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The introduction of IMO, an integrated model for designing for open-ended play ☆

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ABSTRACT

Designing for open-ended play poses specific new challenges to designers. Designing for closed games includes defining rules and goals to balanced the game properly. A design for open-ended play has no predefined rules and goals. The design needs to provide users with more freedom to continually change goals and rules of play, which distinguishes the field from designs of closed games. Gaining knowledge on the design process of creating this freedom is essential. For this purpose, an integrated model for open-ended play is proposed. This model is based on a combination of two existing models: Hunicke's Mechanics Dynamics and Aesthetics (MDA) model and Grünvogel's formal models for game design. Both of the above mentioned existing models are generalized to make them applicable for analyzing open-ended play. In the proposed combined model we distinguish between the perspectives of the design, and the perspective of play. It addresses how to handle changing rules and goals, instead of the assumptions that rules and goals do not change. Furthermore, the model was used to improve our understanding on progression and emergence, two key concepts that are commonly used in game design. The *integrated model for open-ended play* (IMO) was used in a preliminary case study with a digital play application, an interactive environment for open-ended play named the GlowSteps, to evaluate the model and to underline our insights on emergence and progression.

1. Introduction

Mankind has developed designs for play in many forms since play began. When children play freely, they often use attributes, or designs in play. Nowadays modern digital technology has changed the way we play. For example, the introduction of the video game has created a new and immersive category of designs for play. Computer games are often designed to create a fine balance between the player's skills and the challenge the game provides [1], resulting in an immersive flow experience [2]. The challenging nature of computer games makes them very appealing; however, the focus on screens makes children less physically and socially active [3].

Unlike many rule-based computer games, designs for open-ended play aim to provide play materials or toys in which rules and goals are less defined beforehand. The design supports the children in defining their own rules and goals during play [4]. Examples of traditional non-interactive play materials for children aimed at open-ended play are LEGO, wooden building blocks, or a sandbox. The advantage of this approach is that designs for open-ended play create possible ways for children to express creativity [5]. The use of open-ended play in playgrounds might open opportunities for ongoing physical play as well. Many research projects focus on the use of appealing mechanisms of computer games in design for physical play, for example [6–8]. In our research project, we investigate how designs for social-physical play benefit by a more open design approach, to create a longer and more diverse play experience, which we refer to as richness in play [9]. We aim specifically at digital applications for open-ended play.

Game design literature provides game designers with many theories and tools to support the process of developing a game, for example [1,10–12]. In addition, *emergence* and *progression* are two commonly used concepts to characterize the development of game play [10,13]. While progression refers to the development in play, say the logical movement of one moment to the other, emergence describes the property of many games in which new situations arise,

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enabling freedom of players to shape/reshape the game. Game designers tools, methods and models aim to support designers to shape rules and goals in such a way that the game play progression or game flow can be improved. However, existing tools and design methods approach rules and goals as time independent and non-changing during play. When creating designs for open-ended play, this no longer applies, since the rules and goals are flexible and not defined in detail beforehand. Traditional game designer tools thus are no longer fit for purpose. Therefore we need models that support a design approach for open-ended play. Some examples of research in open-ended play are known, for example: Tetteroo et al. [6], who uses a model with 3 interaction design levels to describes a four step design process. To the best of our knowledge no generally usable tools are available, that links *design properties* and *formal description* of interactions, rules and goals, to the resulting development of play. This is why we believe new tools are needed to design and evaluate designs for open-ended play.

In this paper we present an *Integrated Model for designing for Open-ended play* (IMO) that addresses the consideration of a less defined setting of rules and goals. IMO is based on two existing game design models. The first is the Mechanics Dynamics Aesthetics model (MDA) [14] that relates design aspects to user experience. The MDA model provides an analytical view on how aspects of the design, the mechanics (for example: the chess pieces, the game board and game rules) are related to the actual game play, the dynamics (for example: a chess player forms a strategy and strikes on pieces of an opponent player). This relates to the question how a design for open-ended play leads to a specific development in play. The second is Grünvogel's formal model [15] that helps to describe games as systems, relating states, transition rules, and interactions. Grünvogel's model [15] provides us with a formalized descriptive tool to define elements of the game in detail. This can help us to define the properties of the design for open-ended play in a more systematic and detailed way. We argue that the above-mentioned existing models for game design are not sufficient for the design of interactive open-ended play, and generalizations of the MDA model [14] and Grünvogel's formal models [15] are needed. In this paper we propose such generalizations that allows for the description of the open-ended play dynamics.

With the development of IMO we expect to provide a framework to investigate what processes influence the development of open-ended play, and how rules and goals emerge, based on the design for play. Furthermore, one of our aims is to develop IMO as a tool to be able to better define emergence and progression in open-ended play. Subsequently, we aim to support designers and design researchers in creating and evaluating interactive environments for open-ended play with IMO. The presented model may provide design researchers with a structure for analyzing the design for open-ended play. The different layers of IMO can help to evaluate how design choices influence the development of play, and how the design might be improved. Thereby we expect such a model might be able to provide designers with better tools to create effective designs for open-ended play.

In this paper we will show how IMO can helps us to understand how the interactions opportunities of the system can be improved, which is the first step in working towards more immersive play experiences. We will underline this approach with reflecting on observations from a pilot study. In this reflection we will show IMO provided us with a structure in which we could pinpoint how designed properties of the design influenced play. The formalized approach made clear how rules and goals developed in the different play sessions. This led us to new insights on emergence and progression in open-ended play.

This paper is structured as follows: the context of this work is sketched in Section 2, where an overview of related work and our own research project is given, including a motivation for the presented work. In Section 3 we briefly review the theoretical background of the models we use and discuss the principles of progression and emergence in more detail. In Section 4, we propose generalizations of MDA and Grünvogel's formal models to make them applicable to open-ended play. This is where we introduce IMO. Next, we describe our new insights concerning progression and emergence that IMO provided us. In Section 5, we describe an initial evaluation of a design for open-ended play, based on a pilot study. We discuss the applicability of IMO and we link our insights on progression and emergence to the pilot study. However, providing full proof of concept is not the aim of this paper, but the presented evaluation does underline our initial insights. Finally, we discuss the potential of IMO for future research.

