
Effects of mobile gaming patterns on learning outcomes: A literature review

Abstract: Within the past decade, a growing number of educational scientists have started to recognize the multifaceted potential that mobile learning games have as a tool for learning and teaching. This paper presents a review of current research on the topic to better understand game mechanisms with regard to learning outcomes. The purpose of this article is twofold. First, we introduce a framework of analysis which is based on previous work on game design patterns for mobile games and on learning outcomes. The framework focuses on two aspects, motivation and knowledge gain. Second, we present a set of patterns which we identified in the literature and that positively influence these two aspects. Our results support the general assumption that mobile learning games have potential to enhance motivation. It reveals that game mechanisms such as *Collaborative Actions* or *Augmented Reality* provide incentive to get engaged with learning and/or a certain topic. With regard to knowledge gain, results are less comprehensive.

mobile games, mobile learning, serious games, game design patterns, learning outcomes

1 Introduction

Within the past five years, the number of mobile learning games (MLGs) has snowballed. For commercial and for scientific use they have been developed for various target groups and learning contexts (Lilly and Warnes, 2009) such as role-based history learning (Akkerman, Admiraal, and Huizenga, 2009), interactively discovering the principles of digital economy (Markovic et al., 2007) or geometry (Wijers et al., 2010). Mobile learning games are considered to have potential for encouraging both cognitive and socio-affective learning in young adults (Mitchell, 2007). Also, Klopfer (2008) argues that mobile learning games enable situative learning offers that make a meaningful and valuable contribution to the process of learning by providing aspects such as temporal flexibility, natural communication or situated learning scenarios.

The highly complex technologies and the many different gaming opportunities available make it increasingly difficult for educational practitioners to decide which game to choose for learning. Re-using and sharing a game is difficult without a clear and detailed description of the benefits, targeted learning outcomes and potential impact. There have been several efforts to find a common structure and language of games to better understand the complex issue (Björk and Holopainen, 2004; Cook, 2010; Kelle, Klemke, and Specht, 2011; Kiili and Ketamo, 2007). Still, there is a lack of scientifically acceptable methodology to evaluate mobile learning

games. Therefore, the purpose of this paper is to define a conceptual framework that helps to evaluate and to categorize mobile learning games and to identify mechanisms that support design decisions of future mobile learning games.

Methodologically, this paper scrutinizes evaluation reports on mobile learning games (MLG). It identifies game design patterns (Davidsson, Peitz, and Björk, 2004) and analyses how individual patterns might contribute to a particular learning outcome. Thereto, the patterns will be lined up against Bloom's taxonomy of educational objects (1975) within the affective and cognitive domain (see fig. 1).

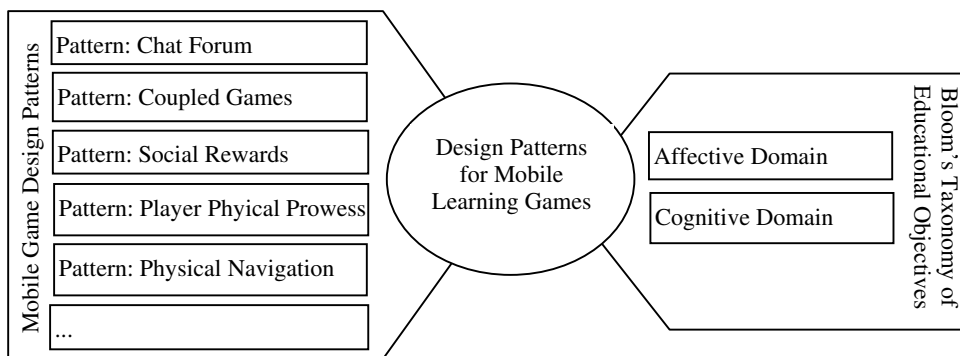


Fig.: 1: Framework for the analysis

The framework might help to better understand the mechanisms of mobile learning games and to make use of the various effects they enable. Thus, the framework raises three questions:

How does a pattern influence learners' motivation to deal with a particular subject or a given learning content?

What are effective mobile game design patterns to support the acquisition of knowledge?

What are best practices for mobile learning games to support knowledge gain?

