Standardization of Game Based Learning Design

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Abstract. The standardization of the design of learning games is a contradictory topic: The existence of a rich variety of domains and applications is in conflict with the desire for unification that would result in improved reusability, interoperability and reduction of design complexity. In this paper, we describe the use of the ICOPER Reference Model (IRM) specification as foundation layer for the design of digital learning games. This reference model incorporates design and development processes as well as standards such as IMS Learning Design, a framework for presenting content according to logical rules like conditions and properties. The paper reports about exemplary learning games that make use of e-learning standards the IRM consists of, and explains about potential and limitations both from the game and e-learning design perspective, resulting in suggestions how to close missing links.

Keywords: IMS-LD, IRM, ICOPER, Game Based Learning, Standardization, Serious Games.

1 Introduction

Ever since the advent of e-learning, various working groups, committees and bodies have been working on achieving standards and specifications for enhancing quality, interoperability and the reuse of learning contents and designs. Examples for such standardization bodies are CEN, IEEE, ISO, ADL, ANSI, DIN, BSI, and NEN, only to name a few [30].

One of the realities of different standardization bodies creating different standards can be a lot of overhead in coordination. As Duval reports [11], as a consequence of this, one of the key problems in e-learning standardization is the lack of experimental validation of the actual usefulness especially of interoperability standards: They are theoretical constructs that are often of premature value, when it comes to practical application. However, there is still a high interest in common standards, amplified by the fact that large parts of the e-learning market are covered by schools and universities that generally support the exchange and sharing of knowledge across institutional or cultural barriers.

Inspired by the successes of the video gaming industry, as well as a trend in pedagogy, e-learning providers are increasingly incorporating game-based learning

approaches. Due to the gaming industry taking the role as technology innovator for learning game incentives, relevant standards are often of a proprietary nature and closely tied to particular pieces of hardware, e.g. game consoles and game controllers. As a consequence of these marketing strategies that seek to preserve unique selling points, digital learning games go with a diversity of formats and file types, involving many different sub-standards relating to technology, content, and subcategories thereof. Nevertheless, similar to other e-learning formats, a digital learning game requires learning goals, learning contents, trajectories through the learning contents, and a structural framework that ties together all these components.

Therefore it seems plausible that game-based learning could benefit from existing work on e-learning standards. In this paper we will explore how e-learning standards could play a role in aligning the different elements that make up a digital learning game. We will analyze a recently developed reference model (the so-called ICOPER Reference Model) that was created from best practice experiences in e-learning for its potential to be used as conceptual framework for the design of learning games.

2   Problem Analysis

Various standards exist in the fields of e-learning and game design, however, little work has been done to connect both fields. With respect to the e-learning part of our scope, recently a big effort has been undertaken to find a coherent model that unites technical and conceptual standards available for the design of technology enhanced learning solutions: The ICOPER Reference Model [29].

In this problem analysis, we will first describe the current situation of learning- and game design standards that are most relevant for interoperability, reusability and reduction of design complexity. Then we will cover the combined perspective of learning game design and point out some problematic aspects that result from the lack of bilateral standards.

2.1   Standards in Game Design

In digital gaming, technical standards have a high relevance that even can be of reciprocal character because many commercial games take the innovation role for technology, spearheading the latest developments and "setting" new standards at a fast pace. These modern technology standards encompass multimedia technologies for input, audio and (3D) graphics and are manifested as "game engines" that serve as mostly proprietary production models in professional game design and development. Examples are the DirectX standard [36], Microsoft XNA [40] for developing Xbox console games, the "Vision Game Engine" [42] for developing multi-platform games, and as final example the CryEngine [35] for developing videogames with the highest cinematic realism of what is possible today. These standards are technical standards, rather than design standards, but in gaming it is often difficult to differentiate between the design and implementation, therefore these "engines" come with documentation on how to design and develop games for them.

