A Model and Its Tool to Assist the Scenarization of VR-oriented Pedagogical Activities

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Abstract: Human learning has become an emerging discipline for virtual reality. In this context, we are interested in VRLE (virtual reality learning environments), which aims at putting the learner of a pedagogical situation in a virtual reality environment. We have found in literature that VRLEs are dependent on a particular field or context and do not allow teachers to define or adapt their models of scenario to new pedagogical situations they might imagine. To help teachers in designing and generating VRLE adapted to their needs, our approach aims at defining a process for the design and production of VRLE that can be instantiated in different pedagogical situations. Our contributions focus on the definition of a scenario's model and the development of an editor allowing the specification of scenarios and pedagogical activities based on VR-oriented pedagogical objects.

1 INTRODUCTION

Virtual Reality (VR) has become a specific disciplinary field, providing the user with an exceptional immersive experience. Virtual Environment (VE), introduced in 1996 (Fuchs, 1996), is represented by a 3D model of real or imaginary data that offers ever more efficient interaction and immersion options (Cazeaux et al., 2005). These options have a great interest in e-learning by allowing the creation of original and dynamic pedagogical situations, detached from the constraints that may exist in real training like risk, cost, or uncertainty. It also brings specific advantages such as the enhancement of situations and the replay. The learning environments that use virtual reality techniques are known as VRLE (Virtual Reality Environments for Human Learning). But designing and integrating learning situations into a VLRE is both complex and costly. Difficulties can be technical, induced by intrinsic interdisciplinary of VR, as well as cognitive, which are inherited from the TELs (Technology Enhanced Learning) (Marion et al., 2009) (Carpentier and Lourdeaux, 2014). So, the model of scenario needs to be planned from the design of the environment where all possible situations have to be considered and cannot be easily adapted to new situations. This constraint does not fit to the teacher-designer's practices (Goodyear, 2015) (Hernández-Leo et al., 2017). The literature developed on this subject is mainly related to descriptions of VRLEs. These VRLEs depend on a particular field or context, and they do not allow teachers to define or adapt easily their models of scenario to new pedagogical situations they would like to imagine. This article presents a research work to propose solutions for helping teachers to design, reuse and deploy their pedagogical scenarios in VRLE. Our objective is to offer technical and methodological solutions that are reusable i.e. that can be applied to several environments, whatever the field or the type of task to be completed. This objective leads us to wonder about the activity of design and operationalization of pedagogical scenarios by the teachers in the target VRLE. In other words, the following questions must be considered: 1) How do we help teachers to express and formalize their learning situations not dependent on a virtual

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reality-based environment? Once the pedagogical needs formalized, how do we operationalize/deploy them in VRLE by respecting the pedagogical intentions of teachers and limiting the semantic losses? 2) What architecture should be used to define services to reuse/adapt existing 3D environments? 3) How do we ensure the interoperability of different 3D environments? 4) How do we overcome the limits of compatibility of technical components?

As teachers' design practices are iterative and participatory, reflection taking place before, during and after the implementation of a pedagogical situation (Bennett et al., 2017), we propose an iterative and participatory teacher-centered design approach. This article is structured in four parts: after the first section, we present a review of the literature on some critical aspects of VRLE. Then, we present our approach based on a VRLE design process, which includes the modeling of pedagogical situations. Before concluding, we present a first version of a prototype of an editor, which embeds our model of scenario to allow teachers to design and adapt their pedagogical situations.

2 VRLE: A LITERATURE REVIEW

In this literature review, we have examined some of the VRLEs in more details and studied the embedded scenario's models in these environments, their architecture, as well as their design and production models. We describe the strengths and limitations of these proposals in relation to the research questions identified in the previous section.

