Can we use Existing Pedagogical Specifications to Design Mixed Reality Learning Games?

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Abstract:
Game-based learning is one efficient pedagogical concept that uses game principles to incite learners to engage into learning activities. Learning games are commonly known as digital environments. In the mean time, new technologies have been increasingly developed, thus providing new perspectives in game-based learning, particularly, mixed reality technologies that merge both real and digital worlds. For instance, they are widely used in mobile learning or learning with tangible interfaces. For the latter, mixed reality technologies make collaboration easier and provide better feedback to users.
We present in the paper a brief study on the state of the art of mixed reality technologies. While the technologies have been experimented in educational settings or in games, they are used only in few learning games. Some research efforts have proven positive outcomes of the latter in learning even they are not widely applicable. Based upon the contributions of mixed reality in learning games, we point out that means employed by designers are as crucial as the pedagogical objectives. Therefore, they have to be taken into account during the design process.
Our research efforts aim at providing tools and methods to support the design of mixed reality learning games (MRLG). One of the first steps during the instructional design is to write the learning scenario. However, there is no universal method to be used in the design process. Thus, in the second section of this paper, we analyze the ability of existing pedagogical specifications to model mixed reality learning games scenarios. In this view, we compare IMS-LD, LDL and ISiS, which all intend to assist pedagogical designer and teachers in the design of new pedagogical activities and in the formalization of existing ones.
Design process of MRLG includes game elements and mixed reality technologies design, particularly in the pedagogical scenario writing. Meanwhile, the specifications mentioned earlier do not fulfil our needs: they all allow a representation of a pedagogical scenario in a workflow, but in our case, a more detailed description of the workflow is needed. The specifications are not suitable to describe the used technologies or the way they are used. Regarding the fun factors, none of the formalisms includes the description of rules and neither game principles nor game objectives.
The last part of the paper discuss different proposals: an extension of a pedagogical specification, a combination of existing specification with a task model for more detailed description, and a new pedagogical specification for mixed reality learning games.

Keywords: learning games, mixed reality, instructional design, learning scenario

1 Background

1.1 Game based learning

Game-based learning is one efficient pedagogical concept that uses game principles to incite learners to engage into learning activities. Nevertheless, the design of these learning games is long and expensive, as it is mainly still an ad-hoc work. Recently, some methods or tools have been proposed, such as EDoS (Marfisi-Schottman et al. 2010), StoryTec (Mehm et al. 2009) or Eduventure (Ferdinand et al. 2005), to support learning game design.
There is no denying that learning games have undeniable assets: they arouse learner's emotion, make one engaged in the training and allow repeated trainings. The fictitious nature of the game enables the designer to imagine an appropriated learning situation, to modify it (for instance by changing the rules) and to improve knowledge transfer and generalization. Some research efforts have proven positive outcomes in learning even if they are not widely applicable (Egenfeldt-Nielsen 2006) (Susi et al. 2007).

1.2 Mixed reality

Recently, new technologies have been increasingly developed, thus providing new perspectives in game-based learning.
Milgram and Kishino (1994) defined the Mixed Reality environments as real world and virtual world objects, presented together within a single display. Mixed Reality (MR) consists of two parts: the augmented reality (in which a real environment is "augmented" by means of virtual objects) and the augmented virtuality (in which a virtual environment is “augmented” by real objects). It includes see-through Head Mounted Displays (HMD), mobile devices such as PDA, Tablet PC or smart phones, multi-touch tables, or even tangible interfaces that control or represent virtual information. In this paper, “device” is used to refer to digital and tangible interactive objects.
Mixed reality has already been exploited in learning or game fields, which use a wide range of devices mentioned earlier. For instance, Zuckerman et al. (2005) use bloc manipulation to teach abstract concepts to children while Liu et al. (2007) create a whole mixed reality class about solar system and plant lifecycle, using HMD to view digital elements and cups to manipulate the latter. As for Leitner, Koeffel & Haller, (2008) which introduce Tabletop gaming augmented with tangible objects.

