Design patterns for learning games

Design patterns for learning games

Sebastian Kelle*, Roland Klemke and Marcus Specht

Centre for Learning Sciences and Technologies,
Open University of The Netherlands,
P.O. Box 2960, 6401 DL Heerlen,
Valkenburgerweg 177, The Netherlands
E-mail: ske@ou.nl
E-mail: rkc@ou.nl
E-mail: spe@ou.nl
*Corresponding author

Abstract: This article concerns the design of self-contained digital games for the life-long learning context. Although the potential of games for teaching and learning is undisputed, two main barriers hamper its wide introduction. First, the design of such games tends to be complex, laborious and costly. Second, the requirements for a sensible game do not necessarily coincide with the requirements for effective learning. To solve this problem, we propose a methodology to the design of learning games by using game design patterns and matching these with corresponding learning functions, which is expected to reduce design effort and help determining the right balance between game elements and learning. First empirical results indicate that such a methodology actually can work.

Keywords: game-based learning; design patterns; serious games; learning functions; pedagogical patterns.

Reference to this paper should be made as follows: Kelle, S., Klemke, R. and Specht, M. (2011) 'Design patterns for learning games', *Int. J. Technology Enhanced Learning*, Vol. 3, No. 6, pp.555–569.

Biographical notes: Sebastian Kelle holds a position as a Researcher and PhD student at the Centre for Learning Sciences and Technologies (CELSTEC) of the Open University of the Netherlands. He is mostly doing research that deals with the meaningful design of digital games for use in higher and vocational education. He graduated from Freiburg University with a Master's degree in Computer Science in 2006 and joined CELSTEC after working for Vienna University of Economics. He is involved in various EU projects.

Roland Klemke is an Assistant Professor at CELSTEC and works in several European projects. His research interests are in the fields of content development and reuse for ubiquitous use. Additionally, he is the CEO of Humance AG and its subsidiary company Bureau 42, where he is responsible for research and development in the product and technology area. Coordinating the technical development team he leads industry level projects for large-scale customers. He received his degree in Computer Science in 1997 from University of Kaiserslautern and a doctoral degree from RWTH Aachen in 2002.

Marcus Specht is a Professor for Advanced Learning Technologies at Centre for Learning Sciences and Technologies at the Open University of the Netherlands and the Director of the Learning Innovation Labs. He is currently involved in several research projects on competence-based life-long learning, personalised information support and contextualised and mobile learning. His research focus is on mobile and contextualised learning technologies, learning network services, and social and ubiquitous media for learning.

1 Introduction

In the design of educational games the main challenge is to find the right balance between gaming and learning aspect. Games have in common the notion of interactivity, which creates a great immersive power, the capturing of attention, and thus have the potential for high motivation and flow experience. As Schell (2008) points out in his book on game design, designing successful games requires a very broad amount of different perspectives to consider. Although we limit ourselves here to the design questions mostly targeting higher or vocational distance education contexts, a tremendous amount of complexity remains to be dealt with.

Our starting point for going into depth of this is exploring game design patterns and how they can be used for education. In fact, we will explore how game design patterns can be mapped onto educational methods and requirements, in order to facilitate learning game design. As a first step we give an overview on notable works relevant for game-based learning on a more general scale. Then, a brief description of game design patterns is given and their combined use in game design. Furthermore, existing pedagogical frameworks are analysed in order to enable a mapping of game design patterns onto pedagogical strategies, and vice versa. Next, the mapping procedure is explained and carried out. The outcomes are presented and discussed and it is explained how these could be applied for enhancing educational game. In a validation with experts we established a first empirical step towards verification and reproducibility of this concept.

2 Related work

Game-based learning in the digital form has already existed for a long while, according to Garris et al. (2002) in two different main forms: as simulators and as motivators. What unites the two approaches is the fact that the gamer gets ‘hooked’ in a series of triggered cognitive processes that have been proven to be beneficial for learning and create a high focus of attention, fostering the desirable experience of ‘flow’. The terminology for the simulation kind of learning games is also known as serious gaming (Susi et al., 2007), which denotes the concept of training for the serious application of knowledge in reality, while learners are not exposed to critical risks they might encounter in the real world (such as medical surgery simulations or pilot training).

The ‘motivator’ kind of learning games (especially in higher and vocational education) rather aim at the self-governed type of learning where a positive learning experience is needed to overcome certain barriers like loss of attention, frustration with difficult to understand content, autogenous demotivation, and the absence of consistence and guidance in the learning process.

As another classification of learning games, Susi et al. (2007) differentiate between military games, educational games, corporate games and healthcare games. We acknowledge that in more recent resources on serious games (e.g., Ritterfeld et al., 2009) educational games are regarded as subclass of serious games.

In this article, we propose that (with focus on learning game for educational/motivator purpose) the use of game design patterns could be of help. In the literature we find also some evidence for this: a collection of about 200 game design patterns compiled by Björk and Holopainen (2004) who proposed to use such *game design patterns*, which describe well-defined and well-delimited components composing a game. The use of game design patterns is a valuable contribution to reducing game design complexity and increasing design efficiency.