2 Analysing Mobile Learning Games

There are a number of mobile game-based learning projects that have already tested and evaluated the effects of mobile games on students' learning. Only few trace their findings back to individual game mechanisms or patterns in order to better understand why a game is successful. Instead, reports often reason effects with the use of the game itself, e.g. "students found the use of Lecture Quiz engaging, they perceived they learn more

Title

using such games...” (Wang et al., 2008). While such statements are vital in that they back up the more self-evident use of mobile devices for learning, they allow no conclusions as to why and how this effect is transferrable and reproducible. In addition, no information is deducible about what gameplay elements influence learning outcomes. Studies often lack empirical evidence on the motivational and cognitive effects that mobile learning games enable. However, literature provides some conclusive evidence regarding the effects of mobile learning games which we summarize and discuss over the course of this paper.

2.1. Basis for the analysis

We reviewed 43 empirical research articles from 2001 to 2011. We collected data from practical projects that have already been completed and which provided information across a broad range of domains (Zellkowitz & Wallace, 1998). Our focus was on mobile learning games designed for teaching and learning (educational games or serious games) with a defined learning outcome. The terms used in the search therefore included the following keywords: mobile educational game, mobile serious game, mobile learning game, mobile game-based learning, (location-based, ubiquitous, mixed reality, augmented reality, pervasive) learning game.

Due to the educational focus of our analysis we excluded 4 papers that had no explicit focus on learning (Table 1, E.1), e.g. the study by Falk et al. (2001). Also, we excluded 12 studies that exclusively focused on the description of innovative technological concepts (Table 1, E.2), such as the approaches by Ballagas and Walz (2007), Chen (2009), Diah et al. (2010), Ferdinand et al. (2005), Mohamudally (2006), Milös et al. (2009), Moore (2009), Martin-Dorta (2010) or Yiannoutsou (2009). For our purpose, an explanation of the effects in relation to individual gameplay mechanisms was crucial. We therefore excluded 9 papers that stated evaluation results on an unspecific level with regard to patterns (Table 1, E.3), e.g. the game contributed to increased learning and motivation (Klopfer et al., 2011; Shin et al., 2006; Wang et al., 2008) or the use of MLGs contributes to the development of collaboration skills (Sánchez and Olivares, 2011). We imply that affordances of up-to-date mobile devices’ hardware (e.g. accelerometer, dual cameras, etc.) have an impact on the game and that they are reflected in the individual design patterns composing a game. The review did not take into consideration a specific age group. The research we reviewed was conducted mainly on pupils and young adults (age range: 10 – 25 years). Possible variations in effect due to that range of age were not considered. The following table sums up the inclusion/exclusion criteria which we applied for the analysis.

Table 1 Inclusion and exclusion criteria for the analysis

Inclusion criteria	Exclusion criteria
I.1 Practical papers that reported evaluation results from pilot studies with a mobile learning game. Must have a clear focus on affective and/or cognitive learning outcomes.	E.1 Reports that involved mobile games that were not used for educational purposes.
I.2 Papers that provided comprehensive mobile learning game design descriptions. Must allow identification of mobile game design patterns.	E.2 Technical reports that exclusively focused on innovation, functionality, playability and/or usability testing.
I.3 Studies that reported on concrete learning outcomes where the learning outcomes can be correlated with a pattern used in the game.	E.3 Papers that provided insufficient data for a pattern - effect determination.
I.4 Papers that are publicly available or archived.	

2.2. Theoretical framework

In order to describe the interplay and dependencies of game design patterns and learning outcomes, we suggest a conceptual framework which comprises two components:

1. The game design patterns for mobile games established by Davidsson et al. (2004)
2. The taxonomy of learning outcomes established by Bloom (1956)

On the one hand, the analysis was carried out on the basis of the patterns described by Davidsson et al. (2004). As an advancement to the work of Björk and Holopainen (2004), who established an initial set of more than 200 game design patterns for computer games, the approach by Davidsson et al. describes gameplay mechanics of mobile games. The patterns provide a common language for industry and academia and help describe the rapidly developing area of mobile games. Each pattern is identified by a core definition, a general definition, example(s), descriptions of how to use the pattern (by listing related patterns or patterns that can be linked to it), the description of its consequences, relations with regard to instantiation (patterns causing each other's presence) and modulation (patterns influencing each other), as well as references.

