**EAI Endorsed Transactions on Serious Games**

Research Article **EAI.EU**

# Enhancing Proficiency Acquisition in Gameplay Design: An Approach Based on Project Based Learning

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## Abstract

Game Based Learning Systems (GBLSs) constitute motivating learning environments. However, despite of many years of research in the area, this kind of system has been used only in a few real learning situations since, its design, development and adaptation still face several barriers. In fact, GBLS design is a complex process. It requires the intervention of actors with specific skills and expertise. Unfortunately, novice game designers, who do not have enough skills inspired from both, educational systems and video games, cannot create relevant and successful GBLSs. To tackle this issue, we propose to assist designers through an Intelligent Tutoring System with good pedagogical practices where learning theories, game designers profiles and skills evaluation are taken into account. This paper, presents an approach that aims to enhance expertise knowledge acquisition for and during the gameplay design. The proposed approach is based on Project Based Learning (PBL) as well as IMS LD specifications.

**Keywords:** GBLS, Gameplay, Pedagogical model , Intelligent tutoring system , Project Based Learning.

Received on 18 November 2017, accepted on 2 December 2017, published on DD MM 4 January 2018



doi: 10.4108/eai.4-1-2018.153532

## 1. Introduction

Recently, increasing attention has been paid to Game Based Learning Systems (GBLSs) that are considered as important resources for entertainment and education. The design of these kinds of environments still faces many pending problems as it requires the intervention of game designers with specific skills and expertise.

The cost and the long elapsed time between evaluating and identifying novice game designer's requirements and the proposal of an appropriate learning process that assists and enhances GBLS design knowledge acquisition constitute the major challenges.

For that aim, we propose to develop an Intelligent Tutoring System (ITS) to help novice game designers to acquire skills related to GBLSs gameplay design. ITSs are knowledge intensive systems mainly composed of five models (Domain, Pedagogical, Error, Learner and Interface models). More specifically, the ITS that we propose uses ontology as a knowledge representation approach for all its models.

For instance, to acquire GBLS knowledge and expertise, we have used an approach based on learning ontology [1]. It aims to enrich and populate a previously developed ontology [2], [3] with new concepts, instances and relationships related to GBLS Gameplay design expertise.

The obtained ontology includes the definition of axioms and rules that are useful to reason or infer new knowledge promoting learning or sharing data within and across organizations and actors participating in GBLSs design processes. It is used to represent the domain model of the ITS.

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In this research work, we describe our vision of an ITS that enables the acquisition of gameplay design skills by using relevant pedagogical approach and good practices.

For that aim, we present first the pedagogical model of our ITS. This model aims to represent the relevant assistance for novice game designers according to their profiles and requirements with respect to learning theories.

The remainder of this paper is structured as follows: In section 2 we describe the general context and major difficulties to overcome; in section 3 we present some works related to GBLS design, attempts to support game designers, as well as characteristics of developed ITS with more attention to their pedagogical models. In section 4 we detail our approach. In section 5 we present preliminary evaluation of our idea. And finally in section 6 we conclude and outline our future works.

## 2. General Context

According to [4], GBLSs "are all about leveraging the power of computer games to captivate and engage end-users for a specific purpose, such as to develop new knowledge and skills". Indeed, they are considered as a branch of serious games that have defined learning outcomes to create learning experiences individually tailored to students based on their cognitive, affective, and metacognitive states.

The GBLS gameplay design is a complex process; it requires the participation of game designers with specific skills and expertise related to both educational and game design [5].

Additionally, actors participating in that process are called to design processes, sub processes and tasks which are complex, diversified and ill-defined. Indeed a domain is considered as ill defined if it satisfies one or more of the following characteristics (complexity, ill defined structure/role, verifiability and formalization problems) [6]. For instance, the sub process related to gameplay design is ill defined, as it contains activities with ill defined structures and contents. Moreover, actors participating in that process do not have pre or well defined roles and tasks. They must adapt them according to one's project requirements and context [7]. Furthermore, gameplay verifiability and evaluation cannot be done during the design phase; existing methods can be applied only during the test phase of the produced GBLS [8]. Consequently, according to these constraints, the gameplay design can be considered as an ill defined domain.

