Game Elements-Attributes Model: a First Step towards a Structured Comparison of Educational Games

Stephanie Heintz, Effie Lai-Chong Law
Department of Computer Science
University of Leicester
Leicester, LE1 7RH, UK
sah91@leicester.ac.uk, elaw@mcs.le.ac.uk

ABSTRACT
Research on the comparison of different design options and implementation choices for digital educational games (DEGs) is lacking, despite the possibly crucial impact of these options on the learning outcome. Although game features with the potential to support learning have been identified and reported in the literature, an underlying comprehensive game model, providing structure for a comparison study and ensuring completeness in covering of all relevant features, is needed. To address this issue a literature search for game models was conducted and the resulting models were analysed for their applicability in this case. Several limitations and shortcomings of the existing models drove us to develop the Game Elements-Attributes Model (GEAM) by consolidating game definitions and models identified from an extensive literature review. GEAM can serve as a foundation for the comparison of DEGs or digital games in general, but may also be valuable for other areas of game studies.

Keywords
Game model, digital educational games, elements, attributes, features, characteristics

INTRODUCTION
In order to utilize the motivating and engaging nature of games to enhance learning, more and more digital educational games (DEGs) are being developed. While the large variety of entertainment games implies that there is more than one solution for building a DEG for a certain learning content, most developers give no rationale (or only a weak one) for why they design a game in one particular way as opposed to other possible solutions. Thus for existing DEGs it is unclear if the same learning content could have been taught more effectively or efficiently by including it in a different game. The aim of this paper is to lay a foundation for answering this question.

The first step to comparing DEGs in a structured way is based on the following concept of games: A game can be seen as a system (Salen and Zimmerman 2004, Fullerton 2008), characterised and constituted by an individual set of features. The presence but also the importance of features define and differentiate games, e.g. the story in a game may be dominant or barely exist. For a DEG with the dual aim of teaching and entertaining, the game can be pictured as a vehicle for delivering the embedded learning content and defining its possible presentation. Given this relation, an individual set of game features of a DEG can influence the learning outcome.

Proceedings of DiGRA 2015: Diversity of play: Games – Cultures – Identities

When aiming at finding and comparing alternative DEG options regarding their educational potential, the initial crucial step is to identify game features that support learning. Wilson et al. (2009) present an elaborate list of such features. Since this list is a pure collection of features without any structure relating them to their role in the game system, it is difficult to evaluate if it is comprehensive and base a comparison study on it. Furthermore, Bedwell et al. (2012) identify several of the features as overlapping and address this issue by building categories, adding a structuring layer of abstraction to Wilson's list. Their results still lack an underlying model that shows how these categories are related, drawing an overall picture of a game and ensuring completeness. To address this issue and find an appropriate model, we conducted a literature search for game models. The models were then evaluated on whether they contain Wilson's game features and a level of abstraction similar to Bedwell's categories. As none of the identified models satisfied these requirements and modification of an existing model would be problematic, we built a suitable model from scratch called Game Elements-Attributes Model (GEAM). It includes features on two levels of abstractions: elements, similar to Bedwell's categories, and attributes, which not only cover, but also add detail to Wilson's features and reveal additional ones, possibly allowing further insight on how game features may support learning. Elements and attributes were both derived from literature searches and review. Since the model gives a structured overview on important features of games, it is considered useful not only for DEG comparison, but also for other areas of game research.

GAME FEATURES SUPPORTING LEARNING

When building a DEG, learning content needs to be included in the game and taught in the process of play, as described in our conceptual framework of basic components of DEGs (Heintz and Law, 2012). With learning content and target learner groups identified, an appropriate game type has to be chosen. The features of a game may contribute to the success of a DEG either by enabling the integration of content or by supporting the learning process, i.e. by motivating the learner and thus ensuring that the game is played until the end and all content is perceived. While studying these pedagogical aspects is beyond the scope of this paper, we lay a foundation by starting from an existing list of game features that are deemed to support learning, derived from the literature, and by means of a game model examine their completeness. Several authors have contributed to generating such a list of features, in the existing literature also called characteristics, or attributes (original terms were kept for the literature review).

Some foundational work was carried out by Malone (1981), who focused on how games can motivate players to learn. Based on his findings he proposed a framework which is built around three categories: challenge, fantasy and curiosity, each comprising game features with the potential to make learning more interesting. While the motivational aspect of these features was well justified, the discussion on how they could be used for educational purposes falls short. Malone claimed that his framework was more comprehensive than previous theories, but since he enhanced it later with the additional category 'control', as well as a discussion on the three interpersonal motivators: cooperation, competition and recognition (Malone and Lepper 1987), other features may be missing as well.

In the following years, more research was conducted in this area, which is summarized in a literature review by Garris et al. (2002). Aiming to unify the findings, they concluded with six characteristics, slightly restructuring but mainly consolidating Malone's list by keeping challenge, fantasy, and control but splitting curiosity into sensory stimuli and

mystery and adding rules/goals, which were originally part of challenge. However, information on how the characteristics can be used for learning, besides increasing motivation, interest and attention, is still limited.

Wilson et al. (2009) built upon the work of Garris et al. (2002). With an updated literature review, also considering game design, they further extended the list of game characteristics, calling them attributes. With twelve additional attributes, this seems to be the most extensive list to date, however its level of completeness is still not clear. An extensive list of 42 references is given with examples of how authors used attributes in their games to teach a certain topic.