So far, some first indications can be found for game design pattern that work for learning contexts (Plass and Homer, 2009; Huynh-Kim-Bang et al., 2010). Although the approaches mentioned provide promising examples, it is still unclear how these game design patterns approaches are beneficial for the development of educational games, i.e., how the available patterns are linked with educational patterns, from the perspective of pedagogical methods and theories.

Malo et al. (2008) take another approach, describing the Rostock model for e-learning (ROME) that they tried out for designing learning games. The ROME model as such was not very successful, but when they extended it by including ‘fascination elements’ into the design, suddenly it began to work. These findings speak for the fact that learning games contain certain distinctive design elements that are responsible for a positive learning experience that is perceived by the learner as joyful game-like activity. Amplified by the successes of the video game industry, educational games have gained in volume and influence (De Freitas and Griffiths, 2008).

The inherent complexity of game design is a main barrier for their wider use in education (Westera et al., 2008). Indeed, the domain of games covers a great diversity of game genres and modes of play (Gredler, 1992, 2004; Rieber, 2005). This produces a greatly fragmented domain both from the perspective of design methodology and the underlying theories. Also, from the design perspective, complexity is hardly reduced by new technological advances which include social networking services in or around the game, the intertwinement of game consoles and the internet as a platform for multiplaying and exchange of content, and the emergence of powerful portable devices for end-users.

In educational frameworks and theories games are accepted to the extent that they often are regarded as a distinct educational method that doesn’t quite conform to the existing paradigms (Smaldino et al., 2011). However, Learning Games can be classified due to their application context, such as target audience and domain. De Freitas (2006) reviews various frameworks that can help teachers evaluate the appropriateness of educational games and simulations for a particular learning context.

Kiili (2005, 2007) focuses on games for experiential learning and looks into the conditions that contribute to achieve experiential flow. Although the research of Kiili explicitly links educational theory with game design, it sincerely reports not to be able to address or improve game design.

The following two subsections will describe in more detail the design perspective from the gaming side, and vice-versa from the educational side.

2.1 Design patterns for gaming

According to Gamma (1995), a design pattern systematically names, motivates, and explains a general design that addresses a recurring design problem. It describes the problem, the solution, when to apply the solution, and its consequences. It also gives implementation hints and examples. Unlike software design patterns that are already touching upon the implementation itself by including reusable code fragments, we are dealing with 'Alexandrian' style patterns (Alexander, 1978) that consist largely of textual descriptions that yield the following three main advantages (Agerbo and Cornils, 1998): encapsulation of experience, providing a common vocabulary and enhancement of documentation.

Table 1 Overview of game design pattern categories

	Pattern category	*Description*
1	Game elements patterns	These patterns describe game objects that define the area of the game reality or that players can manipulate (48 patterns) (example: clues)
2	Patterns for resources and resource management	These patterns describe different types of resources that can be controlled by the players and the game system (20 patterns) (example: resources like energy)
3	Patterns for information, communication and presentation	These patterns describe how information about the game state is treated, for instance hiding of specific information of for carrying out evaluations (20 patterns) (example: asymmetric information)
4	Actions and events patterns	These patterns govern what kinds of actions are available to players, how they relate to changes in the game state, and how they relate to the goals of the players (44 patterns) (example: rewards or penalties)
5	Patterns for narrative structures, predictability and immersion	These patterns deal with storyline, immersion and commitment to the game by the players (31 patterns) (example: surprises)
6	Patterns for social interaction.	These patterns cover how games support social interaction between the players (30 patterns) (example: role-playing)
7	Patterns for goals	Goals give players objectives to aim for when playing games. (26 patterns) (example: gain information)
8	Patterns for goal structures	These patterns describe how gameplay affects goals (20 patterns) (example: tournaments)
9	Patterns for game sessions	These patterns deal with the characteristics of game instances and game and play sessions and the limitations, possibilities, and features of player participation in the game (20 patterns) (example: time limits)
10	Patterns for game mastery and balancing	These patterns describe how the players can use their skills and abilities in playing the game and how it is possible to balance the gameplay for players with different abilities (27 patterns) (example: randomness)
11	Patterns for meta games replayability and learning curves	These patterns deal with issues that are outside the playing of a single game instance (10 patterns) (example: replayability)

Source: Björk and Holopainen (2004)

These advantages are of quite universal nature, and are (among other application contexts) relevant for game design, especially when dealing with the technical implementation. While addressing the intrinsic complexity of computer game design Björk and Holopainen (2004) developed a large inventory of design patterns particularly relevant for games. They proposed an activity-based framework of game design patterns based on the assumption that playing a game can be described as making changes in quantitative game states. By using four different views on games, i.e., holistic (describing the actual activities), boundaries (describing limits of these activities), temporal (describing temporal order of the gameplay) and structural view (the functionalities of a game and their interplay), they identified eleven main categories of game design patterns. These main categories are briefly explained in Table 1 and form the entry point for the mapping procedure described in this approach.