That is why helping novice game designers to acquire necessary knowledge and expertise, constitutes a major asset. To achieve this objective, we shall have an appropriate environment that: (1) Provides to novice actors relevant assistance that respects good pedagogical principles, and which takes into account their skills and tasks. (2) Considers the gameplay design characteristics and constraints (i.e. ill defined domain); which require the adaptation of specific paradigms related to knowledge extraction and elicitation.

Fig.1 presents the two fundamental components which our system is based on. The first one is relative to gameplay design process; it presents steps to follow by the game designer [9]. The second one is a full-fledged ITS; it is structured around five models (gameplay model, game designer model, error model, pedagogical model and interface model).

The gameplay model represents the set of knowledge to be acquired, actions to be performed and rules to be respected by the game designer. It contains the set of skills, knowledge, and strategies of the taught domain which is the GBLS gameplay design. We have chosen to automatically extract GBLS gameplay design knowledge and make it accessible to novice designers.

The game designer model represents the context and skills of the current actor (learner) that are useful to identify the type of pedagogical intervention that should be provided by the system. This model is based on the IMS Learner Information Package (LIP) to represent various characteristics associated to the learner that are needed for the purpose of recording the history, goals, competencies and accomplishments; engaging a learner in a learning experience [10].

The error model represents the set of errors, bugs, and misconceptions that novice game designers periodically exhibit. These are classified into four categories: manipulation errors, semantic errors, syntactical errors and scheduling errors.

The interface model represents the human computer interactions through a well designed Graphical User Interface. It grants effectiveness of the training session by allowing communication between the learner and the instructional system.

The pedagogical model determines the teaching methods as well as the way in which the intervention can take place (alert notification, assistance messages, a detailed explanation …..). It selects tutoring strategies, steps, and actions to follow.

In this paper, we focus on the development of the pedagogical model which constitutes the core of our system as it simulates the decisional behaviour of a pedagogue and defines the mediation to assist learner (game designer) in the learning process while considering good pedagogical principles. The principal aim of this model is to answer to three questions about the intervention modalities such as the goal, the manner and the moment of system implication during the learning process.

Ultimately, our approach allows the representation of expertise knowledge in an efficient and pedagogical manner to novice game designers, through using instructional methods based on learning theory, the game designer profile and errors made during the design process.

Thereby, the proposed system is based on Semantic Service Oriented Architecture [9] to automatically deliver compose, select and invoke business as well as assistance processes. Ontologies are also used to search and select appropriates processes and services relevant to learner's (game designer) profile and skills.

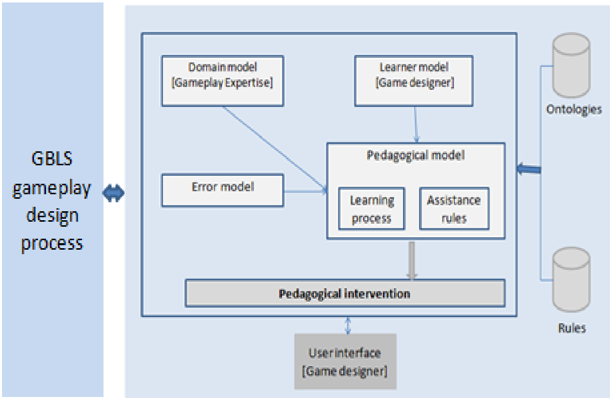


**Figure 1.** An overview of our framework main components

## 3. Related Work

As stated previously, GBLSs are considered as serious games. Gameplay design process of those systems is considered as works related to ours as they deal with a part of the overall Game Based Learning design process. In this section, we explain how gameplay design has been addressed as well as eventual tentatives of supporting game designers in doing their job and to acquire knowledge related to this area. Alternatively, tutoring in ill defined domains will be discussed, as it imposes particular challenges. We provide representative examples of ITS architecture, tutoring strategies as well as their pedagogical model characteristics. And finally we attempt to highlight respective limitations of these works.

### 3.1. Gameplay Design Approaches

Until recently, insufficient attention has been devoted to GBLS gameplay design, since GBLS development is based on storytelling approach with no attention to the gameplay design [11]. Lack of formal models to precisely define gameplay and the non consideration of the gameplay design process in methodologies of designing GBLS has been for a long time a traditional game design problem [12]. For instance, many studies have pointed out needs to present solutions in order to explain game mechanics, and to facilitate its communication as well as automatic manipulation [2][13].