Modern digital games also tend to more and more make use of network features and provide added functionality by connecting to the internet, which requires the

inclusion of a stack of telecommunication standards in the implementation. Already in 1984, Crawford [7] mentioned the possible "connection of computer games over phone lines" as distinctive advantage of computer games over classic games. In his design methodology for computer games he describes a sequence that ranges through the initial choice of goal and topic, a preparation phase in which some research and brainstorming is needed, a structural design phase that has to be evaluated (falling back on the previous phase iteratively), and finally a programming, testing and post mortem phase. The reason for the long-lasting acceptance is that this design method resembles the most widely used software engineering models and has definitions that are sufficiently wide to leave interpretation space for the application on many different types of games. Although the creation of games relies on technical and structured software engineering methodologies, the creative aspect of the design process appears mystifying: according to Adams [1], the idea creation at the early stage of the game design process is more an artistic than an engineering process.

Salen and Zimmerman [26] have compiled a detailed description of important factors to consider for meaningful game design. They promote a systemic approach that frames a game inside a formal, experiential and cultural system that range from closed to open. In their compendium, one of the core elements of game design is the definition of game rules, which create the "game system" structurally. Rules of a game are categorized according to "constitutive", "operational" and "implicit" rules, which can be interpreted corresponding to a scale from "prescriptive" to "own choice". Also the game play as such is equally important, as it is forming the experiential parts of the system. According to Salen and Zimmerman "a game designer only indirectly designs the player's experience, by directly designing the rules". [p. 327].

An example for a game approach that makes use of "implicit" or "own choice" rules is interactive story-telling, which is found in many (especially adventure-) games. Due to the experiential nature of such games it is an approach that is often found in learning games. One of the concrete examples for such an approach has existed in a niche until the eighties, and only had some publicity in more recent times: Interactive Fiction. As described for example by Donikian and Portugal [10], this medium abolishes the difference between author, spectator, actor and character, and creates a big potential for immersion, due to identification with a role and ownership of influence on a non-linear story sequence. The technology supporting this has been evolving for decades from simplistic single-user text adventure approaches up until now where there are authoring systems (e.g. Inform 7) [38] that understand natural language. The output files are usually in a system independent package format called "BLORB" [34], which is interpretable by web-based engines (e.g. Glulx) that boast the power to render a fully-fledged multi-user adventure game to be played in a browser [24].

Another, more general effort of standardizing game design can be found in the use of game design patterns, which preserve knowledge about building elements of games and give information on how to implement them. The approach is described semi-formally by Kreimeier [17] who uses "Alexandrian" proxy patterns consisting of a problem description the pattern is going to deal with, a solution description, consequence description and examples. Björk and Holopainen [2] collected a large fundus of game design patterns, which extends the relatively informal approach of

Kreimeier onto a more detailed and complete level. There, they describe the use of game elements, and their connection possibilities with other elements, indicating links like manipulation, instantiation as well as conflicts between elements (for example: a real-time gameplay pattern cannot be combined with a turn-based gameplay pattern). This approach is also endorsed by Westera et al. [33] who stress the usefulness of patterns with respect to the reduction of design complexity.

2.2 Standards in E-Learning Design, United in the ICOPER Reference Model

With respect to e-learning, Cooper and Kraan [6] point out that standards in e-learning are important because they can avoid that information gets "locked into a supplier's product", and are able to join up different systems because they use the same data backend. While this is particular relevant for interoperability, standardization in e-learning also yields other desirable outcomes, like reusability and reduction of design complexity.

In e-learning there are big efforts to create standards that make learning content transferable between technical platforms and educational scenarios. The ICOPER project [37], funded by the European E-Content-Plus program, reflects such a standardization effort on a meta-level, analyzing different standards on different levels and their interoperability. At the core of the project resides the ICOPER Reference Model (IRM) [29] that is based on a rich pool of best practice examples for the successful use of each substandard that concerns technology enhanced learning.

It embraces all relevant standards available including content related standards, user modeling standards, interoperability standards as well as process oriented standards. The IRM, in its purpose to agglomerate various e-learning standards into a functional concept, shows promising directions, because it helps avoid the hazard of using standards that overlap and cause redundancies, as well as conflicting standards. In this paper the ICOPER Reference Model is chosen as the starting of the analysis.