Figure 1: Comino tabletop Game (Leitner et al. 2008)

Mixed reality technologies enable new prospects in educational field. For instance, it could be possible to learn technical gestures. They have also proven positive outcomes as found in Cook et al. (2008) where body gesturing improves long term learning.

1.3 Mixed Reality Learning Games (MRLG)

Nowadays, only a very small number of learning games are based on MR technologies. Most of them use mobile devices, including “Zoo scene investigators” (Perry et al. 2008), “Reliving the revolution” (Schrier 2006), “Mad City Mystery”(Squire & Jan 2007) and “Eduventure Game” (Ferdinand et al. 2005). Those learning games are investigation-oriented situation in real places and they use handheld mobile devices. It should be noted that the mobile device can also be an HMD (Doswell & Harmeyer 2007). These research efforts justified the use of mixed reality technologies by motivational expectations (game mechanics, curiosity), active pedagogy through a better immersion in authentic context, or pedagogical expectations (better learning transfer). Only qualitative outcomes have appeared, but they were globally positive learning outcomes and strong implication from the learners/gamers, who had fun.

2 Mixed reality learning game design

2.1 Learning objectives in Mixed Reality Learning Games

MRLG refer to three domains: learning, game, and mixed reality. Even if the main objective of these MRLG is toward instructional purposes such as in either e-learning or traditional classroom, MRLG also have other purposes that motivate the use of new means. We extend taxonomy of learning objectives (presented in italics), primarily intended for distance learning (Bilodeau et al. 1999), which classified 15 learning objectives in 5 categories:

- Cognitive objectives:
  - Prior knowledge activation
  - Identification and selection of important information
  - Knowledge organization
  - Integration to previous knowledge
  - Transfer to new concepts
  - Repetition
  - *Embodiment*
- Affective objectives:
  - Emotions, feelings (with regards to the personal experience)
  - Attitudes of the learner
- Motivational objectives:
  - *Individual*
    - *Challenge (through goals, uncertain outcomes, performance feedback, and self-esteem)*
    - *Curiosity (sensory and cognitive curiosity)*
    - *Control (through contingency, choice, and power)*
    - *Fantasy (emotional aspects, cognitive aspects, and endogeneity)*
  - *Interpersonal*
    - *Cooperation*
    - *Competition*
    - *Recognition*
- Psychomotor objectives (aiming at a psychomotor skill or behaviour learning)
- Metacognitive objectives:
  - self-metacognition and knowledge of task and strategies
  - use of metacognitive strategies

We add to the motivational objectives the fun elements in learning games, as found in Malone and Lepper (Malone & Lepper 1987). They distinguished the extrinsic motivation (such as external reward, which does not correspond to our objectives) from the intrinsic one. The latter covers four individual elements of motivation (challenge, curiosity, control and fantasy) and three interpersonal ones (cooperation, competition and recognition). From a MRLG designer perspective, these elements are objectives to attain. Mixed reality technologies can also be a way to enhance motivation, especially aiming at curiosity, fantasy, and cooperation objectives. On top of the motivation, we identified other reasons for the use of mixed reality technologies: embodiment objectives, thus adding them to other cognitive objectives in the taxonomy, psychomotor skills such as technical gestures (already a part of the taxonomy) and the authentic context. From our perspective, the authentic context refers to existing learning objectives featured in the original taxonomy: prior knowledge activation, integration to previous knowledge, or transfer to new concepts.

2.2 Needs for MRLG design

Our research efforts aim at providing tools and methods to support the design of mixed reality learning games. We focus on the step of writing the learning scenario. We think that the use of a formalism to write the scenario saves time in MRLG design and development. Besides, it can guide the designer in terms of creativity, completeness, and structuring the game. Finally, a formalism improves the collaboration in a team work.

A MRLG designer can have in mind some or any of the objectives introduced above when he designs. He may have the need to make those objectives explicit, as well as the means employed to reach those objectives. For instance, one may want to explain the use of competition mechanism to enhance the learner motivation or the reason behind using tangible devices in digital environment in order to enable manipulation.