2.1 VRLEs Design and Production Models

The process of designing and producing a VRLE must consider the pedagogical requirements of teachers in order to answer their needs. The usual approach is to start with technical considerations before addressing pedagogical issues. For example, (Trinh et al., 2010) provide models for the knowledge explanation for virtual agents populating virtual environments. This knowledge focuses on the structure and dynamics of the environment as well as procedures that teams can perform in this environment. This makes it possible to ensure the different semantic constraints in VR: Internal properties of the spatial object; Spatial relationships between a set of spatial objects; and Semantic of spatial interactions (for example, before and after the state of the spatial tasks).

(Chen et al., 2004) propose a theoretical framework to guide the VRLEs design. This frame is divided into two subsets. The first is called "macro-strategy". It refers to the overall design of the VRLEs and involves: a) The identification of learning objectives (skills, knowledge, etc.) and the relationship between these objectives; b) The identification of pedagogical scenarios allowing the learner to acquire the targeted learning; and c) The identification of the help provided to the learner (resource information, tools, etc.) to facilitate the acquisition of targeted learning.

The second subset is called « micro-strategy ». It refers to the pedagogical scenarios' adaptation according to the type of VRLE that one wishes to design.

(Chen and Teh, 2013) propose some improvements of the virtual environment pedagogical design model proposed in (Chen et al., 2004) This model allows developing and evaluating in a formative way the simulations on a non-immersive virtual system. (Ritz, 2015) provides guidelines for best practices in integrating immersive virtual reality, especially Cave Automatic Virtual Environment (CAVE), into teaching. These guidelines will address a practical need by informing and supporting educators in adapting instructional, design to emerging technology. We note that the proposed models are not easy to achieve for non-computer trainers. Also, they don't allow them to follow the design process of their own VRLEs. The limitations of these proposals are related to the difficulty of implementing their design models and the absence of inadequacy of defining adaptable and reusable models by non-computer teachers in different contexts in order to optimize the design and production of a VRLE (Marion et al., 2009).

2.2 First Section

Many studies in the field of VRLEs have addressed the issue of modelling pedagogical situations in virtual environments. (Marion et al., 2009) propose a learning scenario model POSEIDON able to integrate VRLE in the learning process. The authors use a meta-model that provides an abstract representation of virtual environments both generic and machine-readable. POSEIDON objective is to design VR-oriented pedagogical activities. It describes all the components of a pedagogical scenario including activities in a virtual environment. To describe these activities, each POSEIDON scenario is based on an explicit business model that is independent of the learning environment. This model describes both the characteristics of the virtual environment (entities, activities, etc.) and the concepts used in learning. The approach is based on meta-modelling to provide generic modelling, regardless of the nature or domain of VRLEs, by using MASCARET (Buche et al., 2004). MASCARET is a virtual environment meta-model that provides an abstract representation of the structure and the domain of environments that allow the description of pedagogical activities. It uses different levels of modelling for respectively describing the concepts of an environment, its dynamics and the activities that can be implemented in it. It was also used to ensure the generic side of the POSVET (Fahim et al., 2016) pedagogical scenario model, which allows reusing pedagogical scenarios on different platforms. The main advantage of POSVET is to allow the adaptation of educational activities and to offer to learners a control on their learning. This work aims at adapting the educational scenario to the learners' needs but doesn't offer solutions for assisting the teachers in their design process.

(Chen et al., 2004) propose a theoretical framework which identify four principles of pedagogical scenarios' realizations: The conceptual principle that guides the learner towards the information he must consider; The principle of metacognition that guide the learning process; The procedural principle that indicates how to use the information available in the VRLEs; The "strategic" principle that allows the learner to analyse the learning task or problem to be solved.

According to (Le Corre et al., 2014) an educational scenario in the VRLEs allows to organize the training for a pedagogical purpose, however the scenario is designed for any learner without considering individualities, which can slow learning. These authors (Le Corre et al., 2014) identified the weaknesses of the Intelligent Tutorial System (ITS) PEGASE for virtual reality learning environments (Buche et al., 2010) and identified its lack of connection with the pedagogical scenario, its lack of modularity and its lack of individualization. To fill these weaknesses, they proposed an ITS called CHRYSAOR based on POSEIDON. This new proposal allows defining an educational scenario as an example of an environment based on the environment knowledge representing the domain model, totally expressed in MASCARET, contrary to POSEIDON.