Indeed, gameplay is considered as the core component of games, since it reflects the overall experience during the interaction between a player and the game system. However, there are only a very few attempts to represent gameplay in a formal way [12]. These have unsuccessfully tried to capture the essence of gameplay in a single definition, representation or diagram. Unfortunately these attempts concern only video games.

An approach presented in [14] considers game design with formal methods that can be used to create a language intended for certain aspects of gameplay. This language is based on a mathematical formalism. Indeed, it can be used to detect connections between game elements. It considers a game as a set of objects each of which is able to change its state during the play. The evolution of one's object state is governed by rules (gameplay) and influenced by the players or other objects.

Using mathematical formalism to describe the game system behavior constitutes a very precise specification method. It removes the ambiguity of natural language and makes more precise the description of rules. However, its treatment and manipulation with existing tools constitutes a major challenge. Therefore, a formal model more oriented to computer processing of gameplay is needed to reduce implementation time and errors, which ultimately leads to GBLSs of a higher quality.

In the same context, authors in [15] use Petri Nets to model game systems. They give a first attempt to game design modeling without natural language. Even if Petri Net diagrams can become easier to read and to understand, the final diagram specification is difficult to understand and to scale. Moreover, there are no considerations for pedagogical aspects that characterize GBLSs.

In other research work [16], authors present a circular model for gameplay, containing only two fundamental components namely the player and the game. The player is a human who is elected to play. The game is a system that the player interacts with; everything that is not the player is part of the game. All information about the game is conveyed to the player through clearly defined output channels and all the player's actions in the game are carried through clearly defined input channels. There are usually a relatively set of interactions that are repeated. The changing state of the game constantly prompts new actions from the player. The gameplay typically goes through many cycles of observations and actions.

Despite the proposal of a formal representation for gameplay, this approach eliminates rule concept which constitutes the core of the gameplay. Moreover, this representation considers only the human player, or in real scenarios, non human players can also participate in the game.

In another approach proposed in [13], authors try to present a definition for gameplay. They propose an experimental approach that aims to classify videogames. They develop a tool for indexing and analyzing a large videogames corpus. They define a set of recurrences called "Gameplay bricks." Then, three categories of gameplay bricks called Play Bricks, Game Bricks and Meta Bricks are identified.

However, the used corpus of videogames needs to be extended with more additional kinds of oriented learning systems like GBLSs. Moreover, this approach limits gameplay to rules and actions, but there are other aspects that need to be included as e.g. the game environment (player characters, non player characters…).

In [12], authors present an important overview for gameplay modeling. They propose to apply Model-Driven Development (MDD) to game development, raising the level of abstraction towards conceptual modeling of game. In this approach, they propose a Meta model that takes into account some concepts of gameplay. Indeed, they propose the use of models as a game design specification tool with abstract and simplified representation of game systems. Proposed models can be independent of the specific technological platform used for implementing the system.

Despites its importance to favor reusability and flexibility of the gameplay design, the proposed solution falls short of GBLS designers' requirements. Furthermore, helping novice game designer to acquire specific skills and expertise about gameplay design is not addressed.

Motivated by the goal of providing support on game design which is based on pedagogical and learning strategies, we present characteristics of existing ITSs that have been employed in ill-defined domains as well as their pedagogical models properties.

## 3.2 Intelligent Tutoring Systems addressed to ill defined domains

ITSs had been proven successful in well-defined domains. However, they have not yet achieved the same success in ill-defined domains [17]. Doing so would require specific paradigms for knowledge acquisition, extraction and elicitation.

For instance, knowledge acquisition can be defined as the result of interactions between the learner and his environment. Generally, there are four fundamental approaches such as the cognitive and model tracing approach [18], constraint oriented modelling approach [19], control oriented modelling approach [20] and expert system approach [17].

The first approach seems promising when it is used in well-defined with well structured tasks [21]. Unfortunately, this is not the case of the gameplay design.

Concerning the constraint-oriented and control-oriented modelling approaches, learner tracking is performed at different states of the problem-solving process. Those approaches evaluate the knowledge of the learner accordingly to the satisfaction or not of the constraints corresponding to each state. For instance, SQL-Tutor: [22], KERMIT [23] and INCOM/Prolog [24] are developed using these approaches.

Using expert system approach with ill defined domains and especially with domains that involve design activities is expensive, difficult to implement, cannot cover the different aspects of the correct solution. That is why using an expert system approach to teach and acquire game designers knowledge and skills is not beneficial.