First, a MRLG designer would describe learning objectives and strategies, a detailed description of the activity workflow, location and devices with their positions, uses and descriptions, which distinguish tangible and digital parts as well as interface sketching. Also, the MRLG designer would specify game elements such as fantasy theme, fun goals or game rules. Nevertheless, these elements can be expressed in many different ways. Yet there is no universal method to be used in the MRLG design process. Considering an example of a game with rolling dice, the designer can use a “dice” for players to throw or a game mechanism, called “chance” that randomizes the results for the players.

Having acknowledged this issue, we are interested in if these MRLG elements can be written with an existing pedagogical specification. An attempt has been made to answer this question by analyzing the ability of existing tools to model scenario of learning games based on mixed reality.

3 Existing tools and methods

3.1 Existing formalisms

Despite the lack of universal method to design MRLG, some tools and methods have already been created and used in several fields.

In the educational fields, some teachers already use the learning scenario writing as a way to describe a unit of learning. This scenario can be shared with other teachers or reused in other teachings. For the past ten years, Koper (2001) proposed the first Educational Modelling Languages (EML) to formalize and execute the scenario. His model was based on the activities rather than learning objects. A few years later, the EML was taken as a base to develop the IMS-LD (IMS Learning Design) specification (2003), which is nowadays widely known. More recently, other proposals have been made: LDL (Learning Design Language) (Martel et al. 2006) focuses on interactions between the participants, and ISiS (Intentions, Strategies, and interactional Situations) (Emin et al. 2010) on teacher's goals. It should be noted that ISiS is intended for the description of learning activities but not for their execution.

Regarding mixed systems, they can be described with IRVO (Chalon & David 2007) or ASUR++ (Dubois et al. 2002) models. Both define, for a specific task, digital and tangible elements. However, as they only describe the system at a given moment, in our case, we can only use them in addition to another model to enable a workflow description. This model could either be one of the pedagogical specifications introduced above, or a task model for a more detailed description, like CTT (Paternò et al. 1997).

Last but not least, game design is thus far not assisted with specific designing tools and is strongly dependent to the game designer or the design team itself.

3.2 Comparison of three existing pedagogical specifications

As we first focus on the pedagogical aspects, we analyze the ability of existing pedagogical specifications to model scenario of mixed reality learning games. In this view, we compare IMS-LD, LDL and ISiS, which all intend to assist a person in the design of new pedagogical activities and in the formalization of existing ones. In order to test the specifications, we first made a state of the art of existing models. Then, we used the MOT+ authoring tool (Paquette et al. 2006) to design a MRLG with the IMS-LD specification. For LDL and ISiS, which are more recent, we met the authors of both specifications. In this paper, we will place a focus on the main concepts of the above specifications that are relevant to our research.

IMS-LD (IMS Global Consortium 2003) is, like EML, based on activities, and organizes them as a workflow. All *roles* (learner or staff), *learning objects*, and *resources*, are related to these activities. A scenario (*method*) consists of one or several *plays* for different use cases. Each play is sequentially divided in *acts*, and then in *role-parts*, where a role performs activities.

The authors of LDL (Martel et al. 2006) attempted to propose an alternative to IMS-LD, which could model collaborative situations. Their proposal is centred on the *interactions* between the *roles* held by participants. The interactions are organised inside *structures*, in parallel or sequential order. The interactions take place in an *arena*, and are regulated by *rules*.

The third specification, ISiS (Emin et al. 2010), is different from the two previous specifications because it allows the description of the methods and strategies that the designer wants to use in the learning unit. The first step of the meta-model is to write the *intentions*, then the *strategy* (the method used to teach the intentions). The strategy leads to an organization in *steps*, then described with *interactional situations*. The latter are provided as much as possible with patterns and correspond to the IMS-LD and LDL description level. Therefore, the ISiS meta-model can complete the two previous EML.

