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Learning aware environment: a Laboratorium of epidemiological studies

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Abstract. One challenge of the Laboratorium is to have the capacity to recognize and capture relevant events from observing the human activity, the ability to understand the learning needs and then to provide the adequate feedback in whatever form. Another challenge is the mapping of inaccessible phenomena into the sensible and temporal space of the classroom. Our design combines gaming situations and ambient technologies in the context of learning bio-statistics. This paper presents a method and a formalism to design such classroom activity supported by a learning aware environment. It is a design-based research in which lessons learnt from a first full-scale implementation are integrated into the design of a second implementation. In the latter, students will have to inquire on a nosocomial disease in a hospital.

Keywords: ambient technology, collaborative learning, experiential learning, simulation, multimodality, statistics, epidemiology.

1 Concept and characteristics

Emerging digital technologies are bridging the *biosphere*, where our bodies and activities are developing, and the *noosphere* where minds and intellectual constructs are developing. While language and the related symbolic technology (writing and reading) were the privileged tools to support learning, digital technologies go beyond by producing highly interactive simulations and virtual worlds. Especially significant is the development of augmented reality with the systematic embedding of sensors and system on ship in all artefacts, which open the possibility of a "merge" of both spheres. Here is the challenge of ambient computing. The challenge is to design scenarios allowing implementing "ecological" learning situations without the boundaries of the screen. In ecological situations, classroom-based learning situations are implemented on a regular basis for several groups of students, as opposed to one-day interventions in one class or to controlled studies in the research laboratory [1]. We introduce the concept of *learning aware environment* [2] that adapts to and gives feedback to the learner based on actions interpreted not only in terms of task objectives but also in regards to the didactical intention and the learning at stakes. Our design aims at creating environments that engage learners into scientific inquiry. The making of meaning requires the accumulation of evidences gathered over extended

periods of time with the goal to make argued decision based on these evidences. We focus on the acquisition of the methodology and the organization of the scientific work, in the field of bio-statistics. Students have to organize space and time to collect data, then gather and analyze what they have obtained individually to build a collective knowledge (share data and results). Data being numerous and distributed in space, data cannot be collected by one student. Moreover, given the role of time the experiment cannot be replicated at will. Therefore, close to what happens with field studies, observations have to be planed, showing may be more accurately the relation between observation and theory [3]. As for learning, we focus on interdisciplinary content: mathematical approaches (here statistics) to science phenomena (here in ecology then medicine).

Our design is characterized by (we indicate under brackets how it applies to our situation in epidemiology):

- *Immersive learning experience*. Students experience randomness by immersion into a phenomenon (occurrence of a nosocomial disease at the hospital): they are plunged physically and emotionally into the phenomenon.
- *Simulation*. The simulation evolves over time and space and is accessible continuously over an extended period of time: an otherwise inaccessible professional situation (hospitals are not open to student for such experiences) is mapped onto the sensible and temporal space of the learning context (a medical school).
- *Multimodality*. Rather than centralizing information access on the same media, information on the state of the simulation is available through different media (laptops, phones, DVD players) that are tangible access points to the virtual phenomenon. This is to generate behaviours that are typical of the professional practice of reference.
- *Personalization*. Students collectively design data collection campaigns, and they gather and interpret their own data in order to make a decision (regarding the hospital they are studying). They only get the data they have decided to collect since there are too many to be collected, and data depend on time and location.

2 Motivation

Our design is based on the principles of situated experiential learning [4, 5]. There is a large body of research starting from the claim that one constructs knowledge based on own experiences (from authors like Dewey [6]). Experiential learning is often used in the context of vocational training. For instance, consider flight simulators in pilot training: learners are immersed into a simulated aircraft cockpit where they live a cognitive, operational and perceptual learning experience. All these three dimensions may impact knowledge construction. Inquiry learning and serious games are other contemporaneous examples of experiential learning approaches that may be used in classroom-based learning situations.