Some of Wilson et al.'s (2009) new attributes were already mentioned by Malone (1987) as features subordinate to a category, like adaption (Malone: optimal level of difficulty) and assessment (Malone: performance feedback), both features of challenge in Malone's framework. Others are similar to the existing characteristics, e.g. conflict to challenge, or interaction to control. This suggests that some of Wilson's attributes are related and can be grouped into categories, similar to Malone's (1987) initial work. Bedwell et al. (2012) pursued this objective by using a card sorting technique to capture the mental models of experts (experienced gamers and game designers) on how they felt the attributes should be grouped. Their results suggest 9 categories as shown in Table 1, which also shows Wilson's 19 attributes with short descriptions (the attribute 'progress and surprise' was split by Bedwell).

Categories	Game Features (deemed to support learning)
Action Language	Language/Communication: textual or verbal
Assessment	Assessment: feedback to learn from previous actions Progress: players progress towards the end of the game
Conflict/Challenge	Adaption: adjust difficulty to skill level of player Challenge: progressive, well balanced difficulty + clear goals Conflict: solvable problems Surprise: random element of the game
Control	Control: player's power or influence over elements in game Interaction (Equipment): game responds to player's action
Environment	Location: physical or virtual world the game takes place in
Game Fiction	Fantasy: make-believe, i.e. take on role or simulate process Mystery: sensory or cognitive curiosity to obtain information
Human Interaction	Interaction (Interpersonal): competition, acknowledgement Interaction (Social): activity shared with others
Immersion	Pieces or Players: objects or people included in narrative Representation: perception of game reality, enables focus Sensory Stimuli: temporary acceptance of alternate reality Safety: no consequences other than possibly losing
Rules/Goals	Rules/Goals: criteria of how to win; need to be well-defined

Table 1: Wilson et al.'s (2009) game features, sorted by categories identified by Bedwell et al. (2012).

Due to its extensiveness, Wilson et al.'s (2009) list of game features that support learning is a good starting point for researching the different design options of DEGs. The primary impediment for its usage is the uncertainty about how comprehensive it is. All main

features of games need to be considered for two reasons: (1) They need to be analysed regarding potential further usage for learning and (2) even if a feature does not contribute to learning, the relation between all game features should be studied to gain understanding on how the choice for a certain feature impacts the overall design of a game, i.e. if a certain challenge is chosen, this may impact the features 'interaction' and 'representation' as the challenge needs to be approached and visualized in a certain way. Thus a comprehensive framework capturing all aspects of games and describing games as a whole is needed.

EXISTING GAME MODELS

To reiterate, the goal of the following literature search is to find a construct that describes games and serves as foundation to study game feature, their relation and potential use for DEGs. A game model can provide a structural representation of games, where model is defined as "*a schematic description or representation of something, especially a system or phenomenon that accounts for its properties and is used to study its characteristics*" (American Heritage Dictionary).

Literature Search

To find existing game models, we conducted a search for this term in three databases: ACM Digital Library, Sage Journals Online and Science Direct. Due to the limited search base, besides models directly described in the articles, references to models from other sources were also considered, as long as they were published in a journal, a book, or a conference proceeding. Clearly this search is still not exhaustive, since not all models may be found, and constructs with similar qualities to models, such as frameworks, are ignored. However the idea is to get a considerable overview of game models used in the existing literature landscape.

Search Strategies

The databases were chosen based on the percentage of search results with a high ranking in Google Scholar. Searching for the term "game model" in combination with "computer game", "video game" or "digital game" (and their plural forms), returned about 1500 hits on Google Scholar. Sorted by relevance, the first 100 hits were examined for their supplying database and the five most frequently found databases identified as ACM Digital Library (12), Science Direct (11), Springer Link eJournals (10), IEEE (10) and Sage Journals Online (5). In a next step each database was searched using the same search term as on Google Scholar, with number of results being (presented in brackets): ACM (73), Science Direct (116), Springer (252), IEEE (177), Sage (22). To keep the scope of the literature search manageable, the selection criterion for databases was the percentage of articles from each database search falling into Google Scholar's top 100. For example, of the 22 articles found on Sage, 5 were listed in the top 100, which is $5/22 \approx 23\%$. As of August 2014, the three databases with the highest percentage were Sage (23%), ACM (16%), and Science Direct (10%).

Filtering Search Results

The 211 articles from the combined search results of all three databases were screened for the use of the term 'game model' to decide on their relevance. In some articles the search term was not found in the main body, but only mentioned in references or keywords, or the words had different usages (e.g. 'model' was used as a verb instead of a noun). Some articles applied the term 'model' with reference to virtual 3D models, to an early concept/idea for a single game, or a mathematical model in game theory. Others used 'game model' to describe simulations that are based on a mathematical system, like a

combat or flight simulation. Even when the term ‘model’ was used in the sense of the previously given definition, it sometimes described not the game itself, but something in its context or only one aspect, like a cinematic/theatric model, models to analyse aspects in therapeutic games, or technical models like a software model or network model.

Analysis of Identified Game Models

37 out of 211 articles use the term ‘game model’ in the sense of a structural model that describes games. For 14 of the 37 articles no description of or reference to an actual model is given, so the meaning was derived from the context the term was used in (sometimes not with absolute certainty). Of the remaining 23 articles three describe a model, while the remaining 20 reference game models in other sources. Including the referenced models, discarding three from un-reviewed web sources and one unclear reference, a total of ten game models was found. Three of these models barely include a description of the game itself, as they focus on a different aspect, i.e. the learning process in DEGs (Garris et al. 2002, Kiili 2007) or the game’s relation to reality and meaning (Harteveld 2011).

