example), to play a role into the interaction and the learning process, because, they have their counterpart into the virtual world;
- The second where the seller can also supplement his/her PTA with a larger LCD screen, located in the department and connected to the shop network. This is useful for the sharing of information with the potential client forming a Single Display Groupware (SDG) with the PTA used as the coordination supervisor. This is an example of SmartSpace where some pervasive technologies augment the

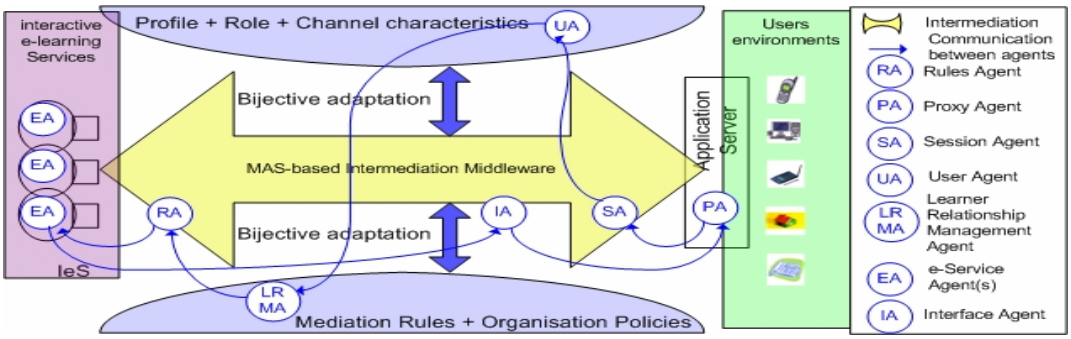


Figure 2: Global view of our infrastructure.

potential of places with services and dedicated apparatus shared by the user owners of mobile devices.

This is a way to follow the vision about Pervasive Computing as advocated by (Satyanraynan, 2001).

# 4 THE DESIGN OF A FLEXIBLE INFRASTRUCTURE FOR P-LEARNING

## 4.1 Dynamic Composition of e-Services for p-Learning with Multi-channel Interactions

Following the movement already started in the field of software engineering, with the Service-Oriented Architecture (SOA) and in the business field, we can show that SOA is also a good framework to reframe the Learning and Content Management Systems (LCMS). This is confirmed by proposals for the future learning systems, seen as a collection of e-Services, such as those of (Wilson et al., 2004) who proposed a framework of e-Learning services for a consensus at the international level. If we analyze this proposal, we can see that the architecture, made of numerous services, can be decomposed into three layers from bottom to top: the underlying layer concerns the data and their persistence across the services relying on some databases. The intermediate layer provides application services (for education it is for example LearningFlow, e-portfolio, authoring, etc.) and common services (AV conferencing, role management, DRM…). The upper layer not precisely described in (Wilson et al., 2004) is called User Agents and is in charge of managing the interaction between the user (through his/her DUs) and a collection of services that composed his/her applications.

This hypothesis about the importance of these future open frameworks of learning services is one of the main assumptions behind the design of our infrastructure, with a focus on the upper layer. But, because at this stage the whole framework of e-Services is still under development, we have decided, pragmatically, to "wrap" already available services derived from existing e-Learning platforms (LCMS existing in open source) providing learning documents; a dedicated e-portfolio (http://elgg.org); And from Wiki like one, in order to be compatible with our specification of the e-Services and with the Web services technology standards (I.e. the SOAP, WSDL, UDDI trilogy). This is the left part of the schema given in figure 2 about an overview of the software architecture.

## 4.2 About the Modeling of Different Contexts and Dynamic Adaptations

The e-Services proposed approach allows us to concentrate our effort on the management of the dynamic composition of e-Services directly in interaction with the learners, that we have called Interactive e-Services, **IeS**, in figure 2. We have already shown (Chevrin et al., 2005a) that this composition is not independent of the characteristics of channel used, as usually think. For us, a channel is the composition of a particular User Devices (i.e. a personal assistant) with a particular communication network, which proposes one or more human communication modalities: textual, direct manipulation through graphical interface, voice….

Nevertheless, we have already done an important research effort for the IeS composition and multi-channel adaptation (Chevrin et al., 2005b). In order to support more general mechanisms for the adaptation of the flow of documents and interaction elements to the different contexts, we have built a meta-model of the context-aware process, following for that purpose the proposals of (Henricksen, 2003).