As regards to knowledge extraction paradigm, several methods are presented in [25]. These are generally based on extracting human expert's knowledge. In this context, several problems have been tackled and presented in our previous work [3].

## 3.3. Pedagogical Model Characteristics

To develop an ITS both efficient and effective, several parameters must be considered such as: Genericity, modularity, individualization, adaptability and pedagogical background. During the past few years, many research works have tried to develop ITSs based on these characteristics and most of them focus on two or three characteristics [26] [27] [28] [29] [30] [31] and [32].

Moreover, pedagogical models developed within these ITSs are not based on learning theories. Also there is no consideration of IMS Learning Design (or IMS-LD) standards [33] to define more flexible and adaptable pedagogical strategies. Furthermore, developed learning strategies are generally based on the target business domain.

In fact, it is important to define an adequate pedagogical strategy that respects learning theories and standards to make pedagogical decisions more efficient and seek to better prepare learner for solving real-world problems and issues.

In this paper, we focus on the development of a pedagogical model to enhance the acquisition of expertise knowledge of gameplay design in pedagogical manner. Our approach is based on two promising alternatives: IMS LD (Instructional Management System Learning Design) specifications that enables the formal description of teaching-learning processes for a wide range of pedagogies including collaborative learning and Project Based Learning (PBL) [34].

# 4. Enhancing Performance and Expertise Acquisition in Gameplay Design

## 4.1. Benefits of Our pedagogical Model

The pedagogical model constitutes the cornerstone of our system. The creation of this model implies to follow up methodological and conceptual strategies. For that, we use learning design specifications as IMS LD and their Best Practices as well as the IMS Rubric [35], as they ensure not only the development of a framework that supports pedagogical diversity and innovation, but also to promote exchange, interoperability and opportunities to create successful learning experiences.

In this regard, pedagogical decisions made by this model must be based on pedagogical approaches that respect learning theory. For that purpose, we adopt PBL method as a pedagogical strategy for our ITS, as it is considered as a combination of cognitive and social constructivist theories [36]. In the following are its main advantages:

- It enforces novice game designer to use multiple learning techniques to succeed, including research, logical deduction, and iterative learning (trial and error).
- It simulates real-world and authentic situations, to avoid traditional learning strategies which are purely academic.

- It fosters opportunities to develop complex skills, such as higher-order thinking, problem-solving, collaborating and communicating.
- It allows access to a broader range of learning opportunities, providing a strategy for engaging multi-disciplinary learners (game designers may be academic or business).
- It includes increase attendance, growth in self-reliance, and improved attitudes toward learning.
- It improves continuous assessment.

## 4.2. The PBL Approach to Gameplay Design Process

Designing a GBLS gameplay demands consideration of several information by the game designer as (operation method, necessary equipment, scheduling tasks, tasks sharing, operating rules and data collection). Therefore, the novice game designer appears in a process in which it plans, conducts and directs alone or collaboratively a set of activities to produce GBLS gameplay.

The presence of these elements in a single pedagogical formula, brings us to give special emphasis on Project Based Learning (PBL) and IMS LD as a pedagogical method to follow. For any given project-based learning activity, learners are assigned to teams and presented with a project description, objectives, document presentation and evaluation rubrics. They are then assigned a number of discrete learning tasks which address all areas of the overall project. These tasks include access to subject matter experts and reviewing online content and resources. Once learners have completed all of the discrete tasks, they are evaluated by delivering their final project [34].

Figure 2 presents activity diagram related to gameplay design based on PBL.