(Carpentier and Lourdeaux, 2014) and (Trinh et al., 2010) propose models based on a centralized and indirect control of an emerging simulation based on a learning scenario content model. This model is based on an environment populated by autonomous virtual characters and the user is free to act as he wishes. The learning scenario design is carried out in two steps: the dynamic objectives are determined from the user's activity, then a learning scenario is generated by these objectives and implemented through simulation adjustments.

Based on These studies, we identified that the model of scenario must not be planned since the design of the environment where all possible situations must have been considered. Previous works on teacher's design's practices pointed out the limits of the frameworks proposed in the studies we examined. In this research work, we aim at proposing solutions to: Help and support teachers to produce VRLE adapted to their needs; Help teachers to design, reuse and deploy their virtual reality oriented pedagogical scenarios.

2.3 Functional and Technical Architecture for Producing VRLE

Among the studies that addressed the question of the functional and technical architecture of VRLE, we have identified those of (Lanquepin et al., 2013), which propose a platform called HUMANS (Human Models based Artificial eNvironments Software). This platform offers a generic framework designed to produce personalized virtual environments. It allows modelling mainly the human system via the virtual human "AVATAR" which makes it difficult to adapt it to other environments or pedagogical situations. The objective of this project is to set up generic and independent scenario systems, able to create environments that can be adapted to different situations in a virtual environment. HUMANS offers an adaptive scenario approach via its SELDON module. The SEDLON model is extrinsic, which means that the scenario is considered as an additional step in the framing of an existing virtual environment, and not as an integral part of the design process for that environment.

The GVT (Generic Virtual Training) project (Gerbaud et al., 2008) aims at developing a platform for producing pedagogical activities such as maintenance procedures. This platform is based on visual metaphors. This concept is important because it focuses on interactions with objects using a menu of icons representing the possible interactions between the object and the user. The generation of scenarios describing the sequence of these activities in a well-defined order is a complicated task in GVT.

For this reason, (Mollet and Arnaldi, 2006) used the LORA language. This language allows the creation and edition of scenarios. Each scenario is composed of steps representing the actions and the links between them (transitions). GVT distinguishes between the activity scenario that describes the procedures to be performed in the environment, and the pedagogical scenario, which promotes the reusability of existing scenarios. A limitation of GVT is that, owing to the industrial context in which the project is located, it can only be used to learn procedures (Marion et al., 2009) that are difficult to adapt for other contexts.

The analysis of these functional and technical architectures for producing a VRLE has revealed that they have been developed for specific domains, they do not address the problems of design (adaptation or reuse) and operationalization of scenario models directly by teachers according to their pedagogical situations.

3 PROPOSAL FOR AN RV ORIENTED DESIGN PROCESS

In order to help teachers in producing or generating a VRLE, we propose a methodological solution based on a design process (Oubahssi et al., 2018) that includes several steps from the definition of the learning situation to its operationalization. This iterative and user-centered process was defined from existing ones in TEL, and adapted to the specificity of VRLE (Abedmouleh et al., 2012) (Choquet and Iksal, 2007) (Oubahssi et al., 2004). In a first step, teachers express their pedagogical needs. Then they are led to formalize them according to their learning situations. The second step of the process consists in identifying and adapting the 3D environment in which the formalized scenario and the necessary VR tools will be instantiated. This is a service that allows the reuse and adaptation of existing 3D environments to make them compatible with the situations desired by the teacher. The third step of the process is to operationalize scenarios on one or more 3D environments. The fourth step is dedicated to simulate and test the generated VRLE. Preceded by a learning step, the process uses a phase of adaptation of situations modelled according to the results obtained. It should be noted that the literature review allowed us to highlight two observations: on the one hand, the need for a model of scenario specific to VR-oriented scenarios, on the other hand, a tool able to provide the necessary elements for modelling such pedagogical situations.