This allows the description of the relationship natures and the constraint associations, between the different contexts and their effects on the main elements used in this ontological model. This leads to the design of our own adaptation metamodel that we cannot present in detail here. In this metamodel there are four main entities around the user/learner, forming the core of the model, which are: the Organization (responsible of the intention: training) the Context, the Activity and the Channel. The activity is linked to the learn-flow model that can be expressed with the concepts of IMS-LD, our other workflow metamodels.

In our collaboration with a Tunisian research team, we have made a new step by considering the concept of activity as part on the context. In fact, we have proposed a new approach, which is the bijective adaptation between contexts and user activities (Malek et al., 2006). The next step of our works is now to plug this "bijective adaptation system" (symbolize by the bi-directional links in figure 2) on our intermediation middleware for supporting more pertinent ubiquitous interactions. Up to now, it was the activities that were adapted to the context. From now, from this point of view, the context may be also adapted to the activities if it is possible and pertinent.

We retain from the previous works on context-aware computing that there is a need for better models of contexts and models of adaptation of services which are context-sensitive. At this stage we reuse some results and technological solutions of previous researches, for the parts of the context that is not directly related to the learning situation. It is the user profile, the technological context with an emphasis on the channel context, and some parts of the physical contexts, such as the detection of position in front of a Single Display Groupware for the seller of our proposed scenario in section 3.2. Our effort is put mainly on the parts of the context that is directly related to the learner activities. Effectively the activity itself is also a context, especially through the history of the past episodes of learning and also the work activities. In the proposed scenario this means that we must adapt the p-Learning environment to the professional situation, for example the nature of the present activities of the sellers, and the presence or not of a potential buyer.

### 4.3 The Software Architecture for Intermediation based on a Multi-Agents System (MAS)

We present now our overall software architecture based on a Multi-agents System. This is an evolution of our previous infrastructure developed for research in multi-channel and multimodal interaction in mobile-Commerce (Chevrin et al., 2005b). This architecture is dedicated to the management of the intermediation between the IeS and the channels used during an interaction. The central principle of our solution is that the data, document, flows are going from an abstract form (elaborated into the IeS) to a concrete form, in the Application Server that manages the different channels accesses, through the chain of transformations, close to those given in figure 1. The heart of our architecture, as given in Figure 2, is implemented using the MAS technology. The MAS role is to coordinate the use of the other parts of the prototype, i.e. the context, the organization policies, the intermediation between the IeS and the channels used (synchronously or not) during the interaction with the user, etc. The adaptation of the IeS is done through the intermediation middleware already presented in details in (Chevrin et al., 2005b).

The interest, of using a MAS as a substrate for the design and implementation of our infrastructure for p-Learning, is of course due to the already well known flexibility, and potential to support evolving systems, of MAS as dedicated middleware for pervasive computing. But less known the multi-agents paradigm is also useful for some complex and dynamic mechanisms required in multi-channel and multimodal interactions with the end users, the learners. The two main mechanisms are:

- The fission mechanism: where the abstract document can be split into contextual sub-elements that are adapted for, and routed to, the right channel. This form the multimedia output in a multi-device context (more in section 5);
- The fusion mechanism: where two input channels (i.e. voice and graphical selection) used during an interaction with the user, a session, are combined, in order to form a request: understandable by the middleware agents and directed to the right service. This is the multimodal mode of interaction.

For the MAS we have used a technological platform that is relatively mature now, JADE (http://jade.tilab.com/), in operation in several projects on mobile communications supported by telecommunication providers, and that offers the possibility to deploy software agent even inside the User Device, due to its implementation in JAVA, and its respects of technological standards for interoperability.

# 5 EXAMPLES OF ADAPTATION FOR THE PTA SCENARIO

In the proposed scenario, the seller as a learner can do three types of activities, which are contextualized:

- Access to the learning contents by navigation guided by a network of concepts relative to the selling domain (ontological model and adaptive hypermedia);
- Access to the learning contents through the product datasheets or frequently ask questions;
- After a dialogue with the client, selection of a similar case already solved (for example problem of a home studio configuration), which help her/him to give a better advice to this client (Case-Based Reasoning);