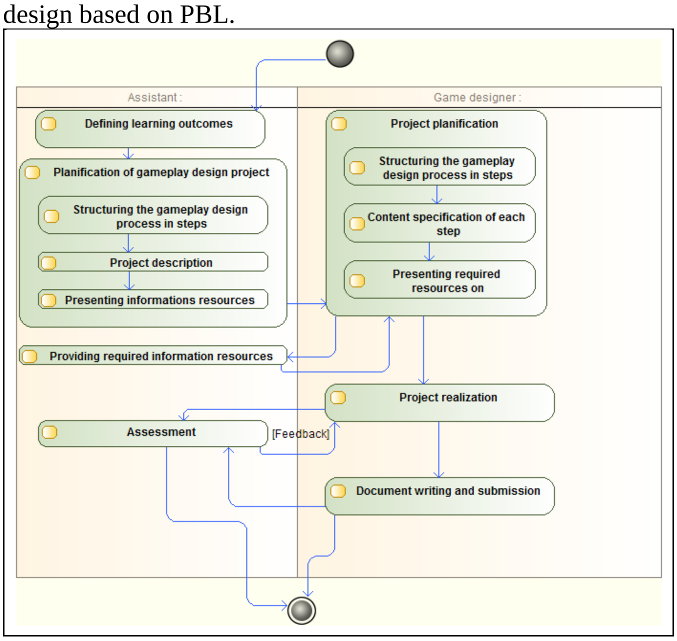


**Figure 2.** Activity diagram related to gameplay design based on PBL

## 4.3. The Assessment Module

One of the major objectives of our work is to propose the best fitted learning process accordingly to the novice game designer profile.

For that purpose, instructional decisions, learning outcomes definition, assistance provision as well as units of learning creation must be founded on the game designer assessment. Based on the PBL principle, the learner assessment process is a continuous process. This implies that, at various points within the process when developing and implementing the project, the teacher must monitor, assess and intervene, to achieve the intended learning outcomes.

In this context, IMS Rubric presents a standard that allows defining a multi assessment grid. We adopt this standard to assess game designers during their work.

For that aim, we define:

- The dimensions of quality that list a set of areas to be assessed.
- Levels of mastery that represent the level of performance.
- Commentaries that present intersection of each dimension of quality with level of mastery. They constitute a textual description of the qualities of performances and products on that dimension at that level.
- A score value related to the game designer's level of abilities.

To evaluate each parameter allowing the determination of game designer performance, we define a set of rules based on the error model.

For example, the dimension of quality related to game designer ability to order gameplay design steps can be measured through the following rules:

$$\text{SchedulingError.value} = \text{true if SchedulingError.Identifier } != \text{Null and SchedulingError.number } != 0 \qquad \text{(Rule 1)}$$

$$\text{If SchedulingError.number} = 0 \text{ then GameDesigner.Level of ability} = \text{"exemplary". Or if SchedulingError.number} = 1 \text{ then GameDesigner.Level of ability} = \text{"Proficient". Or if SchedulingError.number} = 2 \text{ then GameDesigner.Level\_of\_ability} = \text{"Particially proficient" Or If SchedulingError.number} > 2 \; then\ GameDesigner.Level\_of\_ability = \text{"Unsatisfactory".} \qquad \text{(Rule 2)}$$

$$\text{SchedulingError.identifier} = \text{Err}_{\text{or1}} \text{ if Task1 } != \text{"domain\_characterization".}$$
$$\text{SchedulingError.identifier} = \text{Err}_{\text{or2}} \text{ if Task2 } != \text{"game envirnment definition".}$$
$$\text{SchedulingError.identifier} = \text{Err}_{\text{or3}} \text{ if Task3} != \text{"gamebrick definition"}$$

$$\text{SchedulingError.identifier} = \text{Err}_{or4} \text{ if Task4} \, != \text{"game rules definition"}. \quad \text{(Rule 3)}$$

## 4.3. Intervention Rules

During the design process of GBLS gameplay, the system's intervention must be made according to rules in order to respect the autonomy of the learner on one hand and to achieve the learning outcomes on the other hand.

For this purpose, an intervention rule constitutes the core of the pedagogical decisions as it describes operationally, fundamental requirements' as well as possible modalities, objectives and moment to execute assistance actions. That is why defining intervention goal, intervention moment and intervention techniques is highly required.

### Intervention Techniques

To meet different users' needs regarding assistance, several techniques can be used such as assistance messages, user interface changes, and automatic creation).

### Intervention Moments

A pedagogical decision allows knowledge acquisition during the learning process. However, intervention moment to support learner must be done at the right time that respects the learner's requirements, learning outcomes and the learning strategy. For that aim, we adopt a mixed modality that allows intervention following explicit user request (reactive) or when learning outcome or pedagogical strategy demands pedagogical intervention (proactive).