Table 1. The e-learning standards used in the IRM

Standard	Description
RCD / LOD	Reusable Competency Definitions / ICOPER Learning Outcome Definition (LOD): LOD is an application profile based on RCD, a data model that
PALO	Personal Achieved Learning Outcome profiles
LOM	Learning Object Metadata, a standard to describe metadata for learning objects
OAI-PMH	Open Archive Initiative's Protocol for Metadata Harvesting, a protocol specifying the harvesting of metadata of learning objects in repositories
IMS-LD	IMS Learning Design, a standard for sequencing content according to logic (e.g. adaptive) rules, as well as user roles
IMS-QTI	Question & Test Interoperability format, defining a data format for online assessments

With the help of these standards the main components of the IRM are formulated:

- The Domain Model
- Process Models
- Service Descriptions
- Data Schemes

The domain model consists of high-level learning context scenarios, which are drawn from institutional, corporate, professional and re-skilling training practices. The domain model is developed around key concepts such as learning outcome, learning design (including teaching method), learning content, learning opportunities and assessment.

These need to be matched for the respective purpose of each learning scenario and therefore are more of exemplary value. The domain model thus becomes a context-based scaffolding for designing the necessary processes and entities defined in the IRM so that they fit the domain or context.

Also, the IRM covers instances of process models serving learners, learning facilitators, and other stakeholders in the delivery of outcome-oriented teaching. In addition, the IRM contains service descriptions for search and retrieval, publication services, user management services, recommendation services, harvesting services, registry services, and validation services. Finally, data schemes are given for providing the relevant technological frameworks for storing dynamic data, schemas for personal achieved learning outcomes (PALO) and learning designs to be included on the backend side. The data model of the IRM was prototypically implemented by the ICOPER project in the Open Icoper Content Space (OICS); it covers a recommendation how to create a competence map for learning outcomes, an incremental model for different layers to create learning processes, a concept model, a domain model and, finally, a process iteration model on how to design IRM based solutions.

2.3 Standardization in Game-Based Learning Design

For making digital games that work for learning purposes, both aspects of gaming and learning and the standards relevant to them have to be combined. According to Ebner and Holzinger [12], there are important advantages in standardization of technology such as compatibility, transferability and reusability. Also, there are advantages like social benefits, enabling standardized jargon to efficiently communicate among specialists of a specific subject. Disadvantages can be found mentioned in reduction of variety, retard of innovation as well as "excess inertia", which Farell [13] describes as the impediment of "switching from one standard or technology to a possibly superior standard or technology". One of the key reasons for dealing with standardization is that the creation of learning games is a very costly enterprise, as reported for example by Van Eck [32] and Moreno-Ger et al. [22]. Each time a learning game is developed it requires a hand-tailored design and implementation from scratch. As possible solution to the problem they discuss the repurposing of commercial "off the shelf" (COTS) games for learning. Although such repurposing is easier said than done, it can save a lot of design and implementation effort. A concrete

example is described by Gee and Hayes [14] in which the role-playing game "The Sims" is adapted for collaborative learning purposes.

Still, the use of standardization in game-based learning has controversial aspects. Besides the possible hazard of reducing variety, Squire [31] points out that in the information age certain fundamental principles of economic reality have changed since the dusk of industrial age: Conformity has been replaced with diversity, compliance with initiative and standardization with customization.

Therefore, standardization may come at the cost of customization and other advantages that are related to flexibility of design methods, content, user interaction and other factors. This also has consequences for gaming: The reduction of flexibility might reduce motivation, fun and the possibility for immersion in game play, which is fundamental to the success of a game.

Relating more specifically to the topic of game-based learning, however, the situation of standardization is more on a taxonomical level. The Serious Games organization [27] as well as Breuer and Bente [4] have made the effort to pool together a taxonomy for serious games, in which a wide scope of different categories are listed. Unfortunately, this does not include any technical standards or recommendations on how to design or implement serious games.

Using a classification taxonomy is nevertheless a starting point to get an overview what different types of serious games exist and what are examples. According to Breuer and Bente serious games can be classified according to platform, subject matter, learning goals, learning principles, target audience, interaction modes, application area, controls/interfaces and common gaming labels (puzzle, quiz, etc.). This can help to inspire a learning-game designer to consider all options during the early stages of the design process.

The situation of standardization in learning games seems not very systematically developed but that does not mean that there are no working examples. When it comes to the implementation of a digital learning game, as reported by Livingstone and Hollins [18], various technical standards for gaming can be put to use, such as different standards in 3D technologies (for instance, VRML, X3D, COLLADA, OpenGL and WebGL), browser languages and also different kinds of multimedia standards like flash or, more lately, HTML5, for example for the use in mobile devices.