From the previous section the following requirements - by which each of the remaining seven models was evaluated - are derived:

- The model includes the features listed by Wilson et al. (2009).
- The model gives a structure with categories similar to Bedwell et al. (2012).

We analysed each model regarding the two requirements. Results for identified inclusions of Wilson’s features (second column) and for categories or other layers of abstractions (third column) are given in Table 2. When features used to describe the models could not be matched exactly to those listed by Wilson, the ones identified as being related are listed in round brackets. The numbers in square brackets show how many of Wilson’s features were found to be included in each model. Features which could not be matched with Wilson’s are listed as ‘additional’ and the ones which rather represent a category as ‘too broad’.

Conclusion from Search for Existing Game Models

Most of the models include only up to five of Wilson’s features and do not have any level of abstraction (e.g. categories). The MDA model separates game features into mechanics, describing game components on a data and algorithm level, dynamics, describing the game behaviour at run-time, and aesthetics, describing the player’s perception. While mechanics and dynamics describe games as a system, they are only explained on a general level in the model; an elaborate list of features is only given for aesthetics. However, since games may cause different experiences for different players, it is difficult to compare them on the basis of player perception. This issue also applies for some of Wilson’s features, e.g. mystery and surprise, which will be addressed later in the paper. Amory’s model includes the highest number of features and has a hierarchy of multiple levels, but the structure is not well explained and several features seem to be overlapping (e.g. exploration and discovery; narrative spaces, drama, story and backstory). Multiple theories have been merged in Amory’s game object model, which makes it bulky and somewhat incoherent.

Model	Features	Categories
classic game model (Juul 2003,2005)	Rules, Outcome (Goals, Assessment), Player Effort (Challenge, Control) [3-5] *additional*: Players attached to Outcome, Negotiable Consequences	No hierarchy
generic gaming and simulation model (Klabbers 2003)	Actors (Human Interaction), Rules, Resources (Pieces or Players) [3-4]	No hierarchy
MDA: mechanics, aesthetics, dynamics (Hunicke et al. 2004)	Derived from aesthetics: Sensation (Sensory Stimuli), Fantasy, Narrative (Game Fiction), Challenge, Fellowship (Social Interaction), Discovery (Mystery, Location) [6-7] *additional*: Expression, Submission	Separation in mechanics, dynamics, aesthetics
game object model v. II (Amory 2007)	Communication, Challenges, Problem Space (Conflict), Engagement (Control), Interaction, Exploration (Location), Drama + Story (Fantasy), Social Space (Human Interaction), Authentic + Graphics + Sounds (Sensory Stimuli), Goal [10-11] *additional*: Fun, Technology, Memory, etc.	Up to 4 layers
game design atoms (Brathwaite & Schreiber 2008)	Players + Avatars + Game bits (Pieces or Players), Challenges, Goals [3] *too broad*: Mechanics, Dynamics *additional*: Theme, Resources, Game State and View	No hierarchy
core elements of the game experience (Calvillo-Gámez et al. 2010)	Interaction, Control, Environment [3] *too broad*: Game-Play *additional*: Ownership, Enjoyment	No hierarchy
active game model (Ruch 2012)	Rules, Narrative Path (Fantasy), Screen + Speaker + Controller (Control, Interaction), Visual Asset + Music + Sound (Sensory Stimuli) [3-4] *additional*: Physics of Game World	Separation in player, machine, aesthetic, interface

Table 2: Game models identified in the literature search, analysed regarding the two requirements.

As it seems difficult to further modify Amory's model to meet the requirements and since in the MDA model details are missing for the mechanics and dynamics of games, we deemed it necessary to start from scratch when building a game model to address the initial research question. However several insights gained from the analysed models can be taken into account during the process of building the new game model. Juul's model seems a good starting point, since it was designed to serve as a definition for games, giving strong arguments for being comprehensive and listing main components shared by all games. Brathwaite's description of game design atoms is derived from a foundational chapter of their game design book, indicating that similar books on game design might be interesting sources for further input. Some terms have already been identified as being too broad, which shows that the depth and level of detail of the model needs to be decided on, when considering which features to include in the model. Adding more detail to Wilson's features can give valuable insight, but keeping the research question in mind, the amount

of features should be restricted, to allow an approachable comparison of DEGs. While including an abstract level close to Bedwell's categories gives the model a fundamental structure, the aim is to focus on the breadth rather than the depth to achieve comprehensiveness.

DEVELOPMENT OF A GAME MODEL

The development of the new game model is divided into two steps, (1) the identification of basic components of a game, which will be called elements and mapped with Bedwell et al.'s (2012) categories and (2) the detection of ways to implement these components in different games, which will be called attributes and should comprise all features listed by Wilson. The model is therefore called Game Elements-Attributes Model (GEAM). Hereafter, to enhance readability the names of elements are capitalized and those of attributes italicised.

Game Elements

The first step in building the new game model is to find an underlying structure of elements that define games and serve as the skeleton of a game - the core concepts that all games share, e.g. having 'Goals' as part of each game. Grounding the model on such universal game elements ensures that it is sound and generic. It further facilitates the inclusion of more specific aspects which can be identified by analysing how the elements are implemented in different kinds of games. Game definitions should reveal the crucial components of a game, thus elements are extracted from definitions. The resulting set is then further refined by considering game design literature.