2. Related work

2.1. Related projects

With respect to our work, we describe several related existing designs for physical play. Several examples of play installation use interactive elements to enrich playgrounds, and trigger physical play. *Icon* [16] and *Yalp* [17] are interactive outdoor playgrounds that use interactive elements, such as sound and light, to enrich an outdoor playground. These examples trigger physical play, yet they have predefined games, which players can select with help of some kind of interface. *Head-up games* (HUGs) [18] are handheld devices that provide an interactive addition to most existing outdoor games like Tag. The games developed with HUGs are rule based; yet the design does provide more freedom in play of children. The *Play-ware technology project* [8] investigates how a modular system of play tiles can be arranged and programmed to support play for children. In this project an artificial intelligent software platform drives the interactions and adapts those interaction to the situation on the playground.

Examples of interactive designs for open-ended play are *ColorFlares* [4], *Krul* [19], *Morels* [20] and *MagicBuns* [21]. All of these examples are interactive tangible objects that provide opportunities for play, without providing rules and goals for the actual game-play. *ColorFlares* [4] provides simple local interactions, where an object has a colored light. Users can influence the colors of objects by specific actions. *Krul* [19] provides different abstracted sounds depending on how the orientation of the object. Children can use the object and the sounds to enrich their play. For example: in one of the observations with 'Krul' a child pretended he was fueling a car holding 'Krul' diagonal by using an abstract water like sound [19]. Afterwards the child held 'Krul' horizontal, and used a machine like sound of 'Krul' to act out he was driving the car [19]. *Morels* [20] are soft interactive objects, which can be thrown, kicked or squeezed. Two morels in each other's vicinity provide sound feedback. Furthermore squeezing it can charge a Morel, which will eventually results in launches the other Morels. The variety of opportunities to interact with morels, create option for players to define different games. *MagicBuns* [21] exists of five interactive O-shaped objects that can light up in various colors. Users who play with *MagicBuns* [21] have to explore the interaction opportunities, assign meaning to them, and are free to use them in play, in any way. For example: players might define rules for active games like interactive tag by use of the MagicBuns design. In the examples above the designs support open-ended play, yet the interactions programmed in the objects are not adaptive. In our project we aim to enrich the play experience by providing different interaction opportunities in different play situations.

Many of the examples above include multiple interactive objects. Collections of objects are combined together, which form a system for open-ended play. This is one form of an interactive play environment. A different approach on creating play environments uses projections to create an immersive setting of play. By analyzing movements of children, for example by video analysis, the projections are changed or new projected objects are introduced in the play environment. Examples of this approach in designing for play are *The interactive playground* [6] and *Connected Worlds* [22]. The use of sounds and video projection are a powerful tool to create immersive installations. Playgrounds built with multiple interactive objects, are, in our opinion, more open for use or integration in existing play environments. Existing play is mixed with a new layer, which in our opinion provides many new opportunities.

2.2. The I-PE project

In the 'Intelligent Play Environment project' (I-PE) [23] we research how to design interactive play environments for open-ended play. These environments consist of multiple interactive, connected and tangible objects. Opportunities for play arise from interactions of one or more of those objects. Children interpret interactions, and while playing, they assign meaning to them and shape their own play [24]. Children are in control of how play evolves; yet the design should somehow support the actions of the children [9]. This is referred to as supporting *richness in play* [9]. Research focuses on understanding how interaction opportunities should be designed to support the changing and unpredictable nature of open-ended play effectively.

In the I-PE project design, explorations and theory forming go hand-in-hand. Design explorations are done following the Research through Design approach [25] and aim at determining what does and does not work in open-ended play by actually designing working prototypes (in our case the GlowSteps [26]) and test them with users in situ. The main reason for this approach is the fact that it proves very difficult to make design decisions to influence the actual dynamics of play. The ambiguous nature of play asks for an iterative and explorative approach to gain insights. These insights are qualitative and situational [25], however they may lead to new design iterations and eventually to generalized results. Examples of Research through Design approaches are [27,28]. In parallel, existing knowledge and theories on games, play, HCI and other related domains are explored for their suitability for open-ended play. To develop a better analysis of our observations, we work simultaneously on defining models as well as design strategies. This paper is a result of these explorations.

As part of our research project we developed an interactive play environment called GlowSteps [26]. GlowSteps are interactive tiles

Fig. 1. Children playing with GlowSteps.

that can light up, play sound samples and sense if people stand on them. Fig. 1 displays children playing with GlowSteps. Each tile has its own microcontroller device to interpret sensory data and create output according to local interaction rules. A tile can communicate with other tiles. A set of 25 GlowSteps forms a decentralized play environment. The collection of tiles provides opportunities for play. We designed several interaction behaviors for GlowSteps, each focusing on other aspects of the play spectrum [26]. A concrete scenario of play is presented in Section 5. A video of an impression a play with GlowSteps can be viewed here [29].

2.3. Motivation for the development of IMO

Our research in the I-PE project made us aware of the challenges of designing for open-ended play. An interactive design in the open-ended play philosophy should provide cues for children to start playing and give them freedom to define and redefine their play [30]. This can result in more *richness in play* [9], meaning that the design supports the emergence of many forms and settings of play. The fact that open-ended play is less structured, and rules and goals are interpreted and changed by players, creates a new design challenge, in which designers have less influence on the game play development.

We believe a next step in the challenge of designing for open-ended play, is to improve our knowledge on the development of rules and goals, and to better describe the role of emergence and progression in open-ended play. In previous work [9] we described different rules and goals, and how they might be connected to the design properties. Based on rules and goals in play, we can explain the mechanisms progression and emergence. We expect that progression and emergence are two mechanisms that can be used to develop a system that is both *connected* to play, as well as *providing freedom* for players. A design that supports emergence provides players with freedom and leaves the players in control. Progression in the game play provides the players with structure, a logical order in the game play, to build upon. Designing for emergence and progression is discussed in the literature on (closed) rule-based games [10,13]. Designing for emergence and progression in open-ended play is however more difficult, because emergence and progression are strongly influenced by the user creating his own rules. To clarify the role of emergence and progression we need a clear definition of the terms. Section 3.3 will provide a short introduction of emergence and progression.

IMO, as presented in this paper, is an integrated model for designing for open-ended play. The model aims at providing a more systematic, formalized structure to investigate processes in open-ended play in a more structured way. With IMO, and its formalized structure we expect to be able to better define emergence and progression and clarify its role in the development of open-ended play. Furthermore we argue the model might be of help in improving our skills in designing for open-ended play, and provide other designers with tools to do so as well. In this paper we will use the model only in a descriptive manner, yet in future work we expect to provide prescriptive methods based on the presented model.