The pattern *Physical Navigation*, for example, “forces players of a mobile game to move or turn around in the physical world in order to successfully play the game” (Davidsson et al., 2004, p. 18). The MLG *Frequentie 1550* (Akkerman, Admiraal, and Huizenga, 2009), for instance, uses this pattern. Players have to move around to find sources of information and to complete tasks. Also, *Explore* (Costabile et al., 2008) makes use of this pattern. It requires groups to walk around the ruins trying to identify the place the mission refers to.

Title

The pattern *Physical Navigation* is instantiated by (caused by the use of), e.g., the pattern *Player-Player Proximity*, *Player-Artifact Proximity*, *Player-Location Proximity* and *Artifact-Artifact Proximity*. The pattern *Player-Location Proximity* in turn is defined by the distance between the player and a certain physical location which can affect gameplay and trigger an event. *Frequentie 1550* makes use of this pattern. On entering one of the six areas the old city of Amsterdam is divided into (each area dealing with a different theme in medieval times), an introductory video clip is provided. The video clip presents words that can help to complete the assignments in that area (Akkerman, Admiraal, and Huizenga, 2009).

On the other hand, we classified the effects extricated from the empirical studies according to learning outcomes. A learning outcome is the specification of what the successful learner is expected to be able to do at the end of the module/course unit or qualification (Adam, 2004). Learning outcome orientation can be seen within a wider trend in educational technology. One of its main ideas is to prepare students for the requirements of professional life (Vander Ark, 2002). Rather than defining the resources to be used during the learning process, outcome-oriented learning scenarios focus on the results of the educational process, e.g. the skills and content students are able to demonstrate. To depict the various learning outcomes, we applied Bloom's taxonomy (1956) which sorts learning outcomes into three domains:

- affective domain* - motivational learning outcomes
- cognitive domain* - knowledge learning outcomes
- psychomotor domain* - manual/physical learning outcomes

According to Bloom, the affective domain encompasses attitudes and motivation. The cognitive domain deals with the recall or recognition of knowledge and the development of intellectual abilities and skills. The psychomotor domain encompasses manual or physical skills or the performance of actions. For the review we focused on motivational and knowledge learning outcomes. Learning outcomes that relate to manual or physical learning outcomes, e.g. exergames (cf. Lucht, 2010; Yang, 2011) or console games were not considered, as they have a different didactic approach.

For the cognitive domain, Bloom distinguishes six successive levels that can be fostered – Knowledge (e.g. observation and recall of information, knowledge of dates, events and places), Comprehension (understanding information, grasping meanings or ordering, grouping, inferring causes), Application (using learned material in new situations, putting ideas and concepts to work in solving problems), Analysis (breaking down information into its components, understanding organisational structure), Synthesis (putting parts together) and Evaluation (judging the value of material for a given purpose).

Author

The framework described above provides the basis for categorizing gameplay mechanics according to learning outcomes. From this categorization we expect to enable a rather specific use of gameplay elements. We aim at defining which patterns support (a) motivational learning outcomes and (b) cognitive learning outcomes in the six categories from least complex (knowledge) to most complex (evaluation).

3 Results of the analysis

In the following section, we present the results of the literature survey. For the review, we searched practical papers regardless of any particular pattern. In a first step, we scrutinized what games impact motivation (affective learning outcomes) and knowledge (cognitive learning outcomes). We then went into detail, focusing on the patterns used in the games. We listed the patterns and investigated how individual patterns impact motivation or knowledge.

The mobile learning game ARGuing, for example, impacts both affective and cognitive learning outcomes. From the study by Conolly, Stansfield, and Hainey (2011), we identified the following patterns: *Pervasive Games*, *Collaborative Actions*, *Cooperation*, *Communication Channels*, *Competition*, *Imperfect Information*, *Memorability* and *Avatar*. For the pattern *Pervasive Games*, we were able to extricate effects with regard to motivational and cognitive learning outcomes (see table 2 and 3). The pattern *Pervasive Games* for example, impacts affective learning outcomes: Learners are motivated to learn a foreign language. The following sections list our findings from reviewing the literature by patterns and present the effects we identified.