We combine a dynamical simulation based on biological data with a gaming scenario. Usually, a conceptual simulation is a mathematical model plugged on an efficient visualization of the targeted phenomena. However, such simulations are often processed within the limited space of the screen of the computer over a short period of time. Moreover, research on learning with simulations have shown some limits, [7] and [8]: (i) their superiority to a static presentation is not always proven, (ii) they propose to learner an already abstract view of a phenomenon in place of experiences with the material world, (iii) they do not favour critical thinking since students tend to believe any information delivered by a computer, (iv) they favour a try-error strategy obviating reflective work on the initial issue and on the methodology. The development of virtual reality and the so-called full-scale simulations allow the access to spaces beyond the limits of the screen. However, one is still immerged in an artificial world with time and persistence constraints. The idea of embedded phenomena coined by Tom Moher [9] opens ways to overcome several of these limitations. The embedded phenomena framework is used for learning about dynamical and spatial scientific phenomena [9, 10]. It is based on an environment in which scientific phenomena are mapped into the physical space of the classroom. It uses distributed media (e.g. tablet PC) positioned around the room and used by learners to collect data or modify the course of the simulated phenomenon. The simulation is persistent and spatial. Another related work is the participatory simulations used for learning about complex social or scientific models [11]. This design enables learners to become active participants in life-sized, computational simulations of dynamic systems. It provides an individualized experience and perspective on a complex model (e.g. a toy model for disease propagation) to be discovered by playing with the system. It combines gaming situations and interacting mobile devices.

3 The Laboratorium project

The goal of the “Laboratorium” project is to build a place for immersive learning experiences on multimodal simulations. It will be used (i) by students to solve problems and by doing so acquire interdisciplinary skills, and (ii) by researchers to design and study learning aware environments.

One challenges is to incorporate teaching (coaching, instructing, scaffolding, or else) features into the design of learning aware environments. This necessitates didactical studies of the knowledge at stake within the targeted learning context. In our project students learn about bio-statistics. One way to teach concepts and develop skills in this field is classically to have students work on a given issue and on given data. By doing so, one looses two keys steps: (1) the orientation phase where students formalize questions (formulate statistical questions starting from a biological problem), and (2) the phase where they design experiments to answer these questions (including issues like sampling size, measurement method, confusion factors). When working on pre-selected data, students miss the opportunity to experience difficulties

in collecting data and to think about data quality. In our simulation, a variety of possibilities will allow students to confront methods and results and go back to their design if necessary.

The research challenges of the Laboratorium come from two issues related to data collection in research on technology-enhanced learning: (1) conditions under which data are obtained must be controlled and described, and (2) experiments should be non intrusive and be a non singular event in the life of the learners and teachers. In order to fulfil these constraints, the Laboratorium will be used on a regular basis by teachers and researchers. It is located within the institution and partners will agree on experimental protocols to be executed during some of the student activities. Data for research are mostly trails lefts by students while using the system and will be completed by questionnaires and interviews. Our design-based research focuses currently on how to design a Laboratorium that provides students with personalized and authentic experiences. For this, we must first find a compromise between the requirements of the professional reference as it is scientifically and technically defined, and the constraints of a learning situation to be held within an institutional context (issues of time, space, resources, assessment, students initial conceptions, etc). Second, we specify the characteristics of the physical space, the time schedule and the game-play in order to ensure the devolution to learners of the meaning of the situation ([12] p. 41), to provide scaffolding to maintain an evolution of the activities likely to lead to the expected learning outcomes, and eventually to allow the teacher to acknowledge with students the progress that has been made (what is never easy when the situation is rich and students have a difficulty to identify what was the point in learning terms).

Our Laboratorium project follows a design-based research approach and is entering a second phase. With this approach one designs learning environments based on research outcomes through several iterations of full-scale tests and redesign [1, 13]. In a first phase, a Laboratorium has been implemented with an early version of our design. We provided students in bio-statistics with experiential learning in an authentic context (here derived from forest ecology). This allowed to evaluate the consequences of some of the design choices and to work closely with practitioners from the beginning. We will not insist upon the stages of a research-based design [13], but rather present the various analyses that based the formal specification of our learning environment:

A1. Analyses of the knowledge at stake in order to define a learning process: main stages for a beginner in bio-statistics. We used a framework [14, 15] that allows considering different domains of any human experience, namely the “factual, conceptual and interactional” domains.

