# ISSUES OF LEARNING GAMES: FROM VIRTUAL TO REAL

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**ABSTRACT**

Our research work deals with the development of new learning environments, and we are particularly interested in studying the different aspects linked to users' collaboration in these environments. We believe that Game-based Learning can significantly enhance learning. That is why we have developed learning environments grounded on graphical representations of a course. These environments allow us to set up experiments with students in our university. The emergence of online multiplayer games led us to apply the metaphor of exploring a virtual 3D world, where each student embarks on a quest in order to collect knowledge related to a learning activity. In the environment, each part of the world represents a place, sometimes a collaborative place, where students are supposed to acquire a particular concept. Learning objects, artefacts or collaborative tools may be present in each location and a correct answer to a specific exercise gives a key to the students, allowing them to access other activities.

Although the students appreciate this approach, there is a lack of assessment of know-how-type skills, especially for the teacher. Indeed, certain domains present the particularity of exhibiting both theoretical knowledge and practical know-how (operations in manufacturing or medicine, for example). For such contexts, the current Learning Games are not efficient concerning this second point: a unique and full digitalisation of these objects alone is not sufficient to guarantee both effective learning and assessment of the techniques. We consider this as a gamification problem. As a matter of fact, in industrial domains, the learning processes are often based on the use of certain objects that are difficult to include in a learning game. Moreover, although some games are collaborative, an effective collaborative activity is more effective in a real context. Our objective is then to facilitate the transfer by integrating a new object present both in the game and in the classroom.

In this paper, we focus on the way to integrate the use of real objects into the learning game environments. In our approach, we develop a digital copy of the object that will help to exhibit the specific know-how that must be evaluated. It is then easier during the gamification process to include in the learning scenario certain parts that are relevant to the use of such an object and that are achieved in a real context. First, we describe briefly the "Learning Adventure" environment: a generic game-based platform. Then, we explain what the new issues of such contexts are, and how we are able to setup a collaborative learning session with both virtual and real objects. The third part concerns the application to a concrete problem: to identify and manage NonConformities thanks to a Product Lifecycle Management tool. A real experiment has thus been carried out at our university in the PLM domain with the help of a multi-touch tabletop, to validate the feasibility of the approach and illustrate our point.

**KEYWORDS**

Serious Game, mixed reality, Product Lifecycle Management, nonconformity, collaborative activity.

## 1. INTRODUCTION

Nowadays, compared to traditional teaching methods, Learning Management Systems (LMS) offer functionalities that are recognized as being valuable from different points of view. For instance, students can learn at their own speed. These environments also allow the teacher to evaluate specific activities in a uniform way. However, although they enable powerful features, they also receive major kinds of criticism (lack of awareness, few collaborative or regulation possibilities (Kian-Sam 2002)). Moreover, some students tend to consider LMS as unexciting (Prensky, 2000).

That is the reason why, observing the emergence and success of online multiplayer games with our students, we decided to adopt a learning game approach, by developing our own game environment and by using it as a support for some learning sessions. Agreeing with Vygotsky's school of thought and activity theory (Vygotsky, 1934), we consider that the social dimension is crucial for the cognitive processes involved in the learning activity. Indeed, we think that the way of acquiring knowledge during a learning session is similar to following an adventure in a Role-Playing Game (RPG). The combination of the two styles is called MMORPG (Massively Multiplayer Online RPG) and offers a good potential for learning (Galarneau, 2007) reformulated as MMOLE (Massively Multiplayer Online Learning Environment). Nevertheless, although the students appreciate this approach and that Game-based pedagogic tools can significantly enhance learning, there is an obvious need for realistic and reliable assessment about students' skills, actions or behaviours, especially for the teacher. Indeed, for certain specific domains, the teacher needs to evaluate his/her pedagogical session according to two specific points that are particularly difficult to assess via such a learning environment. Certain domains present the particularity of exhibiting both theoretical knowledge and practical know-how (operations in manufacturing or medicine, for example). For such contexts, the current Learning Games are not efficient concerning this second point: a unique and full digitalisation of the objects alone is not sufficient to guarantee both effective learning and assessment of the techniques (Schrier, 2006).

In this article, we will focus on these two points: the know-how and the collaborative behaviour. We will first describe the Game-based learning environment that we have developed, and next focus on integrating a new object concerning the two sides of the world - real and virtual - in order to set up a mixed reality learning game. The main point of this article is how to take into account the new issues due to the mixed reality, and in a secondary point how to gather in the same environment information concerning general learning concepts and business concepts. Finally, in the last part, we will try to illustrate most of these points by means of a concrete example and set out a way via a real experiment to identify and manage non-conformities thanks to Product Lifecycle Management in such a learning environment.