As part of this research work, we propose two contributions for the design phase of the process, a model and a prototype of an editor of virtual reality oriented pedagogical scenarios.

4 VR-ORIENTED PEDAGOGICAL SCENARIO MODEL

According to (Henri et al., 2007), instructional design consists in specifying and modelling pedagogical situations. It is "*above all a work of conception of content, organization of resources, planning of the activity and mediations to induce and accompany learning, and orchestration*" taking into account the pedagogical approach followed. According to this definition, a pedagogical scenario involves the concepts of roles, resources, activities and orchestration. It generally describes the pedagogical objectives in terms of the knowledge or skills that learners must acquire, the prerequisites that describe the knowledge or skills that learners must have, the activities and their sequence, the roles of users involved in the activities, the tools and resources needed to carry them out. It is a question of organizing and structuring the learner's activity, defining the role of each of the training actors and the relationship with the tools and resources used. Many definitions, often associated with the concept of scenario in its different variations and specifications, have been proposed in the literature (Pernin and Lejeune, 2004) (Charlier et al., 2002) (Lefevre, 2009) (Paquette and Leonard, 2014). Although the pedagogical scenario makes it possible to structure the learning context and organize it in the virtual environment and over time, the pedagogical activity and the pedagogical object are essential. The first defines the precise modalities of acquisition, validation and communication of one or more knowledge and the second allows these activities to be carried out (Pernin, 2003). Before presenting our model of scenario, we will first detail these two concepts, which are the basis of our model.

4.1 VR-oriented Pedagogical Activity

In the field of VRLE, the pedagogical situation is considered as a composition of activities realized by a set of actors in a particular environment. (Marion et al., 2009) define a virtual reality oriented pedagogical activity as the task to be performed by the learner in the virtual environment (what), described by the teacher. To that description, the teacher may add pedagogical information in order to instrument this task for a specific pedagogical purpose (how) (Marion et al., 2009). The VRLE is characterized (notably by (Roussou, 2004)) by two inseparable elements: immersion in a virtual world and interaction with modelled 3D objects (pedagogical objects, avatars). The process of activities is described in a hierarchical form. In our model (Figure 1), activities can be organized sequentially or in parallel, and be subject to certain conditions, depending on the outputs of previous activities (Barot, 2014). Each activity is characterized by a set of prerequisites and pedagogical objectives, which the teacher wants to achieve. Each activity can be divided into a sequence of actions to ensure the learner's interaction using different resources to allow immersion and promote learning. The higher the level of interaction with the system, the better the learning is (Frejus and Drouin, 1996). The actions can be divided into some basic behaviours named Virtual Behavioural Primitives (VBP). VBPs can be grouped into four categories (Fuchs et al., 2006) (Schlemminger et al., 2013): 1) Observe the virtual world; 2) Navigate in the virtual world; 3) Manipulate object in the virtual world (allows intercepting actions on objects in the environment in the form of manipulation); and 4) Communicate with others users or with the application (avatar).

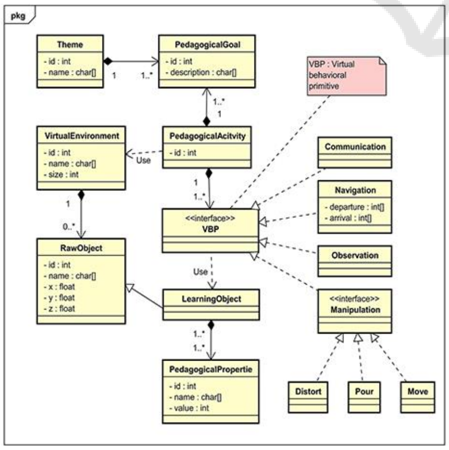

Figure 1: VR-Oriented pedagogical activity model.