3. Related theory

IMO is based on two existing game design models, the MDA model [14] and Grünvogel's formal models for game design [14]. In the upcoming sections we discuss the models and theories, which we believe to be of relevance for the development of our integrated model. We first briefly describe both models as they are. In Section 4 we generalize both models to make them applicable for open-ended play, and combine and align them into one model.

To explain how the various theories have shaped the development of our model in a structured way, we use the canvas shown in Fig. 2. The canvas in Fig. 2 depicts four quadrants. The horizontal axis provides a separation of the canvas in two perspectives, the perspective of play and the perspective of design. The perspective of play relates to how players interpret and use the design during play. The perspective of design describes the *designed* qualities of the application for open-ended play. On the other hand, we like to distinguish between the design and a more formalized representation or system approach. This is included in the canvas by separating a designed model section from a formalized model section, by use of the vertical axis. We will link the theory to this canvas, which will eventually lead to our extended model.

In the upcoming sections we will discuss the models and theories, which we believe to be of relevance for the development of our integrated model. We first describe a design model, the MDA model [14], and secondly formalized models from Grünvogel [15]. We bring both models together on the canvas.

3.1. MDA

The Mechanics-Dynamics-Aesthetics Model (MDA) from Hunicke et al. [14] was originally meant as a tool to understand games. This model, as shown in the canvas in Fig. 3, is used to show the different perspectives the player and the designer have on games. Whereas a designer approaches a game from the *mechanics* point of view while constructing it, a player interacts through experiences, before gradually understanding it's play construction. This is referred to as the *aesthetics* of play. The two perspectives meet in the middle in the *dynamics* layer. The two approaches correspond with our canvas.

The three components of the MDA model can help designers into rethink the design they are working on. The *mechanics* are formed by the basic components of the game. Rules in a game, like interaction opportunities of the interactive play environments, are *mechanics* of a system. Rules define what a player is 'allowed' or 'obliged' to do, and how attributes are to be used [14]. The *dynamics* describes "the runtime behavior" [14] of the game. It is the actual game play. It includes how people use the game system, which meaning they assign to system elements, which narratives they use, and resulting from that, the evolvement of play. This results in a user experience of the players, which refers to the *aesthetics* of play in the MDA model. The *aesthetics* it is outside the scope of this paper.

The MDA model [14] provides a basic structure in which we can describe how elements of game designs (the mechanics) are related to the process of playing (the dynamics). When we aim

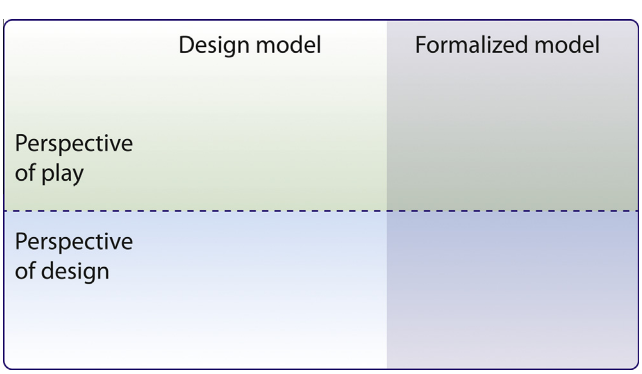

Fig. 2. Canvas that forms a bases for our model.

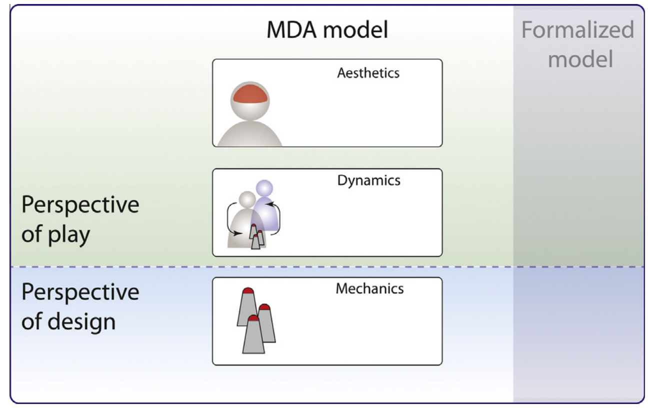

Fig. 3. Visualization of the MDA model [10], placed in the canvas.

to explain how richness in an open-ended play setting might develop, this model no longer fits this purpose. For example: the evolvement of play from one setting to another proves to be difficult to pinpoint, since it might include a change of the rules by the player. In Section 4 we will extend the MDA model to make it applicable to open-ended play.

3.2. Grünvogel: A formalized description of rules and goals

Many theories from the game design literature describe how play or games can be systematically modeled, by defining the *game rules and attributes* in a formalized approach [e.g. 12,31]. When designing games, these theories provide designers with tools to create balance and control in the game. We will use one of these theories as a base for our formalized section of the canvas to analyze open-ended play designs.

A design for play includes the attributes and rules that define play. In a rule-based game such as chess, the rules together with the game board and the pieces, define the game of chess. Rules create structure (interaction) to the game. They define what a player can do and what is 'not allowed'. Different types of rules can be recognized in play. Salen and Zimmerman [12] distinguish three types of rules: (1) Continuative Rules, these are the abstract core mathematical rules. (2) Operational Rules, these are the rules of play, e.g. as printed in a manual. (3) Implicit Rules, these are the unwritten rules. With the latter Salen and Zimmerman [12] point to general rules of play e.g. 'one may not cheat', which applies to many different games.

Using the example of chess, the game board and the pieces are the designed attributes that are used in the game. In the case of board games like chess the attributes are physical, but in video games they may also be digital or imaginary. The rules, together with the attributes create a system. To understand how this system provides a procedural foundation for the game, it can be abstracted into its core construction, which means defining the continuative rules [12] of the game and all possible states or situations in which the game might end up, using those rules.