## 2. LEARNING ADVENTURE ENVIRONMENT

Learning Adventure is a Game-Based Learning Management System representing a 3D environment where the learning session takes place (see figure 1). A particular map (buildings, enterprise areas but also the environment with lakes, mountains and hills) is dedicated to a particular learning activity, for a particular subject. Each part of the map represents the place where a given (sub-) activity can be performed.


Figure 1. An Industrial Map in the Learning Adventure Environment

The map topology represents the overall scenario of the learning session, i.e. the sequencing between activities. There are as many regions as actual activities, and the regions are linked together through paths and NPC (Non Playable Character) guards, showing the attainability of an activity from other ones.

An example of a scenario seen as a map topology is presented in figure 2. Similar models that link pedagogical issues with game elements can be found with a more general point of view in (Amory 1999) and more precisely concerning this approach in (Carron 2008).

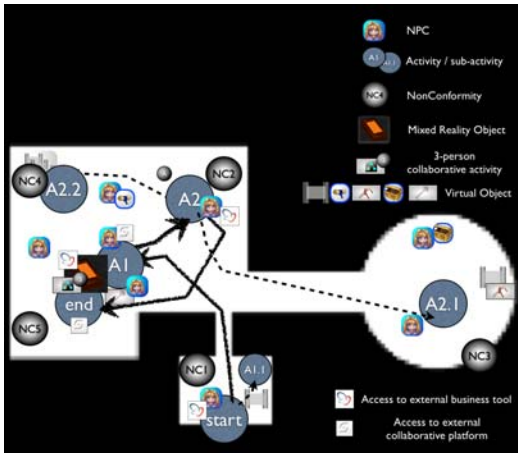


Figure 2. An example of a Scenario Seen as a Map Topology

As explained previously, Learning Adventure is based on a role-play approach (Baptista 2008). Players (students or teachers), possibly represented by their own avatars, can move through the environment, performing a sequence of sub-activities in order to acquire knowledge or/and solve problems (here finding and identifying non conformities, see figure 2). Activities can be carried out in a personal or collaborative way (see (Dillenbourg 1996) for a list of cooperation abilities): one can access knowledge through objects available in the world, via help from the teachers, or from work with other students.

Although such game environments and characteristics are well known to our students, the so-called «digital natives», some reminders are always proposed at the beginning of the pedagogical session. This first playable part called the Newbie Park allows us to describe the main functionalities, and explain the use of certain specific collaborative tools that are present in this game or this particular learning session. Moreover, as in many collaborative sessions, this part can be seen as a “warm-up activity” in order to get students’ minds into an appropriate “ready to play for learning” state. As regards Learning Games, our experience shows that such a first step is crucial, as is a final debriefing phase in order to help cement the knowledge acquired (Garris et al., 2002).

The environment is generic in the sense that it is not dedicated to a particular teaching domain. With the help of a pedagogical engineer, the teacher adapts the environment before the session by setting pre-requisites between sub-activities and by providing various resources (documents, videos, quizzes) linked to the course. Experiments have been set up for learning English as well as Project Management or Object Oriented Concepts in Computer Science. The collaboration takes place in L.A. by constituting groups of users. The NPC will give objectives to the members of a group and allow them access to collaborative tools such as white boards, file boxes or a “collaborative plan elaborator” similar to a structured discussion forum. It is then possible to construct group knowledge with specific tools. Naturally, in order to communicate with other players a chat tool is available (bottom left corner in figure 1).

It is possible for the students to embark on several knowledge quests in parallel. That is why it is important for them to be aware of the quests currently active. In order to facilitate navigation inside the game, the objects or NPCs to be reached in the active quests are displayed on a compass (upper right corner in figure 1). Moreover, one can easily reach one’s *user model* and consult the current content of one’s bag (see bag window open and icons on the right hand part of figure 1). Nevertheless, as explained previously, certain specific skills (particular manipulation, know-how) or behaviours (collaboration) are difficult to assess by staying only in the virtual world, and underscore the necessity of reintegrating some parts of the game into the real world. From our point of view, the relevant work is not trivial in nature and raises some new issues that have to be taken into account in order to keep the advantages of serious games (immersion, motivation).

## 3. ISSUES OF THE GAMIFICATION PROCESS WITH MIXED REALITY GAMES

In order to illustrate our point, we will take the example that will be the focus of the experiment described below.