Interactive storytelling has a specific relevance to the design of learning games, and the IMS-LD standard has been shown to have this potential [25]. This can be done by creating conditions that rely on an extended propositional logic control (also known as IMS-LD Level B) which fire upon certain user behavior. For example: if the user behaves in a certain way, the system may detect that and react adaptively by rearranging the order of content consumption. In [16] Gruber et al. describe how IMS-LD is used successfully to present an interactive course on architecture making use of such adaptive content sequencing. This enables a certain degree of "free movement" of a learner inside a coherent structure, which incorporates the challenge to solve a quest in order to advance on different paths through the learning content. In line with the principle of Open Information Access, this "free movement" can be interpreted as educational pattern that can be found in adaptive storytelling, as well as constructivist learning. Likewise, the IMS QTI specification would allow for quiz-like approaches of game-based learning [15].

This demonstrates that e-learning standards for adaptiveness and assessment have a potential to enrich game designs with functionality that is relevant for learning. In the concrete example of IMS-LD used here with the "Recourse" authoring tool, however, some limitations were detected, for example that in practical application repeating a certain activity was not possible, once a "unit of learning" had started [16].

While this is a concrete example of a learning standard that doesn't quite live up to its theoretical power, on a more general note, in the design process the initial choice of one of the available standards is highly speculative, and there is no sound argumentation to know up-front which e-learning standard is appropriate for what learning game purpose. There may be some flexibility in choice, but not every e-learning standard is going to be of equal usefulness to the design of learning games, due to different requirements. To tackle this we need a more refined approach that helps to streamline design routines without omitting to consider important standardization methods.

3   Using the ICOPER Reference Model as Bridge between Gaming and Learning

The fundamental assumption in this paper is that parts of the ICOPER Reference Model can be used to build the bridge between gaming and learning. One of the key questions about building this bridge, is how the existing ICOPER Reference Model can be exploited for use in game-based learning design, where are possible gaps, and resulting thereof, how the existing IRM can be extended.

In addition to an overview of the status quo on existing approaches we found evidence about (i.e. learning games that use e-learning standards that appear in the IRM), we also will report about our own experiences and what we could learn from them. Finally, we will give recommendations on how to use the IRM for the design of learning games.

3.1   E-Learning Standards Applied in Games

In this section, we will shortly revisit the literature on existing learning games that have been using e-learning standards. As mentioned above, there are only few examples of learning games that make use of e-learning standards. The way IMS-LD theoretically works for the use in adaptive game-based units of learning is described by Burgos et al. [5]. They explain how the Level A and B of IMS-LD can be mainly used for creating the adaptivity of content presentation: Level A consists of user-modeling (users, roles) and content related components (environments, resources, links, activities). Level B consists of logical properties, conditions, calculations, global control elements and monitoring services. The architecture that enables the game-based learning approach relies on a proxy layer for communication between "game activities" (gamelets that correspond to interactive content elements) and the learning flow.

As a practical example, of this approach Moreno-Ger et al. have created an adaptive game [21] using IMS-LD as control framework for a video game on chocolate making. In this example, the SLED-player environment [41] (a tomcat-based web server module

that interprets the XML-based units of learning that are the output of IMS-LD based authoring tools) works as an aggregator for the game content, while providing logical properties and conditions that steer the sequence of the game content, as well as user roles. It is, therefore, an example for the learning process controlling and triggering gaming elements.

For use in a virtual world environment, Livingstone and Hollins [18] explain how interoperability can be achieved between learning management systems (LMS) and Second Life, a massively multiplayer online role play game that had its zenith in 2007, which remains of interest for experimental use of 3D game learning environment research. The design here consists mainly of a proxy layer between Moodle and the virtual world, which enables communication by means of http requests and XML-RPC calls (roughly: a standard that does the opposite of http requests: sending instructions that are executed on a web server), thus providing the linkage between dynamic objects in the virtual world and the LMS. Since most of the interaction happens inside the "game" world, this is an example for the gaming side taking control over the learning process; however, the communication layer puts the two aspects in balance and enables activities in both directions.