Grünvogel defined models for a systematic description of a game as a system [15]. We will explain the model using the example of a game of chess. In this model, the game is defined as a triple $\{M, F, S\}$. In this triple, the rules can be represented as the function F. The collection of all possible states, which are all possible configurations of the chess pieces on the board, is defined as the game space S. Using the example of chess, the position of the pieces on the board describe a specific state of the game system s. When players prepare a game of chess, they place the pieces on the board, which is the starting state s_0. Every move of a player observes the current state s of the game, and he or she defines an action, which can be described as input for the game system. All actions of users of one game of chess describe a monoid m, in which the starting point forms the neutral element ε. A monoid here is one sequence of actions that defines one specific game as it happened or could happen. All possible monoids that lead to a valid game are defined in M. In essence this model can be used to describe all possible ways in which the game can evolve. For each game, a different monoid m will define a different route through the game state space S. See Fig. 4 for a representation based on the models of Grünvogel [15] in our canvas.

Grünvogel restricts his models [15] by stating, the function F is time independent, and thus it does not change during play [15]. This means the model assumes that the rules of the game do not change during a play session.

3.3. Progression and emergence

Progression in play describes the development of play, or the fact that players move from one state to another, for example by following a storyline or procedure. Progression can be described as 'movement towards a destination' [32]. Progression provides players with structure in the game, as one step of a player in a game has a logical link with the previous step. Using the game descriptions of Grünvogel [15], progression can be described as a logical shift from one state of the game space to the next one, using the game rules. Chains of these steps describe the progression in the game towards the end of the game. Progression can be defined as:

Definition 1. Progression in games describes the logical chain of events in the development of a game.

The term emergence is used in different contexts of research, each with a different definition. A general definition of emergence by Fromm states: "a property of a system is emergent if it is not a property of any fundamental element" [33]. In game design literature emergence is defined slightly different: "Emergence is the primordial game structure, where a game is specified as a small number of rules that combine and yield large numbers of game variations, which the players then design strategies for dealing with" [13]. The board game Chess, for example, has a fairly limited amount of game rules that define the behavior of the pieces on the board and what a play can and cannot do, yet the possible amount of game outcomes is enormous. We propose to define emergence in play as follows. This definition aligns the description emergence in game design literature [10] and builds on the description of the MDA model [14].

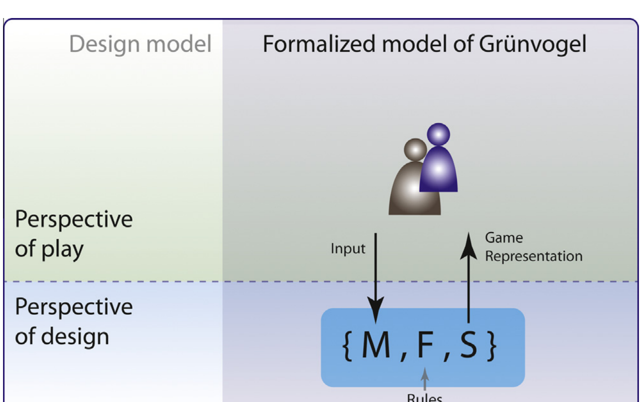

Fig. 4. Visualization of the formalized model of Grünvolgel [11], placed in the canvas.

Definition 2. Emergence in play arises if a small number of mechanics in play yields a large variety of dynamics in play.

Emergence and progression can be approached as two complementary mechanisms in a game system [13]. The work of Dormans aims at providing tools for how emergence and progression can be integrated in rule based games [10]. An interesting game is often a system in which emergent and progressive properties are balanced. In general we can propose that emergence accounts for openness and freedom in play development, and progression supports structure and direction in this development. The two mechanisms provide play with the needed balance; a structure to build upon and freedom to be creative and provide the possibility to diverge in different directions. By analyzing this balance between emergence and progression we expect to develop more insights on how to design interactive mechanisms in the play environment that can somehow adapt to the dynamics of play.

4. Generalizing for open-ended play

Until now we have discussed theory focused on closed (rule-based) games. Most of these theories explicitly or implicitly build upon the fact that rules and goals are pre-defined by the designers of the game and do not change during play. In case of open-ended play, rules and goals are much more flexible, and change during play. The scenario below describes an example of open-ended play.

A group of 6 children plays a game of tag on a stretch of land confined by two lines of trees. They agree on the following rules: if a player gets tagged, he or she has to join the tag man to tag the others. If everyone is tagged, the last player tagged becomes the new tag man and the game starts again. After a while one of the players, almost being tagged, grabs one of the trees and says: "I am safe because I am touching the tree". Almost immediately, the game changes to tree tag. Players get a point for every time they cross the trees from one side of the field to the other. If someone gets tagged the tagger and tagged player switch roles. When it appears too hard for one tagger, the children agree on adding a second tag man.

From the scenario described above we can recognize that in open-ended play rules and goals do change during play. For example, the number of taggers changes, and trees are introduced as a new attribute in the game. The existing models described in Section 3 do not deal with this change of rules and goals. In the following paragraph we propose a generalization of those models for open-ended play.

We discuss this approach in two steps, first we discuss the MDA model [14], and secondly we provide a formalized description of the design and rules of play. Subsequently, we use the same canvas as we used in Section 3 to explain our work.

4.1. MDA generalized

The original MDA model [14] assumes *fixed rules and goals*. When we use an open-ended design approach, rules and goals are no longer solely defined in the system design. The boundaries between mechanics and dynamics begin to fade. For example: during a play session a player proposes a new rule. Is this rule then part of the dynamics, as it arises during play, or is it part of the mechanics, as it represents a new algorithmic component of that specific moment of play? If we consider fixed rules and goals as a special case of a broader field of open-ended play, then Fig. 5 proposes a generalized MDA model. We propose to distinguish two