### Intervention Goal

In [37], authors define six intervention goals. For instance, we present the presentation goal; it aims to describe tasks to be performed by the learner. Explanation goal; it consists on offering to learner additional explanations about a task. The reminder goal; it aims to remind the user by procedures or principles, (e.g. he cannot perform such an action before another.).The Guidance goal; this is to show the user how to perform a task, by graphical means (highlighting, selection, arrow, flashing, etc.). The motivation goal; provides the user with information affecting their emotional state (encouragement indication upon step completion, etc) and finally the feedback goal; it consists on offering the user additional information on system activity (propagation of data, new accessible resource, etc).

## 5. Implementation and Testing

To represent all concepts and rules related to the pedagogical model, we make use of an ontological formal presentation that respects not only the whole system technical infrastructure, but also to make it automatically manipulated, shared and flexible. This ontology includes axioms and rules that are useful to reason or infer new knowledge promoting learning purposes or sharing data within and across organizations and actors participating in GBLSs design processes.

Moreover, the development of a solution that supports pedagogical diversity, flexibility and innovation, while promoting the exchange and interoperability of gameplay design materials, is one of the key challenges in the GBLS design industry today. For that purpose, we adopt the IMSLD specification to present the pedagogical model based on PBL.

Our methodology follows the three main steps of Ontological Engineering [38]: analysis, conceptualization and formalization, followed by an evaluation of the ontology.

Analysis: This step consists on creating a glossary of terms including an informal description for each term. Table 1 presents some terms related to our pedagogical model that are inspired by PBL and their corresponding concepts in IMSLD standard.

Table 1. Pedagogical model component's

| PBL concepts | IMSLD concepts |
|---|---|
| Project | Play |
| Step | Act |
| Task | Activity |
| Learning task | Learning activity |
| Support task | Support activity |
| Learning objective | Learning objective |
| Prerequisite | Prerequisite |
| Resources | Resources |
| Actor | Role |
| Team | Learner |
| Teacher | Tutor |
| Learner | Learner |

Conceptualization: This step requires the definition of concepts, relations and constraints (axioms). Figure 3 illustrates two rules defined in WSML [39]. The first one presents necessary elements to have a validate assistance rule. The second one illustrates values related to the sensitization assistance rule.

```
axiom valid_assistance_rule
    definedBy
        ?x[intervention_objectives  hasValue _boolean("true")]
        and ?y [intervention_moment hasValue _boolean ("true")]
        and ?z [intervention_manner hasValue _boolean ("true")].
```

```
axiom valid_assistance_rule_sensitization
definedBy
?a [hasvisibilty hasValue _boolean ("true")]
and  ?b [intervention_moment hasValue ("Proactive")]
and ?c [assistance_message hasValue _boolean ("true")]
and ?w[intervention_objectives hasValue ("guidance")] .
```

**Figure 3.** Axioms

Formalization: With respect to the architecture of our future system which is based on SSOA, Web Service Modeling Ontology (WSMO) [40] constitutes an appropriate environment which provides functionality that covers various related Semantic Web Service Tasks in an integrated modeling environment such as the modeling ontology. Figure 4 presents an extract of the pedagogical ontology formalized through WSMO Studio.

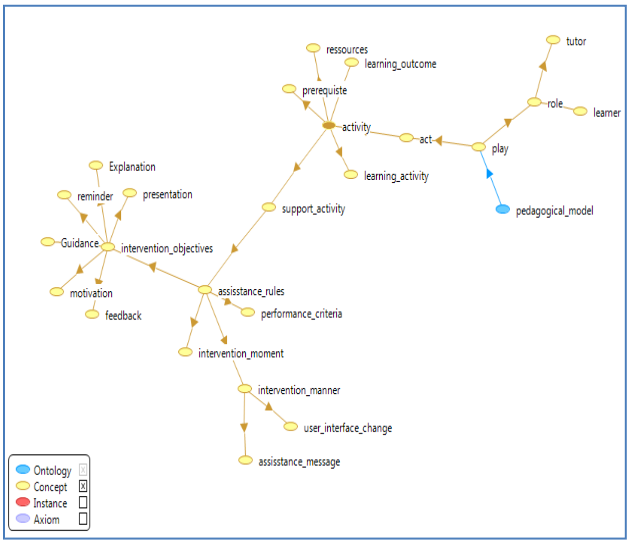


**Figure 4**. The pedagogical model ontology

Testing: WSMO contains an integrated Stratified IRIS reasoner to query the ontology described in WSML. Figure 5 shows examples of queries applied to our ontology to define characteristics of a sensitization assistance rule that is applied to learners with unsatisfactory ability.