2.1. *Affective learning outcomes*

The literature found in the course of this review indicates that MLGs have strong motivational effects. In traditional instructional design, the concept of motivation is vital for the process of learning: In order to initialize learning and subsequently to successfully process knowledge, motivation is crucial (Klauer, 2007). In the course of our analysis, we identified several patterns that positively influence motivation both in terms of fun as well as getting engaged with a learning environment or a certain topic to develop intellectual abilities and skills. Table 2 lists these patterns, describes them and presents their effects. The descriptions are taken from the pattern lists by Davidsson et al. (2004) and Björk and Holopainen (2004).

Title

Table 2: Effects of patterns with regard to affective learning outcomes

Pattern	Pattern Description	Affective Learning Outcome
Collaborative Actions	Two or more players being at the same location at the same time or attacking a target simultaneously.	Students are engaged in the game (Costabile et al., 2008, Dunleavy et al., 2009, Liu et al., 2010, Rosenbaum et al., 2006).
Cooperation	Players are forced to work together in order to progress in the game.	Students exchange and discuss game progress (Klopfer and Squire, 2007). Participants are driven by a good team spirit (Costabile et al., 2008). Players interact more with the object of learning (Sedano et al., 2007).
Social Interaction	Players have the possibility to meet face to face.	Students are engaged in discussion (Klopfer and Squire, 2007).
Augmented Reality (AR)	Players' perception of the game world is created by augmenting their perception of the real world.	Students feel "personally embodied" in the game. Their actions in the game are intrinsically motivated (Rosenbaum et al., 2006). Learners are engaged and motivated to learn and use foreign languages (Conolly et al., 2011). Learners are attentive (Wijers et al., 2010). Students are mentally ready for learning (Schwabe and Göth, 2005). Players immerse themselves in the game (Carrigy et al., 2010).
Pervasive Games	Play sessions coexists with other activities, either temporally or spatially.	Participants are exceptionally activated (Markovic et al., 2007). Learners are motivated to play the game (Conolly et al., 2011). Students' attitude towards learning material improves (Markovic et al., 2007).
Physical Navigation	Players have to move or turn around in the physical world in order to successfully play the game.	Students are highly motivated (Dunleavy et al., 2009). Participants are interested and moved (Schwabe and Göth, 2005). Students's are exited (Facer et al., 2004).
Perfect Information	The player has full and reliable access to information about a game component.	Students are engaged in the game (Admiraal et al., 2011).
Predefined Goals	The goal is explicitly or implicitly stated when the game starts. When the goal is fulfilled, the game is over.	Students are engaged in the game (Admiraal et al., 2011).
Extra Game Information	Information is provided within the game that concerns subjects outside the game world.	Players are curious and interested in the game (Sedano et al., 2007).
Imperfect Information	One aspect of information about the total game situation is not fully known to a player.	Participants are eager to finish the game (Sedano et al., 2007). Players immersed in the narrative (Carrigy et al., 2010)
Score	Numerical representation of the player's success in the game, often also defining it.	Students are motivated to deal with content on a regular basis, positive peer pressure (Douch, Attewell, and Dawson, 2010).
Agents	Entities controlled by the game system, e.g. to support narrative structure.	Students are motivated to deal with the learning material (Liu et al., 2010).

The patterns *Avatar*, *Competition* and *Roleplaying* are not part of the revised list by Davidsson et al. (2004). They are part of the original list of *Game Design Patterns* provided by Björk and Holopainen (2004). However, the patterns seemed to be relevant for the design of mobile learning games too. We therefore included them in the study (table 3).

Table 3: Effects of patterns with regard to affective learning outcomes

Pattern	Pattern Description	Affective Learning Outcome
Avatar	Game element which is tightly connected to the player's success and failure in the game.	Students identify with the game characters (Winkler et al., 2008).
Competition	Struggle between players or against the game system to achieve a certain goal where performance can be measured.	Students are engaged in the game (Wijers et al., 2010). Students are focused and attentive (Admiraal et al., 2011).
Roleplaying	Players have characters with at least somewhat fleshed out personalities. The play is centred on making decisions on how these characters would take actions in staged imaginary situations.	Learners are involved in the game (Facer et al., 2004). Students feel highly engaged and identify with their roles in the game (Facer et al., 2004, Costabile et al., 2008). Students merge with the game (Rosenbaum et al., 2006). Learners are tightly associated with their tasks in the game (Rosenbaum et al., 2006, Wijers et al., 2010). Students take on an identity. They are eager to work together (Dunleavy et al., 2009). Learners felt rewarded and engaged in the game (Carrigy et al., 2010).