Björk and Holopainen (2004) compiled a repository of over 200 game design patterns grouped in these categories. The different design patterns describe the building blocks of a game.

Each pattern comprises the following components: a general description, information on how to use the pattern, some examples, a description of the consequences of its application, and, in some cases, structural information in terms of what other patterns are in conflict. A key characteristic of game design patterns is that they never appear alone. They need to be combined logically with other patterns in order to form a game structure. This is why a game design pattern structurally is defined by its interaction with other patterns. Each pattern may be linked with other pattern types through either instantiation (the presence of one pattern causes the presence of the other pattern) or modulation (one pattern influences the other pattern). This instantiation and modulation can be across different pattern categories.

An example would be the 'resources' pattern, describing the budget, which supports the player's ability to fund actions. Also, the connections for instantiation and modulation with different patterns are indicated. At the more concrete level the resource pattern might be implemented as a 'reward' pattern: the players receive something perceived as positive or are relieved from a negative effect.

The structural linkage between patterns is of predominant importance because the overall game structure depends on it. A simple example of an instantiation connection between patterns is this: *Status indicators* are instantiated by *score*. The instantiation implies that the presence of *score* is reflected as *status indicator* in the game.

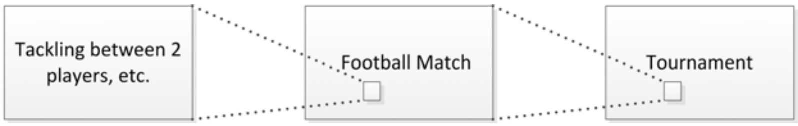
As mentioned above, there are three constraints for linking patterns: instantiation, modulation and conflict. In each description of a pattern all other patterns that can be linked are listed, as well as those that are in conflict. Each pattern thus has a 'connectivity degree' that denotes the number of different patterns that can be linked to it, as well as a 'conflict degree' that denotes the number of patterns logically in conflict. For example, the 'real-time games' session pattern is in conflict with the 'turn taking' event pattern. This is because the dynamic of a real-time game is not waiting for anyone to take turns.

Due to the instantiation linkage, in almost all cases the use of one pattern automatically suggests (or even enforces) the presence of one or more other patterns.

Example. To stick with the 'score' example, a football game could possibly be modelled by starting with the score pattern. Roughly, the score pattern's function in this case is that a team earns a point when hitting the opponent's goal with the ball. By describing this function we already used a couple of more patterns that are necessary to more specifically describe what is going on: *team, point, opponent, goal, ball*. All of these are individual design patterns that in combination provide the level of detail required to describe game elements and rules. In connection with this observation, there is also a phenomenon that could be described as *pattern containing patterns*.

Example. Coming back to the football example, regarding rules and actions, this *containment* would describe individual tackling between two players, then on a more general level the competing of two teams (= football match), finally the local championship and ultimately the world championship (cf., Figure 1).

Figure 1 Containment example of game patterns for football



Such a pattern containment illustrates how the patterns can be understood as building blocks for a game, which, if composed, form 'whole' objects that can be treated as building blocks on the next abstraction level themselves. Mathematically this can be interpreted as a partial order, because it would be possible to combine blocks that are on different abstraction levels. The entity 'football match' for example could theoretically be combined with a second ball, building a new kind of game.

2.2 Pedagogical patterns

Patterns in education are quite common. The Pedagogical Patterns Project (2009) has captured a choice of patterns that are relevant to the application of certain pedagogical strategies that help supporting an educational scenario (a course). An example is the 'early bird' pattern, which describes the method of teaching the most important topics first or as early as possible. The patterns described here have in common that they are applicable to a real-life course scenario. A more generalist approach is described by Winters and Mor (2009) who collected educational patterns for the technology enhanced learning context from practical experience, and then generalised them. However, in order to be able to make the connection between games and learning using established pedagogical theories, we chose a different generalisation model, by extending the scope of pedagogical patterns onto the taxonomy of learning functions.

Grösser (2007), referring to Shuell and Moran (1996), provides a decomposed list of 22 learning and teaching functions that are supposed to make up the pedagogical arena. These learning functions refer to cognitive and metacognitive activities that are provoked to improve the effectiveness and meaningfulness of learning, and they are all directly linked to instructional measures taken by teachers or education providers (see Table 2). For reasons of convenience, Shuell and Moran's functions have been regrouped according to different types of functions (vis. preparation, knowledge manipulation, higher order relationships, learner regulation and productive actions, respectively).