Another approach by Minović et al. [19], [20] describes the use of a meta-model for educational games (called the "educational game meta-model") that is based on knowledge modeling theory. The proposed model makes use of a series of information channels that enable communication between Knowledge Objects (interpreted here as Learning Objects) and the actual game components. On the implementation level, the approach is realized as XSLT-based web client, providing in this example a game-authoring environment and game client presenting an online adventure game in the domain of geography. Despite the promising direction of using open technical standards for creating the meta-model as layer between learning objects and functional game parts, the system is closed in itself, and the aspect of reusable content is missing. Since both authoring and gameplay happens within the "game" prototype, the learning flow is influenced and controlled by the game component.

Del Blanco et al. [8] use a virtual learning environment game, based on SCORM, forming a connection to a Moodle LMS in the background. Similar to the approach described by Livingstone and Hollins [18], the game aspect takes the role of steering the occurrence of learning objects. In another approach by Del Blanco et. al. [9], the LAMS (Learning Activity Management System, [39]) environment was used, encapsulating video gamelets in a quasi-IMS-LD logic, here the "IMS-LD" part was enabling that the LMS took over the sequencing of the game-based content.

Also, Börner [3] describes a Flash based learning game that makes use of the SCORM standard to structure the learning content of the game. For multi-user aspects, a distributed server architecture was used. The design is strongly dependent of the overall learning trajectory; therefore, in this case the learning process takes control over the game sequence.

3.2   Own Experiences

Schmitz and Klemke [28] report on the design of the SPITKOM learning game using e-learning standards that are found in the ICOPER Refernce Model (IRM).

The SPITKOM project is a game-based learning approach to train for the European Computer Driver's License ECDL. It forms an example, how the IRM is used as "slave-standard". The main process is driven by hard-coded game logic which uses the learning outcomes, learning contents, assessments and personal achievement profiles that are explicitly modeled and stored in the Open ICOPER Content Space (OICS). Reusability in SPITKOM can thus be achieved mainly on the level of learning content, thus it would be straightforward to reuse the approach in a different content domain (by exchanging the domain model). However, since the game-logic is hard-coded, it would be difficult to create reuse with a different game-logic – the game component would have to be exchanged with a new one.

Another approach is using the IRM as "master-standard", making use primarily of IMS-LD to design the structure. An adaptive learning game on a quiz-like basis was developed for the training of first aid and basic life support. The basic procedure was, similar to the approach described in [5] and [21], to use IMS-LD Level B for creating the control structure of the adaptive story-telling used in the game. In this case, the domain model was fixed, but the control structure could be easily adapted. For practical reasons the implementation of the game-based learning design we used the Emergo toolkit [23] that provides a similar expressiveness as IMS-LD and the same range of functionality we were interested in. A screenshot is presented in figure 1.
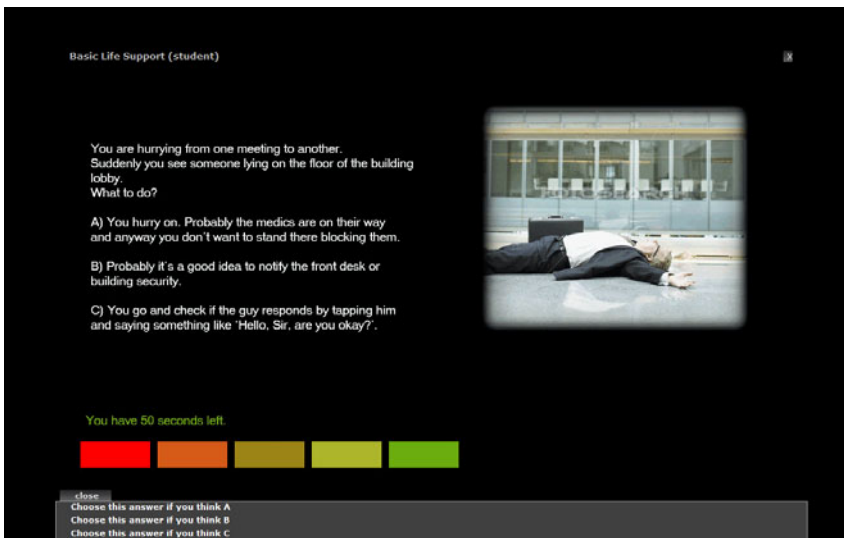
Fig. 1. The Basic Life Support training game, using EMERGO game platform

The resulting prototype was used for performing experiments on the effects of different game design patterns on learning.