Extracting Elements from Game Definition and Design

With the increasing interest in game studies, the issue of finding a solid formal definition for games has been addressed recently. Based on the comparative evaluation of previous work, two oft-cited definitions have been developed by Salen and Zimmerman (2004) and Juul (2011). They agree on the following defining criteria: Rules, Quantifiable Outcome (win or loss), Active Player, and Conflict. Additionally they both point out that games can be considered from three different perspectives: the game as formal system, the player and the game (experiential), and the relation between the game and the rest of the world (Juul 2011). The game model to be created is supposed to represent a formal system, thus features concerning the other two perspectives are not deliberately considered. However, as Player is an element of this system while also being grounded in reality, the experiential perspective as well as the relation between the game and the rest of the world is automatically included to some degree.

Egenfeldt-Nielsen et al. (2013) note that a formal definition of games is "unconcerned with matters of representation" and thus does not need to include aspects such as audiovisual feedback. However, Representation is essential for the design and analysis of games and should therefore be included in the model. Furthermore, Adams (2014) identifies the essential role of Structure in games, acknowledging that the features of a game may change depending on the state or mode of the game (e.g. the player faces a new conflict).

In the first edition of their book about the design of digital (video or computer) games, Rollings and Adams (2003) give a well described set of elements, which are in line with the aforementioned definitions and also cover the aspect of representation. In addition they mention the element "interaction model" which is distinct for digital games, as games "mediated by a computer" (Adams 2010, p.15). The fact that the elements are still

found in later editions of the book and are frequently mentioned in other design books strengthens the assumption of their essentiality. Thus, the core elements of the model are based on Rollings and Adams (2003) with slight modifications: The element "Interaction Model" was renamed to the broader terms "Input/Output"; "Victory/Loss condition", which focuses only on the final outcome of a game, was split into the elements "Goal" and "Rewards/Penalties", as games are often driven by multiple small goals without one final outcome. "Story" is not identified as a core element, but as it usually covers the whole game, it is subsumed by Structure.

To provide a clear and concise representation, the elements of the model as well as their relations are visualized in the form of a diagram, shown in the centre of Figure 1. Gameplay as the central part of a game consists of two elements: Actions and Challenges. The gameplay is driven by pre-defined Goals leading to Rewards/Penalty and possibly a victory/loss condition. The interaction between a Player and the game is mediated by Input/Output interfaces. The Setting of a game is the (virtual) space in which it takes place and is shown to the Player through a Perspective (e.g. defined by a camera position). Rules, as the foundational element, are incorporated into the other elements; therefore, they are not analysed independently in this work. The configuration of these elements can change when playing a game; these varying sets of values of the elements are called states or modes, organized through the Structure of a game, which is often implemented as levels and can be supported through a story.

Matching Elements with Bedwell et al.'s Categories

The categories identified by Bedwell et al. (2012) can be matched to the elements which were chosen as foundation for the new game model as shown in Table 3.

Element	Player	Input/ Output	Actions	Challenges	Goals	Rules	Rewards/ Penalties	Setting/ World
Bedwell	Human Interaction	Control	Control, Action Language	Conflict/ Challenges	Rules/ Goals	Rules/ Goals	Assessment	Environ-ment

Table 3: Game elements extracted from literature as defining components of games, matched with the categories for game features with potential use for learning as derived by Bedwell et al. (2012).

Two of Bedwell's categories lack a direct representation in the new model since they contribute to multiple elements: game fiction and immersion. Game fiction is included into a game as part of Gameplay and the Game World. The same holds for immersion which is caused by the players' engagement in the game, thus additionally being attached to Input/Output.

Also, two elements of GEAM have no direct counterpart in Bedwell's list of categories: Perspective and Structure. Perspective is the link between Game World and Output. Structure enables to track the progress in a game (a feature which Bedwell assigned to the category Assessment), e.g. by providing level and may also facilitate a story, thus also contributing to Bedwell's category game fiction.

Game Attributes

The second step, leading to the final proposed game model, is to identify attributes that inform how an element can be implemented, e.g. the Setting/World of the game can be

two- or three-dimensional. Relevant literature was found based on two search strategies, (1) the identification of research areas concerned with detailed analysis of games and (2) a broad literature search based on a selection of databases and search terms. Grouping the attributes under the previously selected foundational game elements generates the second layer of the GEAM.

(1) Analytical Approach: Specific Literature Search

Besides the already described game features supporting learning, which were derived from educational games research, two more research areas were found to focus on a detailed understanding of game features: game classification and game design.

Game classification research: Although classifying games by genre is known to have limitations, only a few attempts have been made to develop new classification systems. Of the existing literature in this field, two papers (Djaouti et al. 2008, Elverdam and Aarseth 2007) followed the approach of elaborately dissecting games to identify the main differentiating aspects, thereby facilitating the compilation of attributes.

- Djaouti et al. (2008) extract and define so-called 'game bricks', a set of ten core rules to describe the gameplay as central part of video games, by analysing games for the most basic recurrent aspects.
- Elverdam and Aarseth (2007) propose a wider list of attributes by thoroughly comparing games, regarding where and how they differ, generating a collection of so called 'dimensions' and their optional values.

Game design research: Its focus is more practical and often less formal, discussing various aspects of games to give advice on how to create successful games. Several game design books were reviewed (e.g. Koster 2005, Schell 2008, Rogers 2010), spanning a diversity of topics on games, such as technical implementation, the game market, gameplay experience, and storytelling. Some of the books cover game architecture and basic game concepts, but only briefly (e.g. Brathwaite and Schreiber 2009). Four books (Adams 2010, Fullerton et al. 2008, Björk and Holopainen 2005, Perry and DeMaria 2009) are found to be rich sources for deriving attributes.