Table 2 Learning and teaching functions according to Shuell and Moran (1996)

Learning functions	*Teaching functions*
Preparation	
Prior knowledge activation	Reminding students of prerequisite information or asking oneself what is already known about the topic being learned
Motivation	Learner persistence and contribution need to be nurtured
Expectations	Learners need to have a general idea of what is to be accomplished from the learning task. Providing an overview or the learner identifying the purpose of a lesson are ways in which expectations can be initiated.
Attention	Enabling learners to focus on relevant information, disregarding the irrelevant information
Knowledge manipulation	
Encoding	Assisting learners to add personal meaning to new information
Comparison	Making comparisons in searching for similarities and differences that permit the formation of higher-order relationships characteristic of understanding
Repetition	The inducement of multiple perspectives and engaging in systematic reviews are two ways in which this function can be initiated
Interpreting	Assisting learners in converting information from one form of representation to another
Exemplifying	Motivating learners to illustrate by making use of new examples
Higher order relationships	
Combination, integration, synthesis	Learners need to have a general idea of what is to be accomplished from the learning task. Providing an overview or the learner identifying the purpose of a lesson are ways in which expectations can be initiated.
Classifying	Enabling learners to determine categories of concepts
Summarising	Guiding learners in writing short statements that represent information
Analysing	Guiding learners to break material into constituent parts and to determine how the parts are related
Learner regulation	
Feedback	Learners need to interpret feedback on the adequacy and accuracy of their understanding
Evaluation	Providing learners with the opportunity to interpret and evaluate the feedback, as well as the opportunity to evaluate their own work against set criteria and standards
Monitoring	Providing learners with the opportunity to monitor their own learning progress, to determine if reason able progress is being made
Planning	Assisting learners in devising methods for accomplishing tasks
Productive actions	
Hypothesis generation	Encouraging learners to try alternate courses of action or generating alternative solutions
Inferring	Assisting learners to draw conclusions from presented information
Explaining	Guiding learners in constructing mentally and using cause and-effect models
Applying	Teaching learners how to utilise procedures to perform exercises or solve problems
Producing and constructing	Guiding learners to invent a product

The idea that game design patterns may be regarded as distinct pedagogical interventions is a strong point in case for a mapping of design patterns onto learning and teaching functions. Indeed, in learning games, the teacher's interventions are largely replaced with single or combined game patterns. However, Shuell and Moran's description does not entail why and when these interventions would be appropriate, that is, how the learning and teaching functions are related to existing pedagogical models and theories. Therefore, as intermediate step, the most relevant educational taxonomies are sketched below to establish the link between game patterns and learning functions.

Very similar to the domain of gaming, pedagogy theory is known to be diverse and fragmented. Multiple perspectives are required for sufficiently describing it. In the following a selection of existing pedagogical taxonomies, which may be useful for linking with game design patterns, will be briefly explained. For this we start from the principal perspectives of any teaching and learning situation: pedagogical designs, instructional events, pedagogical goals, learning activities, learners' attitudes. For each of these perspectives we selected the most prominent representative framework or taxonomy that features extensive research evidence and practical validity, that is widely accepted in the field: Heinich et al.'s (2001) pedagogical designs, Gagné's instructional events (Gunter et al. 2006, originally Gagné, 1965), Robinson's pedagogical goals (Long and Robinson, 1998), Kolb's (1984) learning activities and Keller's (1983) model for attention, relevance, confidence and satisfaction (ARCS). Although these taxonomies are not exhaustive, their combined multiple perspectives may quite well represent the pedagogical aspects relevant for our context. For the sake of brevity, we do not elaborate these taxonomies further in this article.

3 Mapping of learning functions on game design patterns

Also, for the combined perspective there is the desire for finding orientation with the help of classification: Breuer and Bente (2010) mention a taxonomy that supports such an effort in terms of establishing certain axes along which a learning (or 'serious') game needs to be spanned during its design: platform, subject matter, learning goals, learning principles, target audience, interaction modes, application area, controls/interfaces and common gaming labels (puzzle, quiz, etc.).

Going deeper into the direction of combining games and learning, for instance, Garris et al. (2002) has suggested a general descriptive model, which links both gameplay and learning. While gameplay is considered an ongoing cycle of interactions with the game environment and feedbacks on the actions performed, in this model the connection with learning is made explicit through a regular debriefing process which connects the game experience with the outside world. Although Garris' model explicitly links gaming and pedagogy, its level of abstraction doesn't quite match the inclusion of game design patterns. Likewise, Bopp (2006) has extensively analysed the issue of mapping gameplay with educational activities. He organised the overall game-based learning process into subsequent phases. However, while this approach gives clues about how to organise a learning game's instructional sequence, there is still the need for identifying what exact game elements are relevant for the corresponding learning activity.

With the main challenge being a sound mapping between pedagogical/learning functions and game design patterns, the considerations above advocate that a clear reasoning behind a mapping is possible. We have to acknowledge the fact that there is a dependence on oscillating factors like context, domain, scenario and type of learning game. It is therefore either necessary to freeze those variables and only look at a specific scenario in order to validate hypotheses of what combinations fit well, or to identify those game design patterns that are likely to form a mapping result with relevance to a universal application spectrum. To come up with a mapping that we can build on, the latter approach seems more sensible, making use of only those patterns that reside relatively high on the 'containment' scale (i.e., abstraction level). These 'universal' patterns can subsequently get instantiated into more detailed sub-patterns, which is a process directed by the property of instantiation. Additionally, as factor for the choice of patterns, a relatively high connectivity degree of patterns should be accounted for. That means that there are patterns that can be connected to a certain number of other patterns via instantiation or modulation links. If there is a big number of such possible links, the connectivity degree is high. The connectivity is noted as the middle value of the triple behind each pattern in below mapping tables.