In quality management, a **nonconformity** is a deviation from a specification, a standard, or an expectation. Certain specific information systems known as PLM (Product Lifecycle Management) are dedicated to providing information about such defects. It is quite difficult to identify, via a serious game, such skills that generally impose debates between the students/players featuring descriptions of the problem.

For example, our proposition was to create both a specific tool and an object able to exhibit such skills. For our example, it was important for a student to be able to present to the other ones and observe with them the possibly defective objects: we chose to create a multi-touch tabletop in order to provide a collaborative tool for that purpose. Nevertheless, depending on the context, many other interface objects could be envisaged (Feedback/Data gloves (haptic devices), 3D goggles, Kinect, physical objects ("tangible things"), QR Code, NFC Tag, etc.).

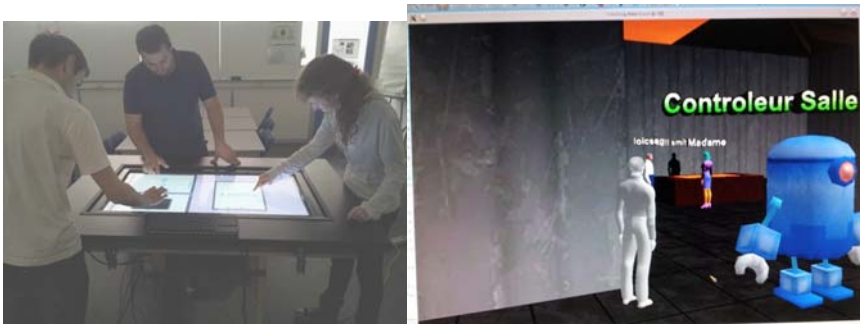


Figure 3. Students Debating About Nonconformity around the Table and the Representation of the Corresponding Scene in the Learning Game

The problem of the gamification process (i.e. the transformation of common business processes into one or several game scenarios) is already well identified, but concerning MRLG (Mixed Reality Learning Games), some brand new problems have appeared.

First of all, to remain coherent, it is important to find a way to pass "naturally" from the virtual world to the real one. Our idea was to use a specific object that existed in both worlds. This object would be used to support this transition smoothly (like a transitional object in the psychological domain). Another good side effect of this object is to help the user to reinvest their acquired knowledge more easily outside the virtual game.

A second problem concerns the access to this object: as we are working in a collaborative session, several students may require access to this object at the same time. When this object represents a (group) exclusive (or non-shareable) resource, the learning scenario has to be adapted to such a configuration in order to avoid any delay. As a matter of fact, any delay would result in instant disengagement of the students.

Moreover, it is now well known that good collaboration is effectively achieved with a group of 3-5 persons at most. We have then to ensure that the players of the same groups will progress together at the same speed and will be synchronized thanks to the scenario evolution.

A Serious Game concerning change management has already been proposed as a solution for specific training in matters of industrial problems. The purpose here is to be more general and go further concerning the gamification process by including mixed reality in such learning games. Mixed reality has allowed us to take into account new needs, but it also means that some new problems have to be addressed.

As seen in table 1, for each problem relative to mixed reality that we have detected, we have proposed a solution.

Table 1. Examples of Mixed Reality Issues

| Domain | Issues | Virtual World | Real World |
|---|---|---|---|
| **Pedagogy** | Concrete assessment (know-how, manipulation, gestures) with a specific device. | Virtual representation of the specific device (no evaluation) | Real Object/ Specific Device (effective work) |
| **Entertainment** | Keep the learner immersion | Coherent Story leading to the specific object | Integration of clues and challenges that remind us that we are in a game. |
| **Collaboration** (intra-group) | Synchronize students in the same groups | Propose some optional mini-quests | Small groups with an active role for each one. |
| **Collaboration** (extra-group) | Synchronize groups of students (no wait for access to a group exclusive resource) | Change the order of the quests. | Access to the real world |
| **Content** | Assessment of content | Indicators thanks to traces | Camera or results reintegrated into the game via digital input. |
| **Scenarization** | Retain a complete game feeling. | Beginning and end in the game. | Small moments in the real world. |

In fact, the main points in the table above are not the solutions that are proposed for illustration but rather the issues. These solutions are not exhaustive, and must be adapted to perfectly fit with the context. Nevertheless, these issues have to be resolved because setting up such experiments is very costly and generally cannot be easily done again. Indeed, logistical problems increase with collaboration and mixed reality needs. It is important to anticipate these problems and keep motivation and immersion at a high level.

These considerations have permitted us to prepare a serious game in mixed reality that has been experimented in a real context. The following section describes the content of this scenario.