In one of the phase of the scenario, the seller asks the client to follow him/her to a specific apparatus placed inside the store department in order to augment the potential of his/her PTA. In this pervasive learning situation, the fusion and fission mechanisms are used to support the collaboration of the user device, his/her PTA, with the SDG (see figure 3 for the setting), that requires a fission operation, or even with the mobile communication system owns by the potential client (i.e. downloading of commercial information). The data and documents provided by the IeS of the left part of the architecture as described into figure 2, must be dynamically split into different streams depending of the contexts, for example the user preference and the present characteristics of the two or three channels in action. Same the use of a voice channel in input jointly with user action on his/her tactile screen of the UMPC required a fusion operation in input in order to analyze the request in accordance, also, with the present contexts of interaction. In this case, we will have several particularities such as using multi-devices and "physical objects" of the environment such as the shared display or RFID tags on products.

The Figure 3 shows an example of SDG arrangement. This SDG is composed of four distinct channels: two are visual, one small and private viewed by the seller, one large and public viewable by several persons; the voice channel directed to the seller, and private, thanks to the Bluetooth auricle; and possibly the data channel of the client mobile system if connected, for example by Bluetooth link, to download commercial documents and guidelines.

The heart of this scenario implementation is the dynamical fission of the different information on the different channels. Projects like (Han et al., 2000) deal also with this subject.

The Figure 2 shows the different software agents implemented to manage the fission mechanisms. The Session Agent keeps a state of the different channels used, and in this way, the data fission. For the moment, only one software agent (Proxy Agent), manages the routing to the dedicated channels.

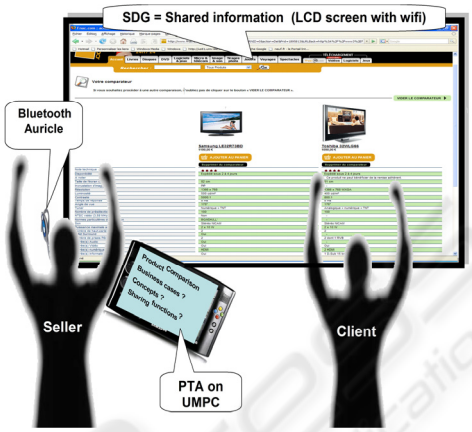


Figure 3: Example of SDG arrangement in the PTA scenario.

# 6 CONCLUSION

The application of advanced technologies and models introduces the possibility to dynamically adapt the contents and the services composition to a particular learning and learner situation, in accordance with various contexts, including his/her past experiences as learner and the present situation as worker, and the impact of his/her mobility on location, proximal resources… The new step, called pervasive learning environment, is to realize the potential of the pervasive computing vision (Satyanraynan, 2001), which proposes the extension of mobile computing with the potential of Smartspace, where the user interaction and experience can be enriched with concrete objects, having their computerized counterparts, and by e-Services embedded into the surrounding (for example the office, the shop…) and supported by an invisible and very proactive, attentive, infrastructure.

However the potential of designing and using pervasive learning environments is hampered by two interrelated problems: First to find real needs and significant situations for this proposition; And second by the lacks of open infrastructures, and equivalent of the past LMS, adapted to context-aware dynamic adaptations of contents and services, and the multi-channel and multimodal nature of the user interactions that are inherent to the use of small, limited, embodied, mobile devices.

We think that professional world with the demand for continuous training and learning on

demand of workers in real situations (professional activities and contextual physical settings) is a good candidate for an application of the potential of p-Learning. For that purpose we are developing a first solution, called the Personal Training Assistant, supporting the counseling and selling of products that are complex to master and in continuous evolution, the sector of TV HD in our case. This is a new learning scenario that has a great interest for the retail industry and its evolution to e-Retail.

Our contribution, to the second problem solving, is to propose an infrastructure sufficiently open and flexible to support a wide range of p-Learning settings. However the difficult problem is about the reuse of the previous different contexts models and the standardization of the information they can provided. In p-Learning we think that this must be done pragmatically by reusing Context Provider Services when they are available, for example as results of more general researches in pervasive computing, or even proposal from international consortium such as Liberty Alliance for the management of the digital identity of the learner including his/her profiles as users of e-Services.

As researchers in the field of Technology Enhanced Learning, we must concentrate our collective effort on the definition and modeling of the part of the contexts that are particular to the learning activities and processes. This elicits the weakness of currents standards for e-Learning, such as SCORM for the learning objects or IMS-LD for the pedagogical scenario and learning activities, because they offer no possibility to specify and support dynamic adaptations that are context-aware.

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