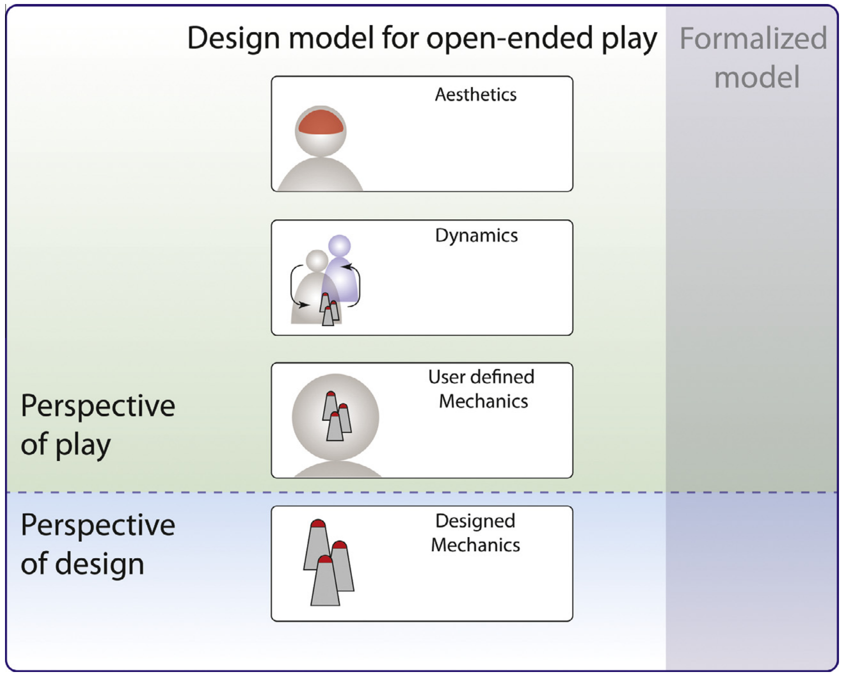

Fig. 5. Visualization of the design model for open-ended play, based on the MDA model [10], placed in the canvas.

separate layers in the mechanics. This extra layer supports the fact that part of the rules and goals are predefined in the design, and others are a dynamic component, which change during play.

The lower layer describes the designed interaction opportunities of the system. We will refer to this layer as the '*Designed mechanics*'. The mechanics in this layer describes properties of the design, which include a fixed set of rules, or interaction opportunities. The second layer, named '*User defined mechanics*', describes the actual set of rules and goals introduced by the players during play. Players define and change the rules and goals. Players interpret the '*Designed mechanics*', and create interpreted rules. Depending on the situation users might also add rules.

The two upper layers correspond with the original MDA model [14]. The '*Dynamics*' layer describes 'the runtime behavior' [14] of the application for open-ended play. Players will define actions depending on the situation in play. Finally play will lead to a play experience, which is described in the '*aesthetics*' layer.

The separation of the mechanics layer of the MDA model [14] into two layers makes the model more applicable to analyze open-ended play applications. The separation into two different layers makes it possible to distinguish the interaction opportunities as provided by the design, and the rules and goals as defined by users as a base for their play. With this separation we believe we can better recognize how aspects of the design are interpreted and used in play. This helps in analyzing how design choices support the development of rules and goals in play. Eventually, with this knowledge, we might be able to better design for emergence and progression in open-ended play. We will discuss this in more detail in Section 4.4 of this paper.

4.2. Grünvogel generalized

The fact that rules and goals change during play in open-ended play also has implications for the formalized description of our game based system. In this case, formalizing rules and goals becomes more complex which makes it necessary to reconsider the formalized description of rules of game (as described in Section 3.2) based on the work of Grünvogel [15].

The formalized models of Grünvogel [15] describe the game based on a fixed design and a fixed set of rules, which results in a fixed description for that specific closed game. In designs for open-ended play, the actual construction of play, which is defined by players during play, is not fixed. Instead it evolves over time. Nevertheless the interactive design for open-ended play exists of a logical system that, comparable with the game description, contains a state space, and certain programmed rules to organize how the system shifts from state to state. Players can interpret the procedural mechanism of the interactive system and use them in the creation of rules in play.

It becomes clear that we have to distinguish the formalized description of the interactive design and the description of rules and goals as defined by players. This corresponds with the two perspectives of our proposed canvas. We can use the perspective of the design to describe the designed interactive system. The perspective of play describes the user-defined system, which evolves over time and which is based on rules and goals created by the players. This separation is comparable with the additional layer in the MDA model [14] (see Fig. 5).

We will now explain our proposal for the formalized model description, as shown in Fig. 6. The description of the interactive design in use is formalized as the triple $\{M,F,S\}$. In this description S represents the state space of the designed system, which is a collection of all possible states that the system can have. F describes the *designed interaction rules*, which are the transition rules of the designed system. An example of a transition rule could be: 'when an object is touched by a user it will light up in green'. M describes input from users on the designed system. This input points to input that is meaningful from the perspective of the designed system (for example, a signal that a play object is touched by a player).

Assume users now interpret the designed interaction rules. With the created interpretation of the design, the users might create their own game. In this game construction they assign meaning to the interaction of the objects and add rules. From the play perspective a second system emerges which is different than the designed system. In Fig. 6 this system is described as the triple $\{M',F',S'\}$, in which F' describes the user defined rules, S' describes

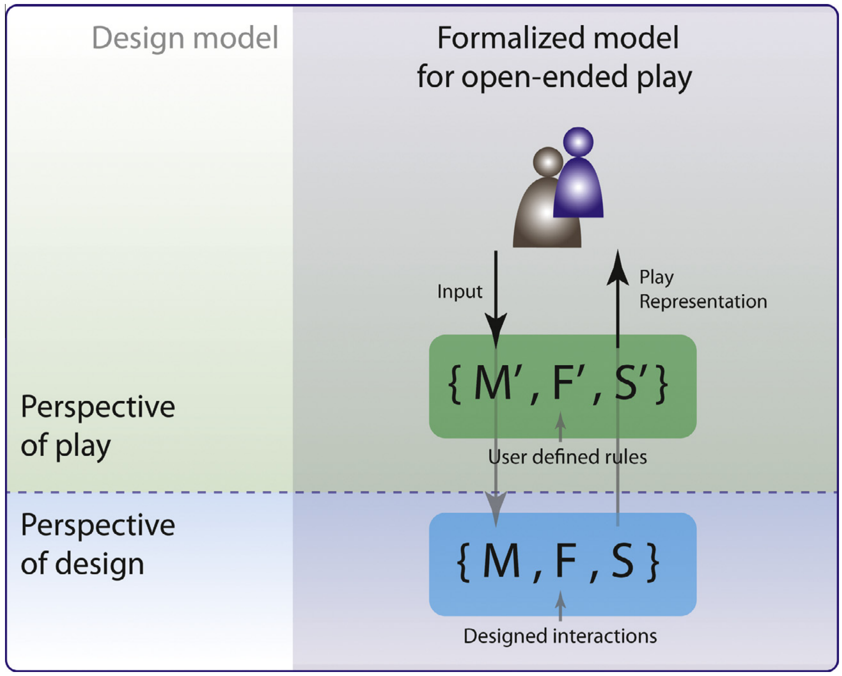

Fig. 6. Visualization of the formalized model for open-ended play, based on Grünvogel [11], placed in the canvas.

the state space, connected to the rules. The state of the system represents the setting of play. From this setting of play, players will define their actions. M' describes those actions as the input that is meaningful from the perspective of play. Note that the definition of $\{M', F', S'\}$ in open settings of play changes over time, and might not be the same for all players.