4.2 VR-oriented Pedagogical Object

In some research works, a pedagogical object is presented with either the term "*pedagogical resource*" or "*learning object*" (LO) (Pernin, 2003). Specifically, the IEEE-LTSC (Learning Technology Standards Committee) working group proposes the following definition: "*A learning object is defined as any digital or non-digital entity that can be used, reused or referenced during learning activities...*" (Learning Objects Metadata Working Group, 2001). The pedagogical object is considered as a set of information gathered to attain a learning objective. Typically, it is designed by the teacher and can take various forms (Pernin, 2003). For our approach, we are interested in the notion of virtual reality oriented pedagogical object. A VR-oriented pedagogical object is presented in the form of a raw object with educational and technical properties. A raw object, also called 3D object or graphic object, is a knowledge acquisition entity. Properties are used to store values associated with these objects. Some technical properties are common to all objects (such as those that govern the position, shape or color of objects), while others are specific to the object or the learning domain. For example, a H2O solution can be used as a pedagogical object. It has educational properties such as concentration, volume and vaporization temperature.

As part of our research work, we aim to define a platform based on the concept of virtual pedagogical objects. This environment includes rules that describe the dynamic behaviour of raw objects and their educational properties. These rules define the value of the object's properties according to actions taken on the object or on the environment. For example, a cube (raw object) should have the technical properties "*weight*" as well as "*position*" and if it is released, it will fall and become deformed. It can be associated with educational properties related to gravitation to be used in a pedagogical context such as a physics course. The objective of this platform of VR-oriented pedagogical objects is to ensure their reuse in various situations regardless of the learning context.

4.3 VR-oriented Pedagogical Scenario Model

The pedagogical scenario model we proposed has been designed from the theoretical analysis of the different existing scenario models in the fields of TEL and VRLE, and the design of three examples of different pedagogical situations. Our proposal is illustrated with an example in section 4.4. One of our objectives is to develop a VR-oriented pedagogical scenario editor that embeds our model allowing teachers to easily design and adapt their situations (in scenario form) and generate their own VRLE.

According to (Marion et al., 2009), a VR-oriented pedagogical scenario, describes the organization of activities in a virtual environment, the pedagogical goals associated with them - in terms of knowledge or skills -, the prerequisites, the roles of different actors in the educational situation - whether they are teachers or learners - and the tools and resources that are necessary to realize these virtual activities (virtual objects (raw or pedagogical)). The entities composing our proposed VR-oriented pedagogical scenario model are illustrated in figure 2. Our model was designed using the different concepts necessary to describe a pedagogical activity in a virtual environment.

Among the specificities of our proposal, we note the tools of interaction (VR tools), the types of interactions (Virtual Behavioural Primitives: VBP) and the concept of a VR-oriented pedagogical object. Our proposal is an enhancement of existing models by a refined description of activities (using the VBP concept) where learners interact with a device in order to take into account the specificities induced by the execution of activities in a virtual environment. Our approach aims at creating a model that links the description of the pedagogical activity to the learner's activity in the virtual environment. The scenario model must keep its generic and flexible character in order to be able to be adapted to different contexts for scenario realization without the need to modify its description.

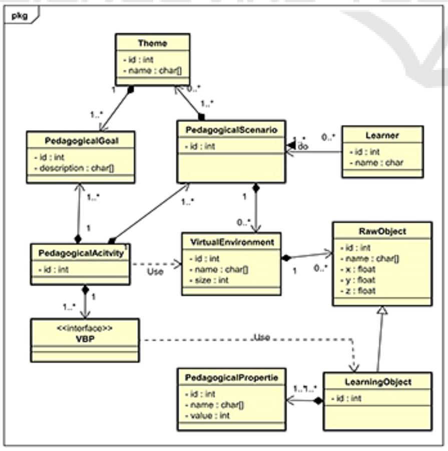

Figure 2: VR-oriented pedagogical scenario model.