- Adams (2010), as author of the book from which the GEAM elements were mainly derived, also discusses associated game attributes.
- Fullerton et al. (2008) present a list of elements that overlap to a large extent with those of GEAM and give several attributes for them.
- Björk and Holopainen (2005) extract design patterns from games, based on a framework with components somewhat related to GEAM's elements. They present more than 200 patterns, many of which are considered to be too detailed for the inclusion in GEAM.
- Perry and DeMaria (2009) provide long lists of examples on design choices. Specifically, relevant attributes are identified from their discussion on 'experience designing', which covers the elements Game Activities (Actions), Challenges, Goals and Rewards. The listed examples are very detailed, but some are grouped as categories, which can be considered as attributes.

In addition to literature from books, the following paper has been found to be another detailed source for game attributes:

- Owen (2004) describes in his paper the anatomy of games in a still experimental stage. Aiming to identify key features of games, he discusses a set of components, overlapping with the elements of GEAM.

(2) Analytical Approach: Broad Literature Search

With a similar selection process as for the game model search, the same three databases were chosen for a broader literature search to identify game attributes: ACM DL, Sage, and Science Direct. To keep results at a manageable size, the search was restricted to abstracts-only. While the terms 'elements' and 'attributes' were chosen to describe features on the two levels of the GEAM model, their meaning may differ in other sources and similar terms could be used. Taking this into consideration, four search terms were used with the aim to find features which contribute to the selection of attributes for GEAM. These terms are listed in Table 4 together with the number of search results for each database. It is noticed that this search is not exhaustive, but aims to identify attributes that may have been missed by the specific literature search.

In the first step, articles from mostly unrelated research areas like math or economics were filtered out (21) along with a few articles that were not accessible or in a language other than English (16). Screening the remaining articles with the search terms, game features were extracted and analysed for possible inclusion as attribute in GEAM (Table 4).

Search term	ACM DL	Sage	Science Direct
game element/s	55 (20)	12 (3)	21 (4)
game component/s	4 (0)	8 (0)	7 (0)
game characteristic/s	3 (3)	15 (0)	16 (1)
game attribute/s	1 (0)	5 (2)	6 (3)

Table 4: Number of hits for each database and search term; in brackets: number of papers actually listing game features.

Duplicates were removed from the obtained list of attributes and results with similar meaning grouped together to identify representatives. These were then matched to the appropriate game element.

Results by Game Element

Player: In game design books (Björk 2005, Fullerton 2008) as well as game classification literature (Elverdam 2007), it is described that players may *play alone* or *with others*. As soon as other players are involved, their relationship can be studied as being *competitive* or *cooperative*. In addition Fullerton (2008) notes that players may still *play on their own* even if others are involved in the game (e.g. in multiplayer online games someone may still play without interacting with others). Sources from the broad literature search reveal another aspect describing player relation: *communication*. The identified attributes describe Wilson's features interpersonal and social interaction.

Input/Output: Adams (2010) gives a list of input/output devices, which was further extended by the first author to cover commonly used devices for playing digital games in combination with respective input devices, resulting in a detailed list of attributes for Wilson's interaction (equipment) feature.

Actions, Challenges: Most attributes for these elements were found in Owen's (2004) discussion paper, who lists the Actions *build*, *destroy*, *move* (as journeying), *place*, *collect*, *communicate* and the Challenges *opponent*, *obstacle*, *puzzle*, *quiz*, *reaction time*.

Their validity is further confirmed as they are in line with Djaouti et al.'s (2008) basic gameplay rules, either matching them (e.g. move, destroy), being more generic (communicate instead of write) or turning out to be even more fundamental than Djaouti et al.'s (2008) rules, as combinations allow to describe them (e.g. avoid = move + obstacle or opponent). However, slight modifications were made based on Djaouti's work, e.g. the rule shoot was considered by extending *destroy* with *fight*, a form of destruction. Similarly features found in other sources (e.g. from the broad literature search) were compared with the existing list. In this process, three more challenges were added: *limited resources*, *search & find*, and *savability*, as well as *freedom of movement* (Perry and DeMaria 2009) for the action *move*. The final list covers the following of Wilson's features: control, language/communication, challenge, and conflict. As an aspect of fantasy Wilson mentions that the player may take on a role, usually achieved by another important attribute related to Action: a *character* controlled by the player, which may be *personalized* and cause *emotional attachment* (Adams 2010).

Goals: Goals are closely related to Challenges, as it is the goal to overcome a certain challenge (e.g. beat the clock as goal for the Challenge *time pressure*). The aim is to find features that characterise types of goals without duplicating the description of challenges. Often *various* goals are given in games, called quests or missions (e.g. Elverdam and Aarseth 2007, Perry and DeMaria 2009). Björk and Holopainen (2005) add that the player may have a *choice* in which goals to pursue or even *define their own goals*. The attribute *static* (always the same kind of goal) was added as being opposed to *various*. Besides rules/goals Wilson does not list any more features for this element.