Based on these considerations, a mapping procedure is suggested. The mapping heuristic works according to the following step-by-step scheme:

1 Shuell and Moran's (1994) learning and teaching functions (cf., Table 2) have been used to act as the starting point of this mapping.

2 As a next step, the underlying pedagogical mechanisms of each learning function are identified, while referring to the various pedagogical perspectives listed in Section 2.2. The connection between Shuell and Moran's (1994) learning and teaching functions and the pedagogical models listed in Section 2.2 was done by analysing semantic overlap between those. This means that for each of the pedagogical perspectives the relevant vocabulary and subcategories of the taxonomy are included.

3 Subsequently, the associated pedagogical concepts for the respective learning functions are used to give insight into what makes them work and forms their pedagogical requirements. For example the Learning function of *Applying* can be connected to Kolb's (1984) theory of exploration and experimentation.

4 The next step is to make the choice of game design pattern classes that are likely to support the pedagogical concepts relevant for each of the learning/teaching functions. As representative for a class, a concrete pattern may be chosen. While using the game design patterns inventory of Björk and Holopainen (2004), the names of patterns serve as primary semantic indicator for fulfilling this requirement. Also the verbal definition of each pattern (Björk and Holopainen, 2004), explaining the function of each pattern can be used for this. The method to choose the correspondence between learning function and game design pattern can be achieved intuitively by means of semantic overlap. For example: the learning function of 'repetition' semantically implies a recurring process in order to achieve 'drill and practise', which from a gaming perspective requires the 'replayability' pattern, enabling the possibility to repeat a certain game sequence.

Since the mapping procedure is not a plain algorithm but requires some interpretation by the assessor, we tested the procedure's reproducibility and validity. For this validation test, a sample of 11 game design patterns that are drawn from all the different classes of patterns (cf., Table 1) was taken and presented to ten experts of the topic (who have a proven record of being familiar with the pedagogical theories sketched in Section 4). After a brief explanation of the game pattern, each expert was asked to rate the pattern according to how well it might support each of Shuell and Moran's (1994) learning functions. To do so, the five-step procedure described above was applied. For each of the learning functions the experts rated each of the patterns on a Likert-scale between 1 (least matching) and 5 (best matching). The patterns chosen were: score, resources, asymmetric information, surprises, roleplay, gain information, randomness, levels, clues and time limits. We selected these patterns because they looked promising, in terms of potentially being beneficial for learning games. Also, we needed to simplify the rating process with our experts. It is assumable that if a mapping between education and gaming is already possible with a relatively small pattern set, it can also be achieved with a larger collection of patterns to choose from.

The outcome of this ascertainment yields different perspectives: First, we looked at the patterns that were rated highest for being usable for application in the respective pedagogical scenarios. Calculated on average over all ratings and learning functions, the pattern of 'gain information' scored highest with a score of 4.01 (on a scale 1 to 5) with a quite low standard deviation of 1.098. Other patterns that ranked similarly high were the 'clues' and 'levels' patterns. When looking at the scores of pattern per learning function, we found that 20 out of the 22 learning functions were matched with a game design pattern with a score of 4 or more. Turning this relation around, we observed that all of the game patterns had at least one mapping with a learning function that was rated with 4 or more. In order to check the consistency of our result, we conducted a one-way ANOVA to check where there were significant differences of means in the rating of patterns compared along the group variable 'learning function'. The result was that the most significantly different ratings were done for the 'score' pattern ($F = 4.701$, $p < 0.001$), the 'asymmetric information' pattern: ($F = 2.115$, $p < 0.05$), the 'time limit' pattern ($F = 1.886$, $p < 0.05$) and the 'surprises' pattern ($F = 1.985$, $p < 0.05$). The other patterns were not rated significantly differently, i.e., most patterns were rated to match with different learning functions approximately equally bad or good. Relating to this, we looked for the level of agreement of the experts on their ratings, which were conceived independently: The outcome was measured employing the statistical method of intraclass correlation coefficient, calculated into a resulting Cronbach's Alpha value of 0.768, which can be interpreted as a fair level of agreement (different experts of the field mostly come to the same result). Combining these results, the described mapping procedure could be validated as reproducible.