The proposed formalized model (see Fig. 6) can be of use in comparing the designed system (mechanics) and the dynamics of play. The model might help us to investigate the relationship between the designed system and the system from the play perspective in a more structured way.

4.3. The integrated model for Open-ended play (IMO)

If we combine the design model for open-ended play and the formalized model for open-ended play, (as explained respectively in Sections 4.1 and 4.2) our proposal for an integrated model for open-ended play takes shape. As shown in Fig. 7, the design model, which is based on MDA [14], is aligned with the formalized model, which in turn is based on Grünvogel [15]. Both descriptions include an additional layer that supports the use of the two perspectives, perspective of design and perspective of play.

4.4. Progression and emergence

With the canvas Fig. 7 it is possible to elaborate on progression and emergence in relation to both the play and design perspectives. We argue that, with help of IMO, the two properties emergence and progression can be pinpointed more precisely. IMO can provide a structure in investigating how these properties are linked to the designed mechanics and the actual game play of the players. Understanding this link might help us to create a

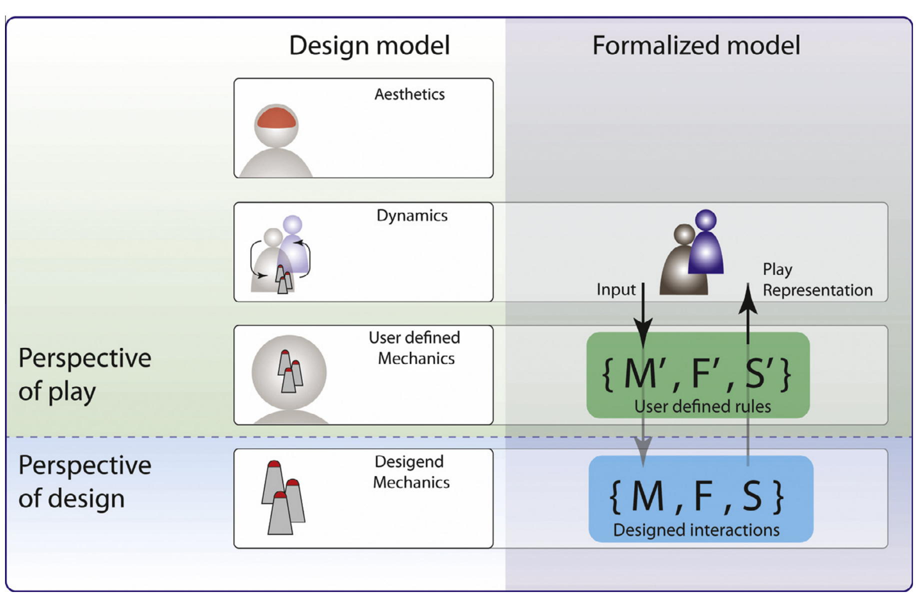

Fig. 7. Proposed integrated model for open-ended play (IMO).

design that better supports richness in play. Richness implies the design supports changing situations in play, and the emergence of new rules and goals. As in (closed) rule-based games, open-ended play progression originates from the structure of the game and its rules and goals. In open-ended play this link becomes less direct. Subsequently emergence provides users with freedom and the opportunity to modify play.

Progression originates from design qualities as well as play. The first refers to the intrinsic progressive value of the *designed mechanics* comparable with traditional game design. We will refer to this as *designed progression*. The second type of progression is the *user-defined progression*. This is the progression that is connected to the rules as defined by players, or the *user-defined mechanics*. Narrative structures and context of the players influence this type of progression. Designed progression and user-defined progression are connected, since the progression in the design might influence the options that players have to define extra rules. We believe that in open-ended play elements of progression are needed in the designed mechanics to provide players with the notion that the game is developing.

Emergence also occurs in two types. The first type of emergence, *Inner emergence*, refers to the fact that the designed mechanics has the intrinsic property to diverge to a variety of different game play developments (dynamics). This coincides with the original interpretation of emergence in closed games like chess [10,13]. In practice inner emergence develops based on the designed mechanics. The interpretation of designed mechanics can create a base to develop multiple options for the development of play. The second type of emergence, *outer emergence*, is the emergence of play, outside the direct interpretation of the designed mechanics. Players enrich their play by the addition of rules, and by enlarging the game space. The game space itself in this case is changed. Outer emergence is primarily driven by the imagination of the players. We believe supporting outer emergence with the design, by adapting the designed mechanics accordingly, we can increase the variations in types and forms of play. The work of de Valk [30] aims at providing tools for this design challenge.

In the following paragraphs we describe how an analysis using our model, illustrates the new insights on progression and emergence in open-ended play. We evaluate a pilot observation of children playing with a design for open-ended play by use of IMO, to understand how designed properties were used in play. Furthermore we analyze how we recognize elements of progression and emergence in those play sessions.

5. Evaluation

The IMO model presented in this paper is based on literature and several observations and discussions on the development of play with GlowSteps. In this section we describe a case in which IMO was used to analyze a pilot study of a design for open-ended play. We have selected one episode of a play session to illustrate our work, however, we have found similar behavioral patterns in other play sessions as well (see example [34] for a description of a more extensive study of play behavior of children using the GlowSteps). Nevertheless the presented work is still under development, and a more extensive validation of our findings will be addressed in future work.

5.1. Case study of analyzing an open-ended play design using IMO

The setting of the pilot study was as follows: a group of six children (age six and eight years old with randomly mixed genders) were briefly introduced to the GlowSteps, without explaining the rules of the interaction behaviors. The children were free to play with the GlowSteps. For this pilot study we used two different interaction behaviors programmed in the GlowSteps. During the play session the two different interaction behaviors were activated, so that the children could play with them both. The first interaction behavior, entitled ‘Catch’, shows a moving light that triggered children to ‘catch’ the light by stepping on a GlowStep that was lit. The second interaction behavior, entitled ‘Create’, provided a more atmospheric light effect, which changed when children stepped on the GlowSteps. A more detailed description of the interaction behaviors, or designed mechanics is explained in Table 1. For this study eighteen GlowSteps were used. Fig. 8 shows a picture of the children playing with the GlowSteps during the study.