A2. Assessment of current context, including objectives of the curriculum, actors involved and their conceptions, time and space constraints, etc.

A3. Analyses of the professional experience, keeping in mind that it serves to provide students with an authentic setting, but not to train them to become specialists in that professional field.

A4. Modelling of trails that will allow us to study student activities in the environment and feed our design-based research.

4 First implementation

Our first study took place in the context of the University of Lyon's plan to include Web-based activities as part of the life sciences curriculum. From the above analyses we designed a first Laboratorium based on a simulation (ecological data), a scenario (students play the role of forest engineers) and a web-based environment. Students learned to behave as scientists, make observations and inferences, design and test sampling strategies, and make decisions regarding forests to be cut down based on their statistical analysis. Participants were about 400 undergraduate students in life sciences at the University of Lyon each year (mean age = 18.8 years old). In order to support a learning process identified with A1, we provided students with five learning activity spaces that are materialized on a web-site or in class. In each space, tools and scaffolds are provided and specific learning objects may be manipulated by students. A space is designed to scaffold students' work for a coherent set of activities. However, none of these activities are prescribed. Spaces foster experiences that are vehicles for learning. In that sense they are virtual spaces. For instance, one learning activity space was designed for students to experience variability and the failure of deterministic approaches: they are exploring or experimenting randomness in virtual forests. It is based on Flash™ and uses a repository of data sets (created by students) to be retrieved and aggregated into histograms. In another learning activity space, they learn to problematise an ecological issue thinking as bio-statisticians, and to contextualize statistical objects like hypothesis (this is done with hypermedia web-based courses and personal workspaces). In yet another learning activity space, they learn to make decisions in an uncertain world. This latter space is usually organized in class by tutors and/or students (confrontation of various solutions from different groups of students).

Along the three years of the progressive implementation of this setting (from 2002 to 2004) we examined usability, student motivation, student learning and implementation issues [16, 17]. The first two years, we had the opportunity to compare two cohorts of students, one using paper-based materials and the other the web-site, while making observations in an ecological situation. We collected both quantitative and qualitative data over one semester, each year. Results indicate an increase in motivation, including for students with lower ability or poor interest in mathematics "*I understand why we take a mathematics course although I am in a biology curriculum*". On the other hand, a close comparison of exam performance over a number of learning goals in the field of bio-statistics showed persistent difficulties in this interdisciplinary course: exam scores and type of errors did not differ neither between paper and web-site conditions or between the successive implementations of the spaces within the web-site. However, assessment procedure and content did not change with the introduction of the environment: students' abilities in scientific inquiry were not tested as exams traditionally focussed on content. As for design, this large-scale experiment raised several issues concerning trails of the activity (A4), specification of the scenario (keeping in mind that the formalism should reflect the flexible nature of the scenario), and representation and use for learning purposes of the professional reference (A3).

5 Ambient technology

With the rise of mobile and wireless devices, our second Laboratorium project was initiated with the goal to provide an ambient learning situation that goes beyond the boundaries of the screen. It is intended for a bio-statistical course (followed by about 180 students, about the same age and basic level in statistics as in the previous study) in the medical school of the University of Grenoble (France), and it will be experimented in 2008/2009.

In ambient design information becomes part of the environment around the students, readily accessible. Moreover, the system, as part of the learner potential context, can become aware of the learning at stake (which includes awareness of the fact that the learner may not be able to get some of the information or data he needs). It brings into education new contexts that were usually not accessible in classrooms. Indeed, for ethical and regulation reasons it is not possible for such students to work with real patients in hospitals. The system creates a learning space that engages students into an inquiry (here within a hospital). It is based on a distributed simulation that is able to deliver data on different media. The simulation will use an information system filled with real anonymised data sets, with problems contingent to real data (incomplete information, etc). These data evolve over time as patients come or leave the hospital, or develop the disease. Epidemiologists participating to the project provide these data. To conduct analyses A2 and A3, we organized a series of workshops with a medical school teacher, an epidemiologist and a statistician. Task analysis [18] A3 resulted in a task tree (Fig. 1). Filling a task tree allowed interviewing the epidemiologist on facts and actions, rather than on a conceptual view of his practices. Moreover, the task tree allows visualizing the line of tasks that a learner with a given level of expertise may follow (e.g. green line on Fig. 1) [19].