4 Results

Encouraged by the results of the ascertainment described above, we applied the mapping method using the full set of 200 patterns, grouped into the eleven categories listed in Table 1. The outcomes of the mapping procedure are presented below for each of the 22 learning functions. The following notation is used: to each relevant design patterns, a number triple is assigned following the design pattern name, which denotes the category according to Table 1, the connectivity degree and the conflict degree: '(category, connectivity degree, conflict degree)'. For example the triple (1, 19, 3) behind the 'clues' pattern in Table 3, means that it belongs to the 'game elements' category, has 19 patterns to which it could directly be linked with modulation or instantiation, and it is in conflict with 3 patterns. The following extra condition has been developed for selecting these patterns from the inventory: choosing a pattern with high connectivity degree and/or no conflict degree would present the designer with a large choice of patterns that can be linked to. However, choosing patterns that have a low connectivity degree but possibly a relatively high conflict degree, would limit the choice of other patterns to be linked. For quickly finding an indirect link between low degree patterns, a higher degree pattern (e.g., connectivity degree >20) can be more helpful, so the initial selection of patterns may profit from at least one of those patterns with high connectivity degree and/or low conflict degree.

For practical reasons (workable table size) a series of tables has been used, each of which covers a grouped selection of learning and teaching functions, conforming to the main categories of Table 2.

Table 3 Mapping of 'preparation' learning functions onto game design patterns

Learning function	*Underlying taxonomy element(s)*	*Game design pattern class*
Prior knowledge activation	Gagné's instructional event of 'retrieval' (stimulating recall of prior learning).	Goals patterns, e.g., reconnaissance (7, 18, 1)
Motivation	Chiefly, Keller's ARCS model is of relevance here.	*Various patterns, mostly score related, for example* rewards (4, 54, 1)
Attention	Both Keller and Gagné list attention.	Game elements patterns, e.g., surprises (5, 30, 16), Clues (1, 19, 3)
Expectation	Gagnés instructional event of 'expectancy' (informing learners of the objective).	Goal related patterns, e.g., predefined goals (8, 10, 2), narrative patterns, e.g., anticipation (5, 22, 2)

Table 4 Mapping of 'knowledge manipulation' learning functions onto game design patterns

Learning function	*Underlying taxonomy element(s)*	*Game design pattern class*
Encoding	Kolb's concept of abstract conceptualisation	Information related game design patterns
Comparison	Kolb's concept of reflective observation	Information related game design patterns
Repetition	Heinich's design of drill and practise, Keller's concept of confidence	Meta game patterns, e.g., replayability (11, 23, 8), and randomness (as enabler for meaningful replayability)
Interpreting	Robinsons pedagogical goal of encouraging multiple perspectives	Goals patterns, e.g., Gain Information (7, 21, 1)
Exemplifying	Robinson's pedagogical goal of developing multiple modes of representation, as well as the encouraging of multiple perspectives.	Game elements patterns, e.g., levels (1, 24, 0)

Table 5 Mapping of 'higher order relationships' learning functions onto game design patterns

Learning function	*Underlying taxonomy element(s)*	*Game design pattern class*
Combination, integration, synthesis	Robinson's pedagogical goal of gaining multiple perspectives.	Goals patterns, e.g., gain information (7, 21, 1)
Classifying	Keller's concept of relevance, Kolb's concept of conceptualisation.	Information and communication patterns, e.g., perfect information (3, 16, 8)
Summarising	Gagné's event of eliciting performance, Heinich's design of presentation.	Information and communication patterns, e.g., communication channels (3, 10, 0), patterns for game sessions, e.g., time limits (9, 39, 4),
Analysing	Heinich's design of problem solving	Patterns for game mastery and balance, e.g., strategic knowledge (10, 48, 1)

Table 6 Mapping of 'learner regulation' learning functions onto game design patterns

Learning function	*Underlying taxonomy element(s)*	*Game design pattern(s)*
Feedback	Gagné's event of providing feedback	Score related patterns, e.g., score (4, 18, 0), patterns for game mastery and balance, e.g., near miss indicators (10, 30, 5), information patterns, e.g., progress indicators (3, 21, 2)
Evaluation	Gagné's event of providing feedback, Robinson's goal of self-awareness of knowledge construction.	Information patterns, e.g., status indicators (3, 14, 2), score related patterns, e.g., rewards (4, 54, 1) and penalties (4, 51, 3)
Monitoring	Gagné's event of providing learning guidance.	(same as for evaluation)
Planning	Kolb's concept of concrete exploration	Patterns for game mastery and balance, e.g., stimulated planning (10, 51, 0)

Table 7 Mapping of 'productive actions' learning functions onto game design patterns

Learning function	*Underlying taxonomy element(s)*	*Game design pattern class*
Hypothesis generation	Heinich's designs of discovery and problem solving.	Patterns for interaction, e.g., exploration (6, 33, 1)
Inferring	Heinich's designs of discovery and problem solving.	Patterns for goal structures, e.g., player defined goals (8, 27, 2)
Explaining	Heinich's designs of presentation, demonstration and tutorial, Gagné's event of providing learning guidance	Patterns for information, e.g., direct information (3, 15, 5), game elements patterns, e.g. clues (1, 19, 3), helpers (1,10,1)
Applying	Kolb's concept of exploration and experimentation	Game elements patterns, e.g., clues (1, 19, 3)
Producing and constructing	Ownership of Learning, Kolb's concept of experimentation	Immersion patterns, e.g., creative control (5, 27, 0)

The sequence of tables can be explained as follows: the first column represents learning and teaching functions. The second column identifies the underlying pedagogical concepts, and the third column shows the associated mapping to respective game design pattern classes, as well as naming exemplary patterns.