4.4 Illustrate of the Proposed Model: Example

To elaborate our scenario model, we designed three different pedagogical situations. The first pedagogical situation studied is defined for a physics teacher who wants to explore the notion of gravitation and makes the learner understand that the nature of movement depends on the chosen reference frame. The second pedagogical situation concerns animal experimentation (small mammal model) for a biology teacher. The objective is to offer students an alternative method based on virtual reality to learn the correct actions while respecting the rules of ethics (3R Rule). The third pedagogical situation concerns a pedagogical activity of "Realization of a volumetric dosage" for a chemistry teaching. The pedagogical objective of this situation is "the control of the steps necessary for the protocol design to determine the concentration of an unknown solution by volumetric dosage". We illustrate our proposal with this last situation. This work is based on the co-design process presented in section 3 in which the different teachers participate in the design of the different models of pedagogical situations through an iterative, user-centered approach. In order, to facilitate understanding of the proposal, we will imagine we are in the following situation: the teacher identified pedagogical activities that correspond to the pedagogical objectives. The learner must first choose the reactants necessary to make the dosage and adjust the concentration and volumes of solutions. Then, he/she chooses the material necessary to make the dosage as well as the individual protective equipment. The last pedagogical activity is the realization of the dosage. The first pedagogical activity "Choosing the appropriate reactants" is illustrated in Table 1.

Table 1: Illustration of the pedagogical activity “Choosing the appropriate reactants”.

Pedagogical situation	Realization of a volumetric dosage
Environment	Virtual Chemistry Laboratory
Pedagogical Activity	Choosing the appropriate reactants
Actions (VBP)	Observe the reactants
	Put the pedagogical object "Reactant NaOH" on the cart
	Put the pedagogical object "Reactant H2O" on the cart

5 A PROTOTYPE OF SCENARIO’S EDITOR

Once we place the concept in an interactive context, the instructional pedagogical consists not only in "modeling a scenario", but also in "setting up the mechanisms" necessary for the realization of this scenario (Barot, 2014). Hence, we have developed a prototype of a scenario editor that facilitates the creation of new pedagogical scenarios. The objective is to allow the creation and adaptation of the different components of a pedagogical scenario, in particular the learning environments, pedagogical activities and their organization. The figure 3 illustrates the main interface of our editor. First, the teacher starts by creating a new scenario project. Then, he chooses a virtual environment adapted to his pedagogical situation. We note that the adaptation of virtual environments and virtual learning objects will be realized on the virtual pedagogical object's platform. The main objective of this platform is to propose an environment composed of rules that describe the dynamic behavior of raw objects as well as their pedagogical properties. Having chosen an environment, the teacher has the possibility to choose between two types of views (2D or 3D). In the following steps, objects are selected from the inventory and placed in the chosen environment.

Figure 3: Definition of the RV actions to be realized in pedagogical activity.

6 CONCLUSIONS

We presented in this paper our work under progress, which focuses on the problem of designing and producing pedagogical situations in VRLE. Based on the research questions we have formulated above, we found that in the various existing works: the proposed VRLE or architecture model depend on a particular field and context or was not complete enough to assist the teacher in describing, adapting or reusing a pedagogical scenario. Our approach aims at proposing both technical and methodological solutions to help teachers in their VRLE design activity. Firstly, we developed a process for designing and producing a VRLE. In this paper we are interested in the first part of this process dedicated to the design of RV-oriented pedagogical situations. We first sought to provide solutions to structure pedagogical situations in the form of reusable scenario models. During this step, we worked in partnership with pedagogical teams. We modelled the pedagogical activities and objects described in the pedagogical situation and proposed a scenario model and a first version of a prototype of an author tool. Secondly, we would like to offer experimental tools and services with functionalities that allow the integration, reuse and adaptation of virtual reality oriented pedagogical scenario models in the new VRLEs. Our current work concerns the development of additional functionalities for our editor in order to facilitate the design task of teachers and allow them to reuse and adapt existing situations. Tests and experiments are to come in order to test the model and editor-prototype in various situations and show the generic character of our approach.

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