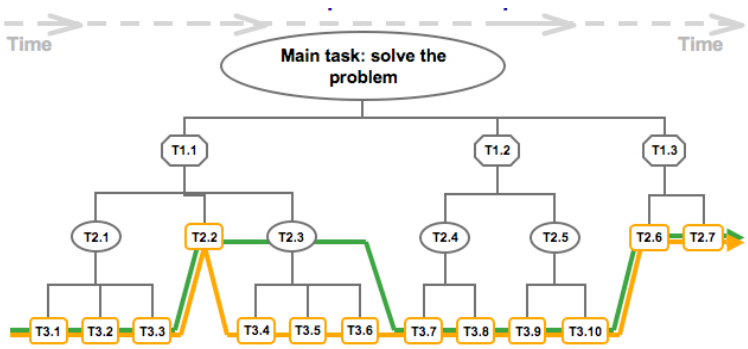

Fig. 1. This task tree starts from the problem to be solved. Tasks on the lower leaves correspond to the actions to be performed to solve that problem (orange line). Between the two, there are tasks and sub-tasks.

Combining A1, A2 and A3 analyses resulted in a design in seven learning activity spaces. One should think of such a space in terms of a conceptual unity of activities, rather than a location or a tool. It is a brick of the learning aware environment where a

number of tools and scaffold will be orchestrated to support a coherent set of activities. What the learner really does is another story. There are spaces to: (1) design the main steps of a protocol in order to study the disease status in each department of a hospital and the risk factors, (2) validate the protocol by submitting it verbally to the heads of the different departments, (3) collect data by interviewing patients and staff in the different departments, (4) submit to the technical platform a request for the necessary medical analysis (X-rays, etc) by secured mail (as it should always be the case for confidential medical records), (5) process and interpret all the data sets, (6) report on the results, write a paper to be submitted to a conference organised by teachers (only half of the papers are accepted and will be presented to the whole class), make a decision concerning actions to be done to decrease nosocomial diseases, and finally (7) present results at a conference, and discuss why results obtained by different groups of student for the same hospital are different (come back to the protocols).

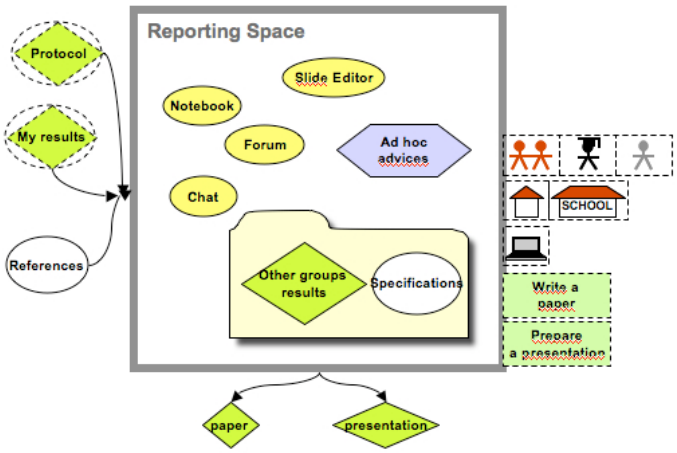

Fig. 2. Students input (resp. output) are connected to the space on the left side (resp. bottom). Spaces attributes are indicated on the right side. Possible activities are indicated in green bricks on the right side. The central space offers to users a number of tools (oval), scaffolds (hexagon) and resources (folder). There are learning objects produced by students (diamonds) and objects provided by teachers (circle).

Consider the reporting space (6): in another design it would be a text/slide editor (tool driven) or a collaborative workspace (interaction driven). By contrast, the reporting space (Fig. 2) was designed to combine three domains of experience (factual, conceptual and interactional), and its design is driven by the learning at stake while reporting (write a scientific paper and be able to criticize others, draw up a synthesis and base conclusions on evidences, prepare a short verbal presentation along with slides and get to the point).