As mentioned, the mapping of game design patterns has been systematised according to semantic overlap between learning functions, pedagogical perspectives and game design patterns. The central element able to do so is the pedagogical perspectives and taxonomies, allowing for a ‘translation’ between learning function and game design pattern.

5 Consequences

By producing a semantic mapping of educational functions onto game design patterns, the main conclusion of the work is that pedagogical key functions can be linked with game design patterns. By establishing this link it may now become possible to design learning functions (and thus courses and curricula in general) in a game-based way, or vice versa.

With this in mind it becomes possible to either find game patterns that correspond to their pedagogical pendant directly, or to combine game patterns in such a way that they trigger, amplify, or altogether represent a certain pedagogical method. This opens three different perspectives that can be distinguished for the practical application of game design patterns in education.

A first option is the enrichment of existing ‘COTS’ (commercial off the shelf) games by means of pedagogy (Van Eck, 2006) to build a coherent learning approach. Interestingly these additions need not necessarily be integral part of the game logic itself. For example a game like ‘Sim City’ can be used for simulating urban development, giving the learners insight on macroeconomic behaviour of a society (Kuntz, 1999). While the game itself does not bear any kind of purposefully added learning function, the nature of the game play and game contents (building and managing a city) may provide sensible learning activities. Here the modifications can be used to extend the scope of the game and to achieve well considered guidance and support functions as well as appropriate integration within the existing learning context.

A second option is the enhancement of existing education practise with game design patterns. Indeed there is research evidence that school lessons often fail to provide the challenging and motivation learning activities that would be required (Mac an Airchinnigh, 2010), especially for new generations of learners that have grown up immersed in a world of internet and video games. Here, game design patterns for learning may be made available in order to allow teachers to include game-like characteristics in their lessons.

Third, the approach opens the possibility to develop methods and tools for identifying hidden game patterns in existing educational practise.

6 Conclusions and future vision

This article has explained how game design patterns can be linked with educational functions. It has given a detailed elaboration of a mapping between the two domains and thus, in principle, has opened up the perspective of pedagogically founded and well-structured learning game design. The main outcome of this approach is that it was possible to form a mapping between classes of game-design patterns and learning functions, which gives suggestions when a learning game designer is faced with the question: *Which game elements might I add so my learning game works for my learning purpose?*

From this perspective, as future direction for research the suggested approach gives a clear taxonomy for validation of the effectiveness of game design patterns in connection with learning functions that are linked together via theoretically grounded taxonomies of pedagogy. The construct of game design patterns for learning helps consolidate these findings and to make them reusable. Also, using patterns, it becomes possible to identify hidden game design patterns within the educational context, or reversely, it becomes possible to purposefully design learning functions composed of game elements. Combining all this, this approach may inspire the creation of new visionary methods and models to enhance teaching and learning.

References

Agerbo, E. and Cornils, A. (1998) 'How to preserve the benefits of design patterns', pp.134–143, ACM. doi:10.1145/286936.286952, Vancouver, British Columbia, Canada.

Alexander, C. (1978) *A Pattern Language: Towns, Buildings, Construction*, Oxford University Press, Oxford, UK.

Björk, S. and Holopainen, J. (2004) *Patterns in Game Design*, Charles River Media, Boston, MA.

Bopp, M. (2006) 'Didactic analysis of digital games and game-based learning', *The Future of Learning: Affective and Emotional Aspects of Human-Computer Interaction*, Vol. 1, IOS Press, Amsterdam.

Breuer, J.S. and Bente, G. (2010) 'Why so serious? On the relation of serious games and learning', *Eludamos. Journal for Computer Game Culture*, Vol. 4, No. 1, pp.7–24.

De Freitas, S. (2006) *Learning in Immersive Worlds: A Review of Game-based Learning*, JISC, Bristol, UK.

De Freitas, S. and Griffiths, M. (2008) 'The convergence of gaming practices with other media forms: what potential for learning? A review of the literature', *Learning, Media and Technology*, Vol. 33, pp.11–20, doi:10.1080/17439880701868796.

Gagné, R.M. (1965) *The Conditions of Learning*, Holt, Rinehart and Winston, Austin, TX.

Gamma, E. (1995) *Design Patterns: Elements of Reusable Object-Oriented Software*, Addison-Wesley Professional, Boston, MA.

Garris, R., Ahlers, R. and Driskell, J.E. (2002) 'Games, motivation, and learning: a research and practice model', *Simulation & Gaming*, Vol. 33, No. 4, p.441.

Gredler, M. (1992) *Designing and Evaluating Games and Simulations: A Process Approach*, Kogan Page, London, UK.