5.2. Analysis of play with GlowSteps

The play sessions of the pilot study were observed and analyzed. In this analysis we observed how children interpreted the provided design and interactions and how they used this in play. Further more we used these findings to further develop our

Fig. 8. Children playing with GlowSteps during the pilot study.

Table 1
Description of the two interaction behaviors for GlowSteps, as used in the pilot study.

Description of interaction behavior ‘Catch (V3)’: ‘Catch’ is an interaction in which a blue light attracts players by moving around from one GlowStep to a randomly selected other GlowStep. The players can catch the moving light by stepping on a GlowStep while it is lit. The GlowSteps will provide feedback (light flash in bright white) to show a player caught the light. When a blue light is caught, it will turn to green, and moves to a randomly selected other GlowStep. The green light moves a bit faster than the blue light, providing more challenge for the players. If the green light is caught, it turns yellow, and again the speed of movement is increased. Subsequently, if players catching a yellow light, either one or two new yellow lights appear, based on chance. If a player step on an inactive GlowStep, this GlowStep lights up in red, until the player releases it.

Description of interaction behavior ‘Create’: In the basic state of the create interaction all lights twinkle in a blue color. When a GlowStep is touched it will show four colors one after the other in bright lights (red, yellow, green and blue). After this a random color is selected. When the player releases the GlowStep the active color will stay on for a moment, and then it slowly fades out. When the light has faded out, the GlowStep switches back to the twinkling blue state. When players move from one GlowStep to another in a rhythmic pace, they might be able to create a trail in one color. Once in a while a random GlowStep lights up and fades out, in a random color. This happens when no players interact for a certain amount of time with the tiles.

Table 2
Summary of observations and provided insights of the pilot study with GlowSteps, and described by using the layers of IMO.

	Design perspective Designed mechanics	Play perspective User defined mechanics	Notes on emergence and progression (provided insights)
Observations with interaction behavior ‘Catch (V3)’	A GlowStep lights up in blue, creating a new state in S. the formal rules F describe that the light will turn off again after a few seconds, unless it is touched by a user. A random other step will turn to the state ‘blue light’	A player can run and try to ‘catch’ the blue light. Behavior of the players showed that they ran towards the blue lights. The players interpreted F and S of the design and used them as rules in play F' and S'	The blue light appears to be moving over GlowSteps. This is an example of designed progression. Children use this progression in their game play. The moving light provides a logical sequence of events that acts as a structure for the game they defined. The origin of this structure lies in the construction of the designed mechanics of the rules F and the state space S, which creates the moving light behavior
	If a player touches GlowStep in the state ‘blue light on’, the formal rules describe that the GlowStep should blink (another state in S) and a random other GlowStep will switch on in green (again another state in S)	If a player steps on the blue light on time, he/she ‘caught’ it! Sometimes the children reacted by yelling ‘yes!’ or ‘I caught the light!’ They reacted more engaged on the new colors	The progression of the moving light triggered a reaction by the children, as they continued to the catch the lights. It appears the changing colors and speed of movement made the children even more challenged. The new colors and the different speed is another example of *designed progression*. The fact that catching a light resulted in a new color, created a notion of development (Although we noticed this was not always noted by all children as cause and effect)
		New rules were added, which created new states for players: being the first to catch the light. This is an example of players adding rules to F' which resulted in an enlargement of the State space S'	An example of rules added by the children is the fact that children had to be the first to catch the light. This provided another mechanism of progression, the goal of being *the first* to catch the lights. This is an example of *user-defined progression*
			The Designed interactions had a fairly repetitive cycle of a few events. It does not diverge (evolve) into many different interactions. From this point of view we can conclude that the ‘catch’ interaction does support *inner emergence* only to a limited extent
	If a player steps on GlowStep that is in the ‘neutral state’ (switched off), it lights up in red (red state). by doing so, the step enters a ‘blocked state’ which means it is no longer available for other states (blue and green) until the player releases the step	The formal rules used during play, were different than the designed rules: The players added rules and states: the players could be ‘in the game’ and ‘out of the game’, depending on if a player stepped on the red light	The fact that the children added rules, and enriched the play situation by adding a factor of challenge and competition is an example of *outer emergence*. This refers to the fact that the game play is shaped around the given designed mechanics. The user-defined mechanics includes new rules to enrich the play situation
Observations with interaction behavior ‘Create’	All GlowSteps show a soft blue light in the ‘neutral state’, if they are untouched. The rules F describe: if a player steps on a GlowStep, it switches through four states in a predefined speed and order. In each of those states the GlowStep shows bright colored lights (red, yellow, green and blue). If a player released GlowStep in one of those colored states, the GlowStep enters a fading state, in which the light slowly fades, and GlowStep goes back to the ‘neutral state’	The players discovered that stepping on a GlowStep made it change to a bright color. The players interpreted F and S of the design and used them as rules in play F' and S'. Players explored how they could influence the colors	The Create interaction has a fairly limited set of interactions in the designed mechanics. The *designed progression* in the system is very limited. Every GlowStep can jump through a few states in S before it ends up in the ‘neutral state’ there is practically no progression in this behavior. The designed mechanics subsequently do not support *inner emergence* for the same reason
		In another example GlowStep were relocated and formed hopscotch pathways on which children tried to jump trails of colors. This is an example of the user-defined mechanics; the rule F' and state space S' are enriched by behavioral rules for the players: copying the trail of colors from each other	In this example of play however, children used the fairly simple designed mechanics to explore and build their own games. An example is the hopscotch pathway. The steps were relocated and rules were added in which the children’s social behavior (copying and comparing results) became an important factor of play. (Which connects to *outer emergence*; enlarging the states pace S' and rules F' to create more opportunities for play). This shows that players can enrich even designs with a small designed progression and inner emergence as such the used defined progression is larger. That is what points out *outer emergence*
	In this example the states S and transition rules F stayed unchanged. Just the ‘Create’ interaction was used	The children imagined one of them being a ‘sleeping dragon’. The dragon was sleeping on a row of five GlowSteps. If the dragon woke up, all other players were not allowed to move. The interactions of the GlowSteps were not used in this game, except those from the ‘sleeping dragon’. The child that lay down sometimes moved to make the lights switch on, and used this as stimuli to start acting out that he/she was waking up	The children added context and rules to their play that was barely connected to the actual designed mechanics. This showed that the user-defined mechanics (F' and S') had very little overlap with the designed mechanics (F and S). The children created a setting in which they mainly used *user defined progression*. This example of play showed *outer emergence* to be a valuable drive (motivation) in the development of play
			However, this rich example of play barely involved the designed mechanics of the system. Play is nearly disconnected from the provided designed interaction opportunities of the system

insights on progression and emergence. The IMO model was used during this analysis. By connecting design properties and observations to the different layers of the model, different aspects of the design and play development were separated.