Table 1: Comparison of three existing pedagogical specifications

		IMS-LD	LDL	ISiS
Learning objectives or intentions	**Global learning objectives**	No	No	In *intentions*
	Method or strategy	No	No	In *strategies*
Scenario workflow	**Level of description**	Three levels of description : *Play, Act, role-part*	*Structures* that can include other *structures*	*Steps* (as many as needed), lowest level with *interactional situations*
	Roles of participants	Yes	In *interactions*	In the *interactional situations*
	Interactions between roles	No	Yes	Yes
	Dynamic aspect of the scenario	*Conditions*	Activity *rules* and *positions* taken by participants	No
Devices	**Used technologies (description of devices)**	No	No	No
	Used resources and tools	*Resources* and *services*	In *arena*	Resources and tools in *interactional situations*
	Interactions with devices	No	No	No
	Interface sketching	No	No	No
	Location	No	In *arena*	In the *interactional situations*
Game elements	**Game rules**	(not intended) Through *conditions*	(not intended) Through activity *rules*	No
	Game principles or mechanics used (ex : competition)	No	No	(not intended) Through *intentions* or *strategies*
	Other game elements : fun and fictitious goals, obstacles or fantasy theme	No	No	No
Use of the specification	**Authoring tool**	MOT+, Collage, ...	component of LDI	ScenEdit, ScenGame
Targeted group		Experts pedagogical designers	Expert Pedagogical designers	High school teachers, pedagogical engineers for professional training

3.3 Discussion

The three specifications allow a modelling of the scenario structure as a workflow. However, they don't describe the same level of the scenario. While ISiS remains at a very high level, insisting on designer's intentions, and staying at generic activities, IMS-LD and LDL use several levels of description to enable a quite detailed description. Nevertheless, we have to acknowledge that there is still a real need of a more detailed description. The lowest level of IMS-LD description is "activity". This level of description is not enough to detail how the learner must perform the activity and the devices to be

used. Moreover, the context of MRLG cannot be specified in IMS-LD, which is lacking in situated learning. Concerning LDL, it focuses on learners' interactions, which leads to a difficult expression of other types of interactions, including those with devices.
The description of mixed reality activities is limited with the three mentioned specifications. They cannot describe the devices used in MRLG, along with a distinction between tangible and digital parts and neither the interface of digital devices nor the physical positions of devices.
In respect of gaming aspects, we found out that game rules could be included in the workflow through conditions, using IMS-LD or LDL. Most of other fun elements (fun goals, game mechanics) can be specified at the high level of description offered by ISiS. They can also be specified in the first level of description of LDL and IMS-LD. In this case, they substitute the "real" activities or learning objectives if the fun elements turn out to be different. For instance, it is possible to specify that a pedagogical objective is either to make players experience something or to describe the activity itself, or to write the game goal – e.g. to reach the highest score. Meanwhile, three of the given examples cannot be done at the same time.
Regarding the learning objectives we introduced earlier, these specifications focus on cognitive or meta-cognitive objectives, but they totally miss the other objectives (affective, motivational or psychomotor). Despite the large amount of aspects of a learning activity that these specifications are taking into account, they do not fulfil our needs.

4 Proposals

4.1 Extension of a pedagogical specification

We cannot directly adapt one of the three specifications for our case because they are not complete enough to fully describe or to design a MRLG. Therefore, our first idea was to extend one of them by adding plug-in to describe mixed reality and game elements. For instance, a MR plug-in would describe the devices and their use in the MRLG, and a game plug-in would clarify game rules or game motivational elements.
But these specifications are too different from what we need to extend them. Indeed, IMS-LD is a very complex language, and even more when adding new elements to it. LDL describes collaborative activities in good manner, but makes the description of interaction with devices very difficult. In our case, this is one major issue of interaction modeling. On top of that, ISiS does not allow a detailed description of the MRLG workflow.
Having all that said, these specifications can be of great assistance to our research efforts. As a matter of fact, we can reuse, in the same or a different way, a lot of the ideas. The way the workflow is described in IMS-LD, based on activities performed by roles, appears to be essential to us, as well as the conditions for the dynamic aspect. From LDL, we retain the importance of collaboration expressed through interactions to be specified in addition to the workflow, of location, and of the existence of rules. ISiS highlights the importance of the learning goals through the concepts of both intentions and strategies, which we would like to exploit by first extending it to the whole of MRLG learning objectives, mentioned earlier in section 2.1.