Gredler, M.E. (2004) 'Games and simulations and their relationships to learning', *Handbook of Research on Educational Communications and Technology*, pp.571–581, Lawrence Erlbaum, Mahwah, NJ.

Grösser, M. (2007) 'Effective teaching: linking teaching to learning functions', *South African Journal of Education*, Vol. 27, No. 1, pp.37–52.

Gunter, G., Kenny, R. and Vick, E. (2006) 'A case for a formal design paradigm for serious games', *The Journal of the International Digital Media and Arts Association*, Vol. 3, No. 1, pp.93–105.

Heinich, R., Michael, M., Smaldino, S.E. and Russell, J.D. (2001) *Instructional Media & Technologies for Learning*, 7th ed., Prentice-Hall, Upper Saddle River, NJ.

Huynh-Kim-Bang, B., Wisdom, J. and Labat, J.M. (2010) 'Design patterns in serious games: a blue print for combining fun and learning', Project SE-SG, available at http://seriousgames.lip6.fr/DesignPatterns/.

Keller, J.M. (1983) 'Motivational design of instruction', in C.M. Reigeluth (Ed.): *Instructional Design Theories and Models: An Overview of their Current Status*, Vol. 1, pp.386–434, Routledge, New York, NY.

Kiili, K. (2005) 'Digital game-based learning: towards an experiential gaming model', *The Internet and Higher Education*, Vol. 8, No. 1, pp.13–24, doi:10.1016/j.iheduc.2004.12.001.

Kiili, K. (2007) 'Foundation for problem-based gaming', *British Journal of Educational Technology*, Vol. 38, No. 3, pp.394–404.

Kolb, D.A. (1984) *Experiential Learning: Experience as the Source of Learning and Development*, Prentice-Hall Englewood Cliffs, NJ.

Kuntz, M. (1999) *Teacher's Guide*, available at http://www.brainmeld.org/TeachingGuideLibrary/BrainMeld-SimCity3000-Kuntz.pdf.

Long, M. and Robinson, P. (1998) 'Focus on form: theory, research and practice', in C. Doughty and J. Williams (Eds.): *Focus on Form in Classroom Second Language Acquisition*, pp.15–41, Cambridge University Press, Cambridge, UK.

Mac an Airchinnigh, M. (2010) *Life after Digitization, Deschooling Society 2010 & beyond*, Conference Paper, available at http://www.tara.tcd.ie/jspui/handle/2262/38888 (accessed on 25 April 2011).

Malo, S., Diener, H. and Hambach, S. (2008) 'Entwicklung von computerbasierten Lernspielen im Spannungsfeld zwischen Aufwand und Anspruch', *GI-Edition - Lecture Notes in Informatics (LNI) - Proceedings*, Vol. 132, pp.365–376, Presented at the Delfi 2008, Lübeck.

Plass, J.L. and Homer, B.D. (2009) 'Educational game design pattern candidates', *Journal of Research in Science Teaching*, Vol. 44, No. 1, pp.133–153.

Ritterfeld, U., Cody, M. and Vorderer, P. (2009) *Serious Games: Mechanisms and Effects*, 1st ed., Routledge, New York, NY.

Rieber, L.P. (2005) 'Multimedia learning in games, simulations, and microworlds', *The Cambridge Handbook of Multimedia Learning*, pp.549–567, Cambridge University Press, Cambridge, UK.

Schell, J. (2008) *The Art of Game Design: A book of Lenses*, 1st ed., Morgan Kaufmann, Waltham, MA.

Shuell, T.J. and Moran, K.A. (1994) 'Learning theories: historical overview and trends', in T. Husen and T.N. Postlethwaite (Eds.): *The International Encyclopedia of Education*, 2nd ed., pp.3340–3345, Pergamon, Oxford, UK.

Smaldino, S.E., Lowther, D.L. and Russell, J.D. (2011) *Instructional Technology and Media for Learning*, 10th ed., Allyn & Bacon, Boston, MA.

Susi, T., Johannesson, M. and Backlund, P. (2007) *Serious Games – An overview*, University of Skövde (Technical Report HS-IKI-TR-07-001), Skövde, Sweden.

The Pedagogical Patterns Project (2009) Available at http://www.pedagogicalpatterns.org/ (accessed on 20 March 2009).

Van Eck, R. (2006) 'Digital game-based learning: It's not just the digital natives who are restless', *Educause Review*, Vol. 41, No. 2, p.16.

Westera, W., Nadolski, R.J., Hummel, H.G.K. and Wopereis, I. (2008) 'Serious games for higher education: a framework for reducing design complexity', *Journal of Computer Assisted Learning*, Vol. 24, No. 5, pp.420–432.

Winters, N. and Mor, Y. (2009) 'Dealing with abstraction: case study generalisation as a method for eliciting design patterns', *Computers in Human Behavior*, Vol. 25, No. 5, pp.1079–1088. doi:10.1016/j.chb.2009.01.007.