Rewards: The broad literature search revealed a range of articles on gamification, using game elements in a non-game context. Commonly used for this purpose is the element Rewards. When identifying attributes described in these sources, the ones with similar meaning were grouped together and one representative chosen for each group:

- *score:* points, point system, achievement points, assessment
- *praise:* leaderboards, medal system, badges, change of the players' virtual status, title, reputation
- *new levels:* gain levels, access to new game space/people/levels, promotions, greater responsibility, leveling up, advancement, progress
- *gain resources:* experience points, virtual currency, gaining new tools, clothes or currency, money and various items
- *power-ups:* power-ups, improving avatar/city/civilization/business to highest level or their own goal

The representative terms were added to the model and Penalties described accordingly, giving more insight on assessment, another feature by Wilson.

Setting/World, Perspective: The game world is a space presented by graphics and sounds. Sources from the broad literature search differentiate for sound between *sound effects* and *music* and for graphics between *fantasy* and *realistic* in addition to *abstract*. Findings also suggest that games have different *graphical detail*. The game space can be *2D* or *3D* as described by most sources and is shown to the player through a Perspective. Elverdam and Aarseth (2007) and Adams (2010) differentiate between omnipresent (overall view) and vagrant (*avatar-based view*), where the omnipresent view may be *fixed* or *freely* movable. While the size of a game world may be difficult to determine, more important for the gameplay is *how much the player can explore* (features mentioned by game design books like Perry and DeMaria 2009). Wilson's feature location describes the world itself, and fantasy as well as representation describe the way it is presented to the player.

Structure: A commonly known structure of a game is its division in levels (e.g. Björk and Holopainen 2005). As in some games these may instead be separate missions or chapters, the more generic term *separate* parts versus *continuously* progressing was chosen for the corresponding attribute in the game model. Elverdam and Aarseth (2007) state that a game can be *finite* or *infinite*, to which Björk add the aspect of *replayability*. They also note that games can have a narrative structure, but since not all games have a *story* (Perry and DeMaria 2009), it is of different importance depending on the game. Story contributes to Wilson's feature fantasy while otherwise structure is related to progress (e.g. which level, how far in the story).

Excluded game features

The selected attributes directly cover 13 of Wilson's 19 features (see Table 1). The remaining six features are included indirectly, as there are two reasons as to why a feature was excluded from the model: (1) it is part of another feature already contained in the model, or (2) it does not describe the game as a system, but from another perspective, e.g. player perception. Both reasons are further discussed below, explaining which features were excluded in the process of building the model and illustrating how Wilson's remaining features are indirectly considered in GEAM.

If features were already represented by one or more elements, then they were excluded:

- Game mechanics and aesthetics are terms that are above the element level, as they comprise elements, e.g. Kosmadoudi et al. (2013) summarize from various definitions that mechanics describe the possible Action and user Interaction with the game based on Rules. As adding an extra layer above the element level has been avoided lest the model become too bulky and abstract, mechanics and aesthetics were excluded.
- Game content or context is rendered in multiple game features such as *story*, *character*, Game World and Challenges. Through these elements and attributes it is already included in GEAM.
- Features like virtual items, entities, or inventory, are different terms for objects in a game. As all objects in a game have a purpose, they are represented by the existing elements and attributes, e.g. the Challenge *limited resources* requires items that represent these resources or the Game World requires different decorative items. This also comprises Wilson's feature pieces or players.
- Aiming to find a consistent level of detail for the whole model, features which appeared as too specific and were covered by a more generic term were not included (e.g. "driving speed" = *move*, "applause" = *sound effect*).

If features describe games as formal systems, they are included. Otherwise if terms describe games from a different perspective, then they are excluded.

- Games can be described from the player point of view (Juul 2011, Salen and Zimmerman 2004), regarding player experience rather than the formal elements that may cause this experience. All game features describing the players' cognitive or emotional state were thus not included in the GEAM. Examples of these features are: concentration, curiosity, fun. As games are designed for players, observing their perception of the game is crucial. GEAM does not include these terms, as it focuses purely on the architecture of the game, but it

allows analysing each feature with regard to the player (e.g. time pressure might enforce concentration). One player perspective which is partially included in GEAM is players' choice (Björk and Holopainen 2005), which can be found in the attributes *personalise* (a character), *choice of goal* and *of setting*. Four of Wilson's features are player related: surprise and mystery are caused by Challenges, *story*, and Game World, sensory stimuli by the Output of graphics and *music*, and adaption depends on the level of difficulty perceived by the player.

- Games can also be described in relation to the real world (Juul 2011, Salen and Zimmerman 2004). Features such as boundaries were not considered, nor the relation between game time and real world time (Elverdam and Aarseth 2007). Mixed-reality games are borderline cases. Features like tangible interfaces could be added to GEAM as *input device*, but seem too specific at the time. Wilson's feature safety is based on the virtual Game World being detached from the real world and allowing actions to be tested and stories to be told without serious impact.
- All attributes are concepts which are above the implementation level (except for Input/Output which describes the technological interface of the game), so all features that describe the game from a software or technology perspective were excluded: GUI, technology, progress bars, clocks and timers, etc. but also random, used to simulate *opponents'* unpredictability or to keep a *puzzle* which has been solved before challenging.