4.2 Combination of existing specification

As each specification is not enough by its own, we suggest a combination of several specifications. Since we cannot adapt the models to our case, we only discuss here the level of description and the interested concepts of the models.
At the higher level, we would have the ISiS level of description, enabling the description of all the MRLG learning objectives. Then, as in ISM-LD, we would describe the scenario with activities and roles. We highlight that a more detailed description of the scenario workflow is needed. Tasks models, like CTT (ConcurTaskTrees) (Paternò et al. 1997) or COMM (Jourde et al. 2010) enable the description of an activity.

4.3 New pedagogical specification for mixed reality learning games

A new pedagogical specification would ideally include some ideas of each of the specifications compared earlier. It would be divided into three levels of description, from the most global to the most detailed: "Global elements" like in the ISiS level of description, "Workflow" like in IMS-LD and LDL levels of description, and "Detailed Workflow" for the lowest level of detail.
The "Global elements" part would describe information about *target learners*, *pedagogy*, *game elements*, and *context*. With "target learners", the designer can specify information related to the

participants like their age, the prerequisites to play the game and the maximum of participants per session. At this highest level, the pedagogical elements are *learning objectives* and *strategies*. The aspects related to game include *game type*, *fantasy theme*, *game mechanics*, *game goals*, and/or *game rules*. A hypothesis we must verify is that rules can be described through workflow and conditions, and therefore, do not need to appear among the game elements. Due to the importance of the context in MRLG that covers the *location* of the activity as well as the list and the position of *devices*, it should be given at the highest level.
At the middle level, a workflow would describe the *learning scenario* in three sub-levels of description: activities, roles and conditions. In parallel, the designer would specify game aspects, which depends on the game type. For instance, these elements could be missions to complete or information about game background (George 2010)
At the lowest level, the previous workflow would be detailed with *tasks* and *gestures* to perform. In parallel, the designer can provide details on devices to use that involve the *description* of tangible and digital interactive objects, as explained in (Delomier 2011). If relevant, interface sketching can also be useful at this level.
We represent the pedagogical specification we propose for MRLG in the following figure.