These practical examples allow for a comparison. While the SPITKOM approach seemed to satisfy the preferences of gamers, the missing part was the explicit teaching method and the corresponding learning design. This was done for the benefit of a

specialized and more game-like user interface. It demonstrates that the requirement of a challenging game experience conflicts with the pedagogical requirements because there was little flexibility regarding modification requests.

In this area the IMS-LD based approach was more flexible, because there, both content and game logic can quickly be altered according to changing learning outcome definitions or learner profiles. Another advantage is that IMS-LD has the potential to use external learning material and, hence, be linked with the service architecture provided by the OICS.

It appears that e-learning driven examples for the design of game-based learning could have the disadvantage more likely to disappoint learners that expect a fully-fledged gaming experience, because they adhere to e-learning standards from the beginning, resulting in a shortcoming on the game-like behavior and feeling of the result.

This leads us to a missing link between game standards and learning standards.

3.3 Duality between Gaming and the E-Learning Design

The two different approaches reflect different design methodologies (start the design cycle from the gaming or the e-learning standards perspective). These approaches match with what we have been trying in practice. Starting the design from the side of learning, it is possible to model the educational process and then iteratively integrate game elements into the instructional design. From the game perspective, the methodology links game elements with learning activities and outcomes.
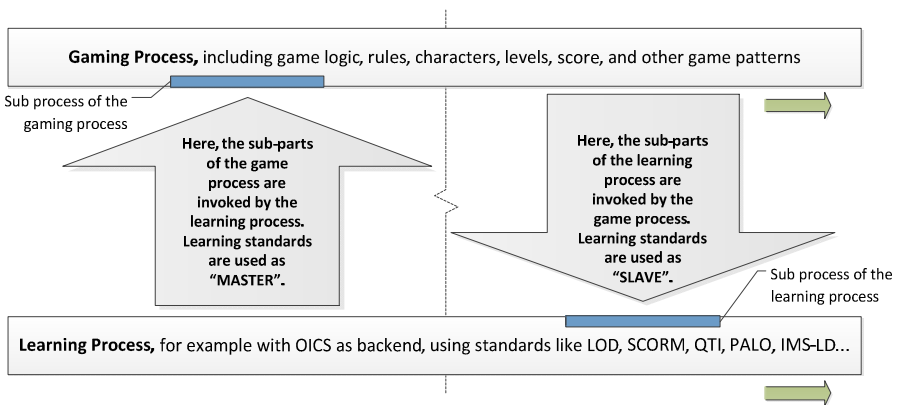
Fig. 2. The "Master" usage of e-learning standards is applied in the Basic Life Support game prototype, while SPITKOM uses the e-learning standards as "Slave" model (in this case: the OICS). The ideal situation would be to have both directions in one learning game.

The result of the two different approaches, i.e. using e-learning standards as "master" and "slave" model (figure 2), proved two main disadvantages. In the case of the SPITKOM game, the problem is that the game component is difficult to adapt and hence provides difficulties for reusability. Also the IRM/OICS needs to "satisfy" the game

requirements, which poses the encounter of rigidness with respect to interoperability questions.

The other approach, i.e. using e-learning standards to start out from, poses the repurposing of e-learning based frameworks for gaming, which turned out to have limitations with the respect to making a learning game that actually has the properties and "feel" of a real game.

Table 2. How the discussed games make use of e-learning standards

Approach	makes use of what e-learning standard	Corresponds to the use of learning standards as	Remarks
Moreno-Ger's Game [22]	IMS-LD	"master"	
Livingstone and Hollins' 3D game concept [18]	SCORM	"slave"	work in progress
Minović's game	Learning Objects	"slave"	
Börner's game [3]	SCORM	"master"	
del Blanco's e-adventure games [8], [9]	SCORM [8], IMS-LD [9]	"slave" [8], "master" [9]	The game design in [9] was done in IMS-LD but the implementation was using LAMS.
SPITKOM game [28]	LOD, SCORM and QTI	"slave"	
Basic Life Support game	IMS-LD	"master"	The game design was done in IMS-LD but the implementation was using EMERGO

In table 2 we summarize how the described approaches make use of e-learning standards. This is concluded by the way the design approach is described in the corresponding literature, starting out by first designing the game component or starting the design with consideration of e-learning standards, which is reflected in the system architecture as described in 3.1. It becomes visible that the list of learning games that use IRM-conform e-learning standards is indeed quite short. This indicates there is still a large gap between e-learning standards and learning game design.