# 4. SCENARIZATION AND APPLICATION TO NON-CONFORMITY VIA PRODUCT LIFECYCLE MANAGEMENT

The implementation of a PLM system significantly alters the organization of the company, particularly in the context of SMEs (Small and medium-sized enterprises). Resistance to change (individual and collective) appears naturally during the start-up of this type of system (Kadiri et al. 2009). Our learning environment is defined for supporting change management in industrial enterprises and to help companies to effectively support their staff in adapting to the changes brought about by redesigning their information systems. The challenge is now to train the employees for them to have the ability to detect and manage nonconformities with such an attractive environment. The relevance of this serious game is twofold: the use of video game techniques to teach the use of PLM to detect nonconformities and evaluate the contribution of mixed reality in assessing particular skills concerning the identification of nonconformities.

Concerning the assessment, all tools are equipped with specific probes in order to obtain information about the learning progression of the students (Marty et al., 2012), even for the specific device where the results are reinvested in the game. For example, all the actions carried out through the interface are collected in the game. We are thus able to know who has made an incorrect manipulation of the business tool or the business process, provided a positive or a negative comment, asked for an explanation, etc. For very particular assessment (that is not numerically observable), we also use camera and real observers present in the room. Generally, the evaluation of the use and ownership of content by a user is needed.

For this collaborative scenario (see figure 2), we have defined two important activities (A1 and A2) that are the main quest in sequence and three sub-activities (A 1.1, A 2.1, A 2.2) that are optional (for synchronization purposes: see table 1). We can add A0 for a starting activity and A4 for an ending one.

The scenario seems basic, but the sequence was in reality not fixed, and three ways of achieving it were expected. The narration proposed by the NPC changed with each group in order to enable access to the multi-touch tabletop at different moments of the scenario and avoid any delay.

One of the difficulties of such games is the definition of industrial scenarios. The aim of the modeled scenarios is to understand the use of PLM in identifying and managing nonconformities. The table below shows the steps concerning the main features that we want to evaluate.

Table 2. Steps of Usage Scenarios

| Steps of the scenario | Example |
|---|---|
| Observe the environment | A battery silo is different from the others |
| Identify five possible NCs | This saber is too short |
| Understand the use of PLM as a tool for collaboration | Have a look at the specific orders that could explain something unusual |
| Collaborative Exchange | Identify formally three NCs |
| Validation | Input/submit the proposition to the chief |

This process is carried out in the Serious Game with a connected PLM system as well as access to a collaborative platform in order to reach some additional learning resources (videos, tutorials). The actions that can be performed in the game are the following: discussion with colleagues and watching a training presentation, collecting information (taking pictures) in order to debate about nonconformities and visualize these pictures on the multi-touch tabletop, filling in the nonconformity form, retrieval of information from the archives, etc. The results are sent via the PLM tool to the teacher who validates or invalidates the choices.

This collaborative scenario has been experimented several times in an ecological context, as we will describe in the following section.

# 5. EXPERIMENT DESCRIPTION AND RESULTS

The experiment in real conditions concerning NonConformities and Product Lifecycle Management has been realised in order to validate our approach at the Lyon Institute of Technology with master's students.

## 5.1 Conditions and Methodology of the Experiment

This experiment was carried out in 2013 at the University of Lyon with co-located settings. During the experiment, a group of 12 students (three groups of four persons simultaneously) with their teacher were present successively in a classroom equipped with 12 computers. Concerning the social presence perception (see (de Kort, 2008)), players were oriented away from each other, limiting mutual eye contact, natural reciprocation of approach or avoidance cues and mirroring. The students were between 24 and 50 years old (PLM Master's) and for the most part familiar with computer use. Each student accessed the virtual environment through his/her workstation, and had a personal (adapted) view on the world. These students used the environment for approximately two hours. They were explicitly allowed to communicate through the chat tool provided with the system and were warned that they would be observed concerning the use of the system. At least two observers were present in the classroom. The students were free to refuse this observation (the same practical work was available outside the learning environment), but everyone agreed to follow the proposed protocol. Finally, the first part of the session consists of a fifteen-minute introductory section called the «newbie park», used in order to present and explain step by step the basic functionalities of the game (collect bag, quest book, skill book).

The same experiment has already been carried out four times (48 students) with similar results that we will explain in paragraph 5.3.

## 5.2 Support for Pedagogical Objectives

The pedagogical objectives explained in the preceding section are supported by a story that guides the knowledge quest with the help of metaphors. For motivation purposes, we integrate the scenario into a futuristic world. Indeed, the challenge is encouraged through NPCs which propose a coherent contest. Immersion is reinforced when the users' actions have a direct impact on the objects of the world. Finally, the teacher was present in the game via an avatar: it was possible to chat with him, to ask for help for example.