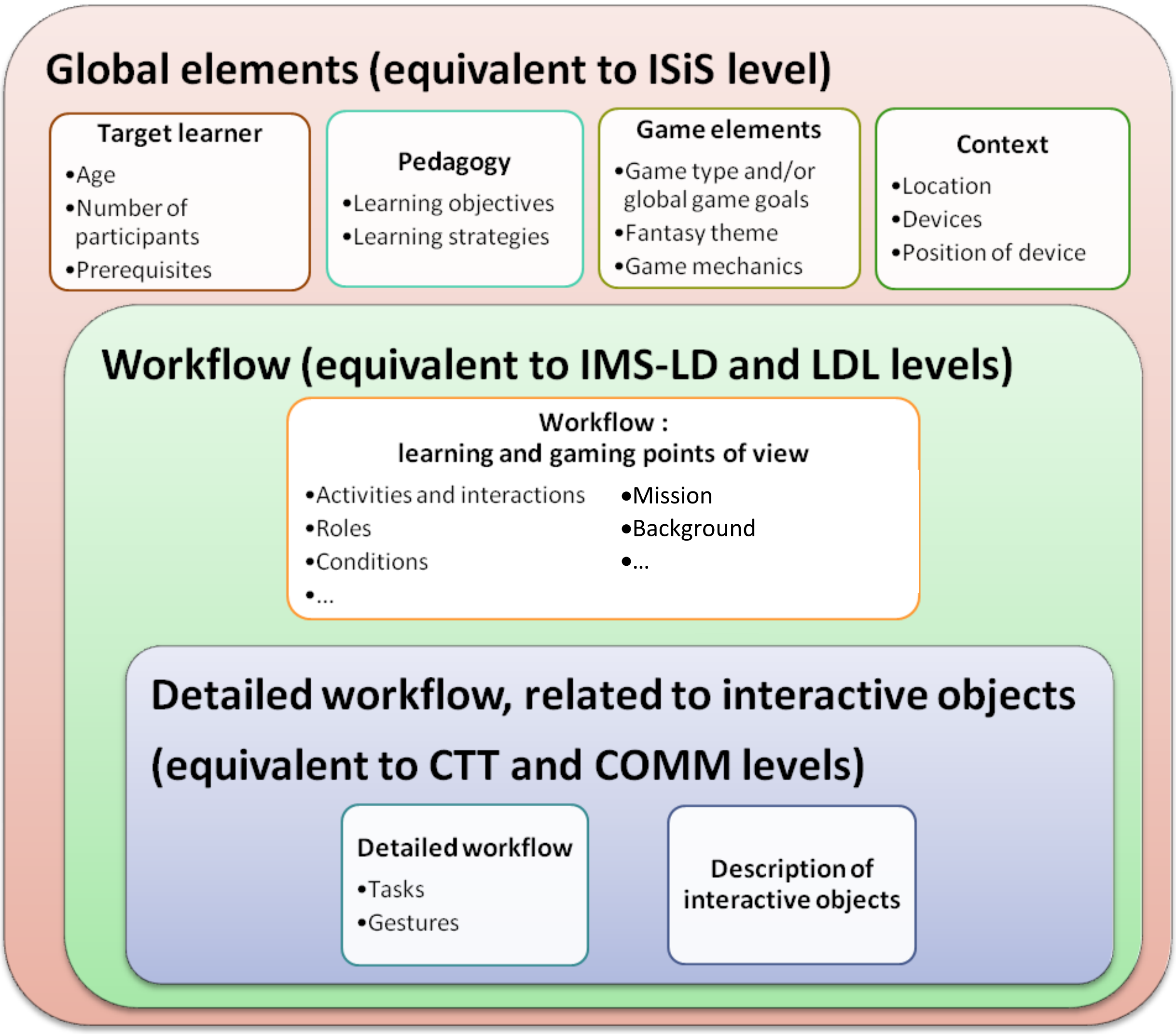

Figure 2: A new specification for MRLG

5 Conclusion and perspectives

The work presented in this paper aims at supporting the design of mixed reality learning games, in order to make it easier and faster.
MRLG design has proven to be harder to describe than more traditional learning environments. Thus, existing pedagogical specifications cannot be served as complete solution to model specific environments such as MRLG. Our proposal exploits most of the ideas already existing for the

description of the learning scenario. Additionally, we also suggested new elements to be included in the MRLG design.

We are expecting that this work will help MRLG designers on the following points:

- To make the collaboration easier for a team of designers by reinforcing mutual comprehension. By using the same terminology, every designer can understand easily people with different background and skills. The methodology could also support the workflow and improve the global project management.
- To guide designers in their conception:
  - To improve their creativity. When possible, we will provide a list of possibilities or examples. Best practices could be useful and should be enriched by the community.
  - To consider every aspect of the MRLG, to organize them and to structure the game. Indeed, the formalism can also be seen as a kind of “to-think” list, as it lists the elements to consider in MRLG design. It also prevents the designer from dividing his attention.
  - For those who don’t know the mixed reality technologies, the formalism helps to integrate mixed reality in the learning game in a good way. Thus, it should help to include relevant mixed reality activities in the learning scenario.
- To reduce the overall time to design and develop a MRLG by favouring the reuse of scenario parts and software components.

In the near future, we will conduct case studies to explore the capacity of our proposal in regards to the full description of MRLG learning scenario. Also, we aim at providing authoring tools with specific human-computer interfaces in order to assist the designers in building efficiently and easily MRLG.

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