4   Discussion

Although there has been proof-of-concept for different applications making use of Learning Objects, SCORM and IMS-LD for game-based learning, a more holistic design approach is desirable, especially when considering the full spectrum the IRM offers with respect to meeting requirements for learning. As a possibility, the Game and Learning aspect could be serialized in the design process, where a first idea and draft concept of a learning game is followed by the formalization of a domain model, which serves as construction scaffold and requirement specification for the remaining parts.

One suggestion is that the definition of game rules could be complemented with learning outcome definitions (LOD) on the learning side as well as control structures defined in IMS-LD. Correspondingly, the design of game play (as a consequence of the game rules) on the learning side are matched with teaching methods and learning design is reflected in adaptive content modules (e.g. SCORM). Scoring may be realized with assessment (QTI) elements.

Finally, the technical requirements engineering as well as implementation of the game design are reflected on the learning side with the content repository Open ICOPER Content Space (OICS), which forms a backend, provisioning content and metadata to fill external learning services with learning material. In addition it offers an assessment infrastructure and user modeling framework, making it a backend for learning management systems; and all the elements mentioned before as being relevant to the design process of learning games (LOD, PALO, QTI, etc.) are stored here. The OICS can therefore build instances of entire domain models, and, when matched with requirements for gaming, a game domain model. This means that it supports instantiating the domain model for game-based learning, so that it helps the design. Although there are still some unsolved issues regarding the implementation part of IMS-LD, with LAMS and EMERGO there exist practically usable authoring and deployment environments that are using virtually the same notation and functionality as IMS-LD. For both there exist working examples of learning games. Well noted, IMS-LD has its primary power to integrate diverse learning activities into Learning Management Systems and sequence them logically. Coming from the gaming side (to integrate learning processes into a game design), other approaches are more sensible such as using Learning Outcome Definitions.

The notion of game design patterns can also be reflected in the IRM by formalizing the more structural type of these patterns (such as storytelling and game-sequencing patterns) for example in BPMN notation, hence, providing important guidelines for the rule set of a game and, on the technical side, the capability to be translated into implementation stubs. In this respect much can still be learnt from the example of Interactive Fiction we mentioned, which is using its own standards that are not (yet) covered by the IRM.

5   Conclusions and Outlook

In this paper e-learning standards were analyzed for their appropriateness for game-based-learning. It is concluded that there are some issues, but also a lot of potential.

While the game industry undoubtedly has a wide variety of de-facto standards for designing games, these often lie hidden behind the walls of large corporations that have to protect their assets. On the e-learning side, it was easier to find openly documented standards relevant to design, more of the type of "de-jure" standards (see [30] for de-facto/de-jure discrepancy).

The synthesis of both gaming and learning can be considered from the game perspective, where the game logic or story components trigger learning processes, or, vice versa, from the learning perspective, where learning control structures define the gaming elements. By analyzing the IRM, missing links were identified between gaming and e-learning. While the game-driven perspective produced more convincing results regarding the user experience, the learning-driven perspective had advantages regarding reusability. The outcome of this observation is that there needs to be more harmonization between game design and e-learning design, for example a technical solution that makes it possible to use IMS-LD directly without encountering limitations as described in [16]. Vice versa, the IRM could profit from the incorporation of standards derived from game design, such as structural game design patterns that encapsulate practical experience of successful learning games, hence contributing to a corresponding domain model.

Overall, the IRM, in its purpose to agglomerate various e-learning standards into a functional concept, shows promising directions, because it helps avoid the hazard of using standards that overlap and cause redundancies, as well as conflicting standards. However, there still needs to be work done for finding a suitable domain model to be instantiated in the IRM for the use of game-based learning. To get suitable findings for this, future research needs to include a more extended testing of available e-learning standards for the use of gaming while continued work on interoperability standards is needed on the technical side, a direction the creation of the OICS points us into.

Acknowledgements

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