Although in the above list spaces are ordered according to a professional practice of reference (above task tree), they might be visited anytime by students that are beginners in this practice. The scenario is thus further described by user stories. The

latter were designed using celtx™ that allows representing particular student routes between spaces, interactions between actors (students, groups, tutors, and main teacher), and time management (student planning, tutor planning). The software designed and used in the context of media creation (screenplays, etc) has been adapted to a pedagogical context for this project. Finally, a simulation data flow (not shown here) and a network diagram (Fig. 3) are added to learning activity spaces and celtx™ user stories to represent this complex scenario. For each situation, there is a different modality of communication and data gathering, e.g. (2) is based on phones, (3) on DVD players (desktops) and laptops, and (4) on secured mail. We are thus working with various objects that are not necessarily desktops. Tools and objects (e.g. phones or secured mail) engage more into a professional experience because they do not have a priori a didactic flavour. They are part of an information system and they can represent, treat and communicate information. They participate to the shaping of the reality lived by students in each learning space (which they support and bind) and to the implementation of the didactical intention (be it explicit or not) of the environment.

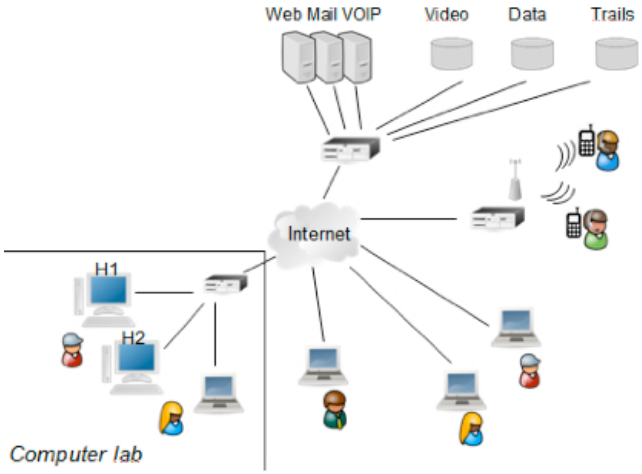

Fig. 3. High-level network diagram. Desktops represent hospitals (H*i*) and are located in the computer lab. Other tools are phones and laptops.

The framework, [14] and [15], used to design each learning activity spaces integrates three domains of any human experience, namely the factual, the conceptual and the interactional domains. Each media has been chosen so that it provides an operational or factual experience of the professional activity it is mimicking. For instance, we chose to use recorded interviews (one desktop per hospital) to represent patients talking in natural language so that students collect answers (on their laptop) standing up in front of the patient's bed and experiencing the constraints and difficulties inherent to this situation (patients that do not interpret correctly the questions, staff that is reluctant to give some information, missing patients the day of the interview, etc). Another example is the validation space (2), where students will present their protocol verbally to a voice mail (and later receive a 'yes' or 'no' answer

by SMS) using their personal phones or (4) when they send/receive secured mails with their own mail system. The interactional domain is described in terms of roles and interactions using Celtx™ (e.g. students are not supposed to speak the same way to patients and to hospital staff). The conceptual domain, that is present in any simulation often overcoming the two other domains, provides students with experiences in representing and conceptualizing their protocols and results. All the media used here contribute to enrich the experience that is the vehicle for learning thanks to the learning aware environment.

6 Conclusion

Learning is a process of adaptation to a part of our environment that has an epistemic value following a kind of economy of effort. Moreover, because of the latter, the context is difficult to describe a priori, it depends on both the environment and the learner intentions and capacity to capture information from the system (an information which cannot be captured is not part of the context and thus context is a construct). Then, the problem is to be able to characterize the context and to use this information to support learning.

Among expected positive effects of our design are its "affective impact" (more emotional interest in the phenomena) and more productive social interactions, added values emphasized by Moher [9]. A Laboratorium will provide students with a rare personalized learning experience. However, a number of conceptual analyses are needed in order to make it manageable and robust enough under the classical practical constraints in school, in particular if it is to become a testbed for research on technology-enhanced learning. We presented the first stages of our design-based research, in particular how needs of the students, specifications of the environment and orchestration are taken into account in the design of the environment, with a number of analyses and representation tools. Several questions will be tackled in the following stages of the project, such as how does it impact the learning outcome, and the teaching task.

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