From the empirical studies we could ascertain that mobile learning games can help (a) to increase learners' motivation to engage with a particular learning environment, in our case this is to play the learning game (Admiraal et al., 2011; Costabile et al., 2008; Rosenbaum et al., 2006; Sedano et al., 2007) and (b) to foster students' motivation to engage in learning activities and to deal with a particular learning content (Douch, Attewell, and Dawson, 2010; Markovic et al., 2007; Schwabe and Göth, 2005). In particular patterns such as *Cooperation*, *Augmented Reality*, *Pervasive Games* or *Physical Navigation* seem to positively influence learners' motivation to deal with a particular subject or a given learning content.

2.2. Cognitive learning outcomes

With regard to "hard learning" (Schwabe and Göth, 2005), it seems that very often the assumed positive effect of MLGs on cognitive learning outcomes cannot be substantiated. Only few studies report traceable distinctions between learning with a mobile device and learning with rather

Title

traditional instruction (e.g. regular lessons). However, some of the evaluations report on positive interrelations between learning with a mobile game and cognitive learning outcomes. In the course of our review we scanned the game descriptions and game evaluations for patterns that may cause such positive interrelations. The following table presents the results. For the cognitive learning outcomes, we formulated the results in line with the verbs Bloom considered as suitable for describing the several levels in written objectives. Table 4 lists the relevant patterns and describes their assigned cognitive learning outcomes. Since table 4 contains the same patterns than table 3, the pattern descriptions apply accordingly.

Table 4: Effects of patterns with regard to cognitive learning outcomes

Pattern	Cognitive Learning Outcome
Collaborative Actions Cooperation	Students memorize their knowledge (Winkler et al., 2008) Students can explain and rewrite the knowledge learned (Liu et al., 2010).
Social Interaction	Students are able to scientifically argument (Klopfer and Squire, 2007). They can rewrite the knowledge learned (Liu et al., 2010).
Competition	Students can memorize the material learned (receive higher scores on the knowledge test) (Admiraal et al., 2011, Huizenga et al., 2009).
Augmented Reality (AR)	Students notice and discuss geometrical aspects of the world (Wijers et al., 2010). They can describe and illustrate a disease model (Rosenbaum et al., 2006).
Pervasive Games	Students reflect on the process of learning (Costabile et al., 2008). Students can recall the learned material (Akkerman et al., 2009). Learners are able to transfer the learned material (practical knowledge and practical experience) (Markovic et al., 2007). Students reflect on their learning. They can solve problems related to the object of learning. They can create new problems related to the object of learning They can judge and evaluate the material for a given purpose – critical thinking skills. They are able to analyse and classify the learned material (Conolly et al., 2011).
Extra-Game Information	Students can rewrite the knowledge learned (Liu et al., 2010).
Roleplaying	Students can give examples for the importance of communication and collaboration (Rosenbaum et al., 2006).

The review revealed that only few studies empirically research the actual cognitive learning outcomes from MLGs (e.g. pre-test/post-test). Papers discuss the educational value of diverse patterns but provide little evidence that this approach leads to better learning outcomes. On the one hand, this is due to the fact that patterns have only to a limited extent been subject to explicit reasearch. But on the other hand, studies seldom explicitly research the cognitive learning outcomes of MLGs. Many pilot studies apply qualitative measurements to evaluate effects. Further research is needed to provide a clearer picture of how individual patterns or groups of patterns function and how they effectuate cognitive learning outcomes. In order to provide an in-depth understanding of the educational effects of game

Author

design patterns for MLGs, we suggest a mixed methods evaluation (Pérez-Sanagustín et al., 2012), which combines quantitative and qualitative data.

4 Conclusion and Discussion

In this paper we have presented the findings from our review of practical research papers on the effects of mobile learning games. It indicates that mobile learning games have the potential to bring about affective as well as cognitive learning outcomes. MLGs can help to increase the motivation to engage in learning activities. With regard to “hard learning” (Schwabe and Göth, 2005) though, empirical evidence is fragmented. In general, the empirical evidence in the literature we reviewed was inconsistent in terms of study design and terminology. The diverse studies had different settings with regard to the statistical base (dependent/independent variables) and the research methods they applied, as they addressed various research interests. Still, some verifiable effects are in existence.