## 5.3 Evaluation and Results

Concerning this experiment, two means of evaluation were chosen:

- Quantitative, thanks to collaborative indicators elaborated with traces left by the users when collaborating,
- Qualitative, with live questions at the end of the session and explicit feedback from the teacher/PLM expert.

At the end of the experiment, the students were asked to answer questions to give feedback about their feelings concerning their work session. The questions (ranking and open-ended ones) evaluated aspects relating to several parts of the learning game (pedagogical content, business concepts, affordance of the objects or tools, scenario-story, immersion, collaborative activities and specifically collaborative tools, and user model evolution). The final question let the students propose improvements concerning weak and strong points of the game. For example, they found that other sub-quests should be proposed, and some people were very interested in exploring the map (and found jokes or amusing allusions). This classification of gamers is well-known (Yee, 2007).

The initial objective concerning nonconformity identification was achieved. The students were unanimous in preferring to work with this environment rather than doing conventional practical work on workstations, and more generally were very enthusiastic about this kind of experiment.

From the teacher's point of view and in the light of previous experiments, it was naturally mandatory to have specific tools supporting him in the monitoring task with the help of an updated user model for each student. As a matter of fact, the teacher is present in the game to validate propositions of nonconformity, but also to give access (/or deny access) to the right students to the "debate room with the real tabletop".

The results were satisfying but the setting-up of such tools and experiments is, as always, extremely time-consuming for the teacher - indeed, even more so than usual. We will see later whether all these facilities may be reused easily in other domains. Other experiments with the same environment but applied to a different domain (electronic teaching with arduino electronic shields) are currently planned with a larger public (60 students) and in another institute of technology.

# 6. CONCLUSION

In this article, we have illustrated a way of integrating real tools into a collaborative session of a learning game in order to be able to assess particular skills or behaviors. Thanks to information found both in the game during the pedagogical session and through the use of a professional business tool, and also with the use of a multi-touch tabletop, we validated this approach with an experiment with our students concerning the management of nonconformity with Product Lifecycle Management Systems, the said experiment being carried out in the Learning Adventure environment. This environment is collaborative, multiplayer and fully observable thanks to traces left during the game. These traces allow us to elaborate collaborative indicators. Moreover, through the feedback collected from these experiments, we are able to obtain new factual indicators of collaboration by exploiting the traces left by the users.

As stated previously, this environment is still being developed and will be aimed at proposing both specific collaborative tools and facilities to help the teacher to regulate a learning session. Moreover in future, we would like to see how teamwork may be self-regulated thanks to specific functionalities of collaborative tools. We have shown an example based on several players interacting and communicating in the same environment, but with the use of real teams and roles, we may also imagine self-regulation, team-regulation or auto regulation by the use of specific rules, as can be the case in Artificial Intelligence. Self-regulation, co-regulation and socially-shared regulation are precisely described in (Hadwin 2010).

Naturally, certain drawbacks persist: we must recognize that it is very difficult for the teacher to be present in the game, help the students and regulate the session, even with these specific tools. For the moment, the indicators that are present are not very well-integrated, because they are very time-consuming to develop. We currently think that we can develop some specific generic indicators dedicated only to classical fields of a domain.

An interesting perspective could be to develop and propose directly within the indicators some basic regulation actions such as "play specific PLM video", "propose new (adapted) content or new (adapted) scenario" or "enable/disable such facility/ies for this student".

Finally, in another project called SLI (Serious Lab for Innovation), again supported by the French Ministry for the Economy, Industry and Employment, we also applied this work to another domain: Innovation in industry. Naturally, another scenario was imagined, developed and proposed for that purpose. Some qualitative results concerning concepts and methodology about innovation are still under processing.

From a more general point of view, "conducting change" is a key issue both for industrialists and students, who will experience such a challenge later on. A generic serious games approach will help us to link the gap between education courses (a theoretical approach thanks to pedagogical resources left in the game) and concrete experimentation in a professional context thanks to the integration of a real business tool (access to interfaces via web services).

## ACKNOWLEDGEMENTS

We would like to thank the AIP Primeca for its support in this project, the French Rhone-Alpes region. We would like also to thank Noura Benhajji, Alizée Arnaud, Mathilde Buleté-Herbaut, Pierre Jacques and Guillaume Dumoulin for their help in developing the software and beta-testing concerning the multi-touch tabletop integration.

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