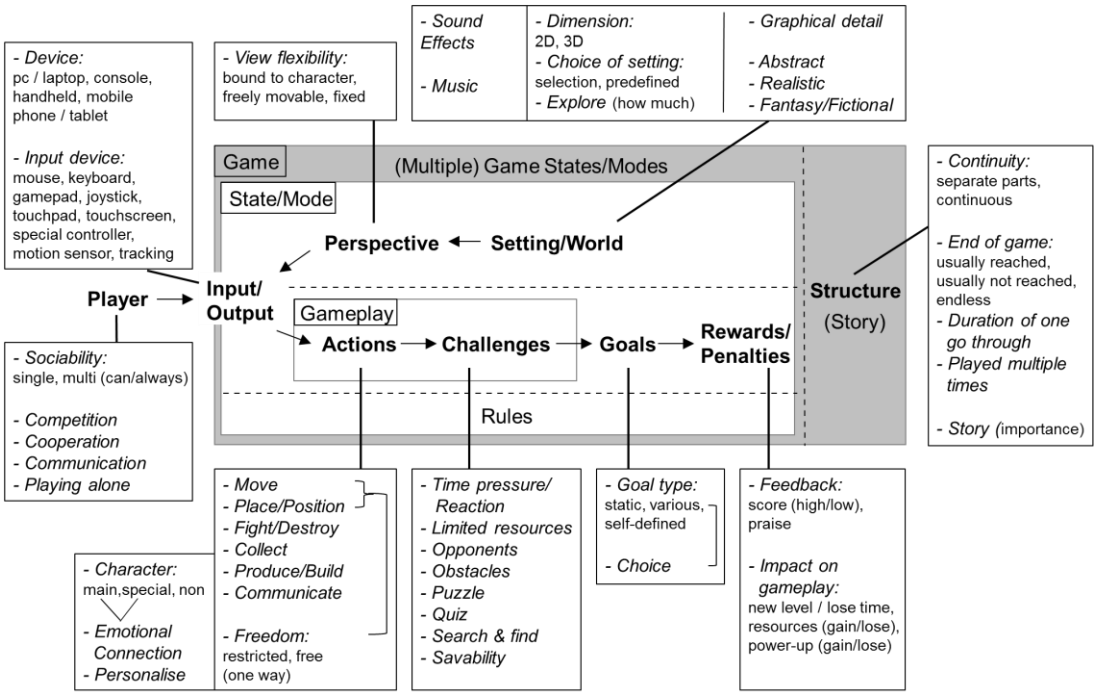

Figure 1: Game Elements-Attributes Model (GEAM). Elements in the centre, attributes in surrounding boxes, lines in boxes show dependencies between attributes.

Game Elements-Attributes Model (GEAM)

As described above, we developed a game model which summarizes the main features of games, also including the ones relevant for learning. The resulting Game Elements-Attributes Model is presented in Figure 1. In the centre of the model the game elements, as core building blocks of a game, are depicted as well as their relations. Each element is connected with a list of attributes, displayed in the surrounding area, building the second layer of the model. A short description has been specified for each attribute but had to be excluded from this paper due to space restrictions. However the names of the elements and attributes should mostly be self-explanatory.

ADDITIONAL AREAS OF APPLICATION FOR GEAM

Although GEAM was developed with the specific objective of further supporting the research on educational potential and design options of DEGs, it may also be useful for application beyond its original purpose.

Gamification: Deterding et al. (2011) define gamification as "the use of game design elements in non-game context". GEAM provides a structured overview on game elements and attributes that may be considered to gamify a non-game context. From the literature search for game attributes, 22 articles originated in the area of gamification of which 10 included a list of features. About 80% of these features were related to the element Reward. Only two articles (Villagrasa and Duran 2013, Ferro et al. 2013) give a more diverse list of game attributes for gamification, for example Villagrasa and Duran (2013) suggest spinning a *story* around the tasks that students have to solve in a class, and utilizing concepts like collaboration and quests (e.g. let students give a collaborative presentation, which is somewhat questionable as giving a presentation seems to be a non-game context, too). GEAM can help improve the understanding of gamification. The elements in GEAM are not unique to games (Huotari and Hamari 2012). Thus the model can be used to analyse the non-game context and identify elements that are already present. For example, if the non-game context is a computer application, it provides Actions and a representation (similar to a Game World) and if it is a lecture it provides Challenges, Goals and a Structure. This knowledge is a starting point for choosing which game features to use in the given context. For the computer application (e.g. a project management software), including more Action attributes may clash with or distract from the existing Actions. Considering attributes from other elements seems more promising, especially from the related element chain Challenge, Goal and Rewards. Hence, not only the selection of attributes but also the structure and relations given by GEAM can support gamification.

Game Design: GEAM illustrates which elements a game consists of and how they work together to generate the game experience. It provides game designers with a general understanding of games, but even more importantly with a structure. Games can be highly complex and exist in a large variety. A fundamental structure helps to organize and keep track of all the details. It may assist experienced designers in sharing their knowledge as well as provide guidance for novice designers in accessing this knowledge. Furthermore, GEAM can support the design process, e.g. by serving as a kind of checklist while giving an overview of the options available for each element. The listed attributes may also inspire designers to think of new attributes or new ways to combine them and thus promote innovation. Finally GEAM provides designers with a vocabulary that facilitates communication within a project by ensuring a shared understanding among the team.

Game Research: GEAM gathers knowledge from multiple sources on what games consist of and presents this information in a coherent model, facilitating the analysis and comparison of games. By breaking down the core concepts of games (elements) into the choices they entail (attributes) the elements are operationalized and can be measured to evaluate games. This enables and fosters all kinds of game research, such as the classification of games and the refinement of game genre or the study of violence in games with all the attributes treated as variables that may influence the emotional state of the player. The model also helps categorize game research by allowing a more exact description of which aspect of a game is studied.