In Table 2 we summarized initial findings from the user studies. Only the most relevant steps were included. In the table we summarized aspects of the designed mechanics (perspective of the design), and user defined mechanics and resulting play (play perspective). Furthermore we summarized how those events provided us with insights on progression and emergence.

5.3. Reflection

From the analysis of the play sessions with 'Catch' and 'Create' we learned that the IMO model helped us to better identify how properties of the design lead to development of play, then when we tried to interpret the behavior without the model. The formalized description helped us to define in more detail how the *designed mechanics* can be analyzed in states-spaces (S) and rules (F), how users interpret those rules and how the freedom of open-endedness creates an opening to change and add rules. For example (see Table 2, first row) in our observations of "Catch v3" we noticed the interpreted F and S as the children ran for the blue light and tried to catch it. In this example F' and S' matched F and S. In the second observations (see Table 2, second and third row) we noticed how the children added rules and thereby they enlarged F' and S', while they still used F and S. From this we learned how designed progression originates from the construction of the designed mechanics (F and S) and, subsequently, how user-defined progression originates from the user-defined mechanics (F' and S'). Furthermore we learned that inner emergence develops from the interpreted rules of the designed mechanics (the user interpretation of F and S) while outer emergence originates from the rules added by users to enrich play (added to F' and S'). For example (see Table 2, third and fourth row) catch interaction shows little inner emergence, while the additions of users to created outer emergence.

We learned when designing for richness in play with interactive systems, the system should create a balance in the different types of progression and emergence. Less designed progression and options for inner emergence, may motivate children into creating their own game play without use of the design. For example (see Table 2, last row) in the 'sleeping dragon game' the children developed a game with user-defined progression with resulting outer emergence. In this situation F' and S' developed nearly completely outside the scoop of F and S. In this situation it might become more difficult to provide elements of progression with the design to support the richness in play effectively (for example in terms of designed mechanics). Additionally, too much options and designed opportunities for play do create a chaotic environment for players. In this case children might again create user-defined mechanics that is less connected to the actual designs mechanics. The design should provide just enough designed progression and inner emergence, to keep the players connected to the designed mechanics, without limiting their freedom to enrich play.

6. Discussion and conclusion

The aim of this paper has been to provide a novel contribution to understanding how to design for (digital) open-ended play applications. Our contribution consists of an *Integrated Model for designing for Open-ended play* (IMO) to explore the relationships between the designed properties of an open-ended play environment and the resulting play dynamics in a structured way. The presented model provides a structure to *analyze* the relationship between interaction opportunities and self-created rules in play and the resulting play dynamics. IMO is based on game design literature, and provides a novel approach to analyzing designs for open-ended play. With help of observations and evaluations of children playing with an open-ended play design, we illustrated how IMO can be used as an analytical tool to clarify the link between the designed playful interactions and the actual game play.

We expect the provided knowledge presented in this paper adds a new tool to the game design research field, which can support designers of play environments or other applications for open-ended play. Using the different layers of the model, designers can analyze in a structured way. By making a link between the dynamics of play to the actual designed mechanics clear, the designer can work more consciously towards the intended design goal.

IMO, as shown in Fig. 7, combines and extends two approaches to define designs for open-ended play. The first approach is an extended version of the MDA model [14]. It provides a generic structure to analyze designs for play. To make the MDA model [14] usable to analyze open-ended play designs, the original mechanics layer of the MDA model is separated into designed mechanics and user-defined mechanics. The second approach of IMO is a more formalized description of the system for play, based on the work of Grünvogel [15]. In this part of IMO, a formalized description of the designed interaction opportunities is separated from a description of how players defined the actual game during play. The formalized model uses states and state transition rules as a base for a more systematical description of the system for play. Both the generalized and the formal approach of the model are aligned, which creates two perspectives: the perspective of design and the perspective of play. These two perspectives can help the designer to distinguish between the properties of the design, and how the properties are used in a situation of play.

With this model we are better able to explain how emergence and progression in (digital) playful applications develop, especially in open-ended play. While developing the model, and by use of the model in analyzing some of our observations, we are able to identify different origins for both emergence and progression:

1. *Designed progression* is the progressive aspect of the designed system; the fact the system does provide structure for players, as a base for the development of play.
2. *User-defined progression* originates from the play dynamics, defined by players.
3. *Outer emergence* explains the fact that the play dynamics changes because new rules and goals emerge during play.
4. *Inner emergence* is focused on how the designed system provides a base for rules and goals for players, and how interpretations of those rules can lead to a larger dynamics of play.

The work presented in this paper mainly aims at using IMO as a descriptive tool, to analyze the design and resulting play. Although this work contains only a brief exploration on this matter, we believe this is a first step in improving design knowledge on designing interactive systems for open-ended play. Future work is needed to explore the use of IMO and to address its prescriptive use in the design process.

In our earlier work [9] we have stated that we could design for richness by using the feedback of the player actions to the system. We are currently developing new interactions for future research in which we used the gained knowledge, described in this paper. With the presented model and our insights on emergence and progression, we believe we will be able to create designs that support different settings of play, by adapting its behavior accordingly. Elements of inner emergence and designed progression can be designed as such they support play, and create freedom for players to enlarge rule sets and create user defined progression and outer emergence. For example: in one of the interactions we are currently developing, we provide two types of interaction behaviors. The first interaction type is proactive and has a challenging nature by providing moving lights and sounds, and time related effects. The second interaction type is more slow, reactive and expressive in colors and sounds. The two are integrated in one system and can gradually adapt from one behavior towards the other. This adaptation process depends on the player's behavior (for example the speed of interactions, or the times a specific interaction is used). These interactions can be designed by using the formalized description and the two perspectives of IMO. We belief this approach can lead to a design in which we balance the progression and emergence, and create more verity in settings of play and outer emergence *by use of* the systems interactions. In future work we will elaborate on how to shape the adaptation process and how richness may be supported by the design, using IMO.

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