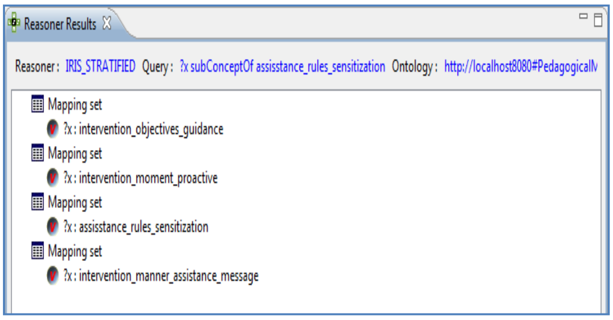


**Figure 5.** Result of query applied on the pedagogical ontology

## 6. Preliminary Evaluation

In this section we present our experience to illustrate our ideas. . We had the opportunity to test the impact of the adapted learning strategy of our ITS with a group of 10 students taking SG pathway for undergraduate students in the Higher Institute of Applied Sciences and Technology of Sousse. Due to schedule and computer availability constraints, the experimentation was made in teams of 10 students.

This use case scenario considers the goal of defining the adequate and sufficient learning content in term of determining the suitable intervention modalities (Intervention objectives, intervention manner and intervention moment) for each user.

When user runs a session for gameplay design, he has to give some basic information about himself, as well as to describe his own experiences in GBLS design as unsatisfactory, partially-proficient, proficient or exemplary. After that, he must solve a questionnaire composed of general questions concerning GBLS gameplay design. Based on the questionnaire results and the learner's self-evaluation, the system categorizes the learner abilities. Thereafter, the system defines the intervention modalities.

Figure 6 presents the first task of gameplay design related to characterizing the GBLS domain performed by student with unsatisfactory experience.

The definition of intervention modalities is related to the assessment result, in this case, for student with unsatisfactory experience, (the intervention moment = proactive; intervention manner= assistance message; intervention goal= guidance).

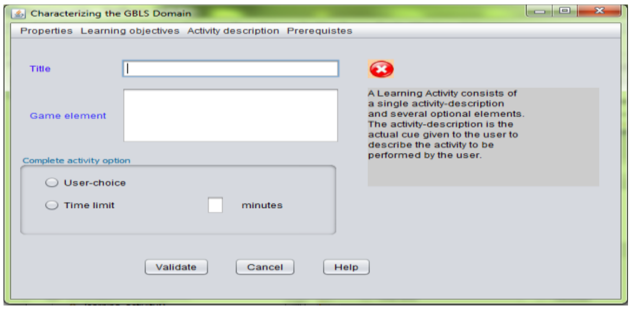


**Figure 6.** The user interface for characterizing GBLS domain

We identify 5 performance criteria that we aim to achieve after each learning session (concept understanding, resource exploitation, information gathering, deadline respect and activities achievement). After the first learning session, we compare the number of students that attend a performance after and before selecting the adequate intervention modality.

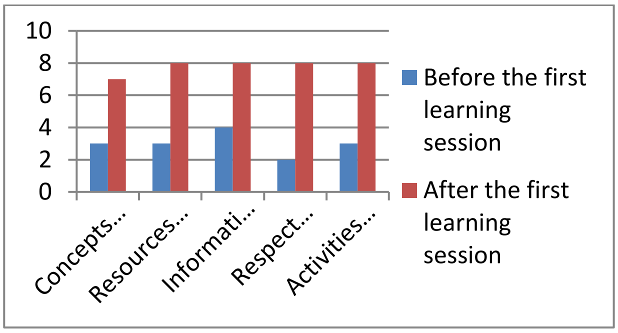


**Figure 7.** Evaluation results

## 7. Conclusion

The principal aim of the work presented in this paper is to present a general vision of the intelligent tutoring system enabling acquisition of gameplay design knowledge by using relevant pedagogical approaches and good practices.

In order to achieve this goal, we focused on presenting the pedagogical model of our ITS that aims to present the relevant assistance for novice game designer according to their profile, requirements and context while respecting learning theories. Thanks to IMSLD, IMS rubric and their best practice in one hand and to PBL in other hand we built a generic, adaptable and flexible pedagogical model that grants the proposition of relevant assistance to novice game designer.

In our future works, we aim to develop the overall intelligent tutoring system as well as its integration in the GBLS gameplay design process.

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