CONCLUSION AND FUTURE WORK

The Game Elements-Attributes Model (GEAM) presented is foundational for further research on design options and comparison of DEGs in terms of their educational potential. When designing a DEG, attributes for all game elements need to be chosen. At the same time the learning content needs to be included. As explained by Garris et al.'s (2002) input-process-outcome model, features of games are paired with instructional content, which induces learning. With the listed attributes, the GEAM provides insights into possible options for this pairing. Different combinations of attributes need to be considered to identify how to best include a given learning content into a game to build a DEG. The GEAM supports this identification as well as furthers research on comparing the effectiveness of different options, which may eventually lead to general guidelines on how to approach the pairing of content and game (attributes). The GEAM attributes add detail to Wilson's features, deepening the research on how learning may be supported by different combinations of game attributes.

BIBLIOGRAPHY

Adams, E. Fundamentals of Game Design, New Riders, 2010 (2nd ed.), 2014 (3rd ed.).

Amory, A. Game object model version II: a theoretical framework for educational game development. Educational Technology Research and Development, 55 (2007), 51-77.

Bedwell, W.L, Pavlas, D., Heyne, K., Lazzara, E.H. and Salas, E. Toward a taxonomy linking game attributes to learning an empirical study. Simulation & Gaming, 43 (2012), 729-760.

Björk, S. and Holopainen, J. Patterns in Game Design. Charles River Media, 2005.

Brathwaite, B. and Schreiber, I. Challenges for Game Designers. Cengage Learning, 2008.

Calvillo-Gámez, E.H., Cairns, P. and Cox, A.L. Assessing the core elements of the gaming experience. In: Evaluating user experience in games. Springer, 2010.

Deterding, S., Dixon, D., Khaled, R. and Nacke, L. From Game Design Elements to Gamefulness: Defining "Gamification". In Proc. MindTrek, ACM (2011), 9-15.

Djaouti, D., Alvarez, J., Jessel, J.-P., Methel, G., and Molinier, P. A gameplay definition through videogame classification. International Journal of Computer Games Technology, 2008 (2008), 4:1-4:7.

Egenfeldt-Nielsen, S., Smith, J. H. and Tosca S. P. Understanding Video Games: The Essential Introduction. Taylor & Francis, 2013.

Elverdam, C. and Aarseth, E. Game classification and game design: Construction through critical analysis. Games and Culture, 2 (2007), 3-22.

Ferro, L. S., Walz S. P. and Greuter, S. Towards personalised, gamified systems: an investigation into game design, personality and player typologies. In Proc. IE, ACM (2013), 7:1-7:6.

Fullerton, T., Swain, C. and Hoffman, S. Game Design Workshop: A Playcentric Approach to Creating Innovative Games. Elsevier Morgan Kaufmann, 2008.
Garris, R., Ahlers, R., and Driskell, J. E. Games, motivation, and learning: A research and practice model. Simulation & Gaming, 33 (2002), 441-467.
Harteveld, C. Triadic game design, Springer, 2011.
Heintz, S. and Law, E. Evaluating design elements for digital educational games on programming: a pilot study. In Proc. BCS-HCI (2012), 245-250.
Hunicke, R., LeBlanc, M. and Zubek, R. MDA: A formal approach to game design and game research. In Proc. AAAI Workshop on Challenges in Game AI (2004)
Huotari, K. and Hamari, J. Defining gamification: a service marketing perspective. In Proc. MindTrek, ACM (2012), 17-22.
Juul, J. The game, the player, the world: looking for a heart of gameness, In DIGRA Conf. (2003).
Juul, J. Half-real: Video games between real rules and fictional worlds. Cambridge (Massachusetts) und London. OLDENBURG 2005; MIT Press. 2011.
Kiili, K. Foundation for problem-based gaming. British Journal of Educational Technology, 38 (2007), 394-404.
Klabbers, J. H. Terminological Ambiguity Game and Simulation. Simulation & Gaming, 40 (2009), 446-463.
Kosmadoudi, Z., Lima, T., Ritchiea, J., Louchartb, S., Liua, Y. and Sunga, R. Engineering design using game-enhanced CAD: The potential to augment the user experience with game elements. Computer-Aided Design, 45 (2013), 777-795.
Malone, T.W. Toward a theory of intrinsically motivating instruction. Cognitive science, 5 (1981), 333-369.
Malone, T.W. and Lepper, M.R. Making learning fun: A taxonomy of intrinsic motivations for learning. Aptitude, learning, and instruction, 3 (1987), 223-253.
Owen, M. An anatomy of games: A discussion paper. Retrieved from www.futurelab.org.uk. (2004)
Perry, D. and DeMaria, R. David Perry on Game Design: A Brainstorming Toolbox. Charles River Media, 2009.
Rollings, A. and Adams, E. Andrew Rollings and Ernest Adams on game design. New Riders, 2003.
Ruch, A. W. Grand Theft Auto IV Liberty City and Modernist Literature. Games & Culture, 7 2012, 331-348.
Salen, K. and Zimmerman, E. Rules of Play: Game Design Fundamentals. MIT Press, 2004.
Villagrasa, S. and Duran, J. Gamification for learning 3D computer graphics arts. In Proc. TEEM, ACM (2013), 429-433.
Wilson, K. A., Bedwell, W. L., Lazzara, E. H., Salas, E., Burke, C. S., Estock, J. L., Orvis, K. L. and Conkey, C. Relationships between game attributes and learning outcomes. Simulation & Gaming, 40 (2009), 217-266.