For both, affective and cognitive learning outcomes, it showed that, firstly, the impact of individual patterns on learning is difficult to determine. The studies we reviewed focused on a set of diverse patterns, which is given by definition. The use of one pattern mostly requires the presence of another game design patterns (Björk and Holopainen, 2004; Klemke, and Specht 2012). From this, other complexities derive: Does a pattern on its own have the same effect or does it require interplay with other (particular) patterns? For example, it was stated that the provision for the pattern *Competition* positively influenced students’ learning (Akkerman, Admiraal, and Huizenga, 2009). The game additionally provided for the patterns of *Team Play*, *Score* and *Cooperation*, which had an impact on the competition between the groups too. Also, the affordances of the mobile devices’ hardware have an impact on the pattern employed by a designer. We implied that the diverse patterns already reflect the technical possibilities.

Secondly, the effects occurred with a given condition of the patterns, e.g. given time, given level, etc. To what extent does varying the conditions of the diverse patterns (game balancing) influence the effect? For example, the provision of *Imperfect Information* was identified to motivate learners to finish the game. What amount of information is necessary in order not to overstrain (discourage) or bore the learner?

In order to reduce such complexities in the pattern approach, further research on the correlations between patterns and learning outcomes has to focus on a limited number of the patterns in existence (Björk and Holopainen, 2004; Davidsson et al., 2004). The study settings have to comprise (a) an experimental variation of patterns, i.e. game settings that enable/disable individual patterns and (b) an in-depth variation of patterns,

i.e. game settings that allow different instances for the same pattern. This way, measurable and feasible results can be obtained that are suitable as a base for design guidelines which define (a) patterns that support the achievement of a desired learning outcome and (b) ways of applying the patterns.

Game design needs to adapt to different target groups, contexts, etc. (Adams, 2010). This in particular applies to the context of educational games. There is a vital need for tailoring learning offers (i.e. educational games) to learners' needs, capabilities and according to learning targets. Intelligent adaptive game mechanisms generally reflect this need. To a certain degree, this also applies to the patterns *Level* or *Score*. This way, the pattern approach reflects varying target groups or contexts. A more specific analysis, e.g. the extend to which individual patterns reflect learners' needs or capabilities, is needed though. Future research needs to verify the effectiveness of mobile learning games and to corroborate their educational value in order to motivate teachers to use such tools for teaching. Otherwise, the educational system may run the risk of disengaging future learners (cf. Klopfer et al., 2011).

5 Further work

From what was mentioned above it becomes obvious that there is clearly a need for more comprehensive scientific studies that scrutinize the functions of the diverse patterns mobile learning games are based on. The main research question we need to address is therefore:

How can an effective mobile learning game be developed that enhances motivation and cognitive learning outcomes?

The framework focuses on two aspects: affective and cognitive learning outcomes. As for the affective learning outcomes, we identified patterns that positively impact motivational aspects. Future research will have to investigate:

How does a pattern or a group of patterns, e.g. the provision for Competition, influence the learners' motivation to actually deal with a particular subject or a given learning content?

For our research, we have to consider groups of patterns because learners seldom perceive single patterns as a game (Kelle, Klemke, and Specht 2012).

Also, the study results show a small, though positive correlation between diverse patterns and cognitive learning outcomes. With respect to knowledge gain, this PhD-work will further investigate:

To what degree does a particular pattern, e.g. Player Physical Prowess, increase the learner's knowledge gain?

Author

Will pupils playing mobile learning games that provide for a particular pattern have better knowledge gains than pupils receiving traditional lesson series?

A comprehensive evaluation is to follow which examines the research questions stated. It seeks to understand which specific patterns have the greatest impact on a stated learning outcome. Also, the degree of effects will be the subject of future studies, for example the degree of motivational effects of individual patterns, e.g. intrinsic versus extrinsic motivation (cf. Schiefele and Schreyer, 1994), as well as influencing variables such as age or the prevailing level of education (i.e. educationally disadvantaged learners).

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