SOLVING THE SIMULATION PARADOX – HOW EDUCATIONAL GAMES CAN SUPPORT RESEARCH EFFORTS

Christian K. Karl
University of Duisburg-Essen
christian.karl@uni-due.de

ABSTRACT

On the one hand, an educational game represents a realistic, experience-based teaching and learning method which aims at the gaining of insights through the experiencing - mostly in teams - of conflict- and problem-based situations. On the other hand, on condition that the displayed excerpt of reality is sufficiently detailed, an educational game can equally be a (supportive) research method, which - especially with the included time-lapse function - can achieve knowledge gains especially from the decisions and their resulting actions of the involved individuals and groups. The aim of this paper is to give a short introduction into a synergistic modeling approach to solve a disruptive effect, named by the author as simulation paradox. This describes the active influence through communicating the results of a data analysis after a simulation, which possibly leads to an adjusted behavior of the simulated individuals in reality and will potentially affect decision focused simulation studies negatively.

Within this paper, a clear linguistic distinction between the terms simulation and educational game is essential. Already at this point it should be noted that within this paper a simulation and an educational game are not the same.

INTRODUCTION

The terms simulation, educational game and their possible variations are used synonymously in literature and practical application alike (Golombiewski, 1995). To foster the understanding how simulation and educational game are seen in this paper a clear linguistic distinction is essential. Therefore it appears necessary to inspect these terms and define them for further handling in the paper. Hence these terms are to be considered further and need to be put in a context and relation to each other. As the concept of a model is the central item of this paper, it is necessary to discuss it in more detail, first.

The term model is ambiguous (Giesen & Schmid, 1976) and is used frequently as well as with multiple meanings (Harbordt, 1974). In general, every emulation of an original can be labeled a model (Dörner, 1984). Models serve the purpose of cognitive insight (pragmatic function) on the one hand and inform about certain relations regarding an existing or future original (semantic function) on the other hand (Busse, 1998).

Even though numerous definitions are potentially available, e.g. due to the fact that the term model is exposed to different viewpoints in the domains of engineering, economics, psychology, philosophy and other sciences, models are principally defined by three fundamental features: 1) the visual representation, 2) the reduction and 3) the pragmatic feature (A more detailed discussion about the background of the term model can be found in Stoff (1969) and Stachowiak (1973)).

Regarding the visual representation, it can be stated that models are always representations of natural or artificial originals (Stachowiak, 1973). Depending on the according purpose of the realization, models therefore are required to be sufficiently similar to the original system (Sauerbier, 1999). Usually models do not comprise all properties of the original they represent (Stachowiak, 1973), as stated by the feature of reduction. This means that less important attributes of the original are omitted by the model designer and the original is thereby narrowed down to typical and relevant influence factors, data, properties, events, information, structures and so on. The pragmatic feature expresses that models cannot always be allocated to an original as it exists in reality, because the model fulfills its substituting function with a limited scope on select theoretical or real operations (Stachowiak, 1973). Consequently, the model can contain elements which are not given in the original.

Salzmann (1976) expands these considerations in regard to educational game models. He added the features accentuation, transparency, intentionality and instrumentality to the educational game model. While the first two of the listed features contain only minor elements of innovation, the feature of intentionality suggests that an educational game model is always developed for a specific aim. This aim can be teaching or education, but also a forecast of the development of future market conduct. The feature of instrumentality includes this consideration. It expresses the idea that each educational game follows an intention or serves a function. Buddensiek et al. (1980) focused especially on the intention of education and training and assigned the following training functions to the models: a) elucidating specific nontransparent structures of an original (structuring function), b) clarifying complex relationships (heuristic function), c) making learning content available which is not accessible in the original (substitute function), d) introducing alternatives to an existing reality (anticipation function), e) questioning an available reality from a real-utopian perspective (function of critique of ideology), f) offering the learner a training possibility for a specific behavior needed in future emergency situations (training function).

Models are structured in themselves by allocating each subject a structured set of potential attributes. Attributes here mean characteristics and properties of individuals, relations between individuals, properties of properties, properties of relations (Stachowiak, 1973). Attributes are linguistically expressed with predicates (Stachowiak, 1973). Hence, abstract statements can be expressed as mathematical functions in models on the basis of attributes respective predicates. As a whole, these statements can form the ground for both simulations and educational games.

Following Sauerbier (1999), a simulation is the execution of calculations in a model, transforming input values into output values. Based on the previously introduced term, the simulation thereby represents an imitation of real processes using mathematical models. Generally stated, a simulation allows to emulate selected events or whole systems in a simplified manner (Wenzel, 2004). Here the primary aim is more to answer questions than to understand processes (Taylor & Walford, 1974). Due to the potentially high degree of complexity (Taylor & Walford, 1974), a simulation is devised to illustrate systems, the relationships and the multiple interdependencies between the included individual elements in detail. This maximum of realism is generally independent of the individuals who use the simulation (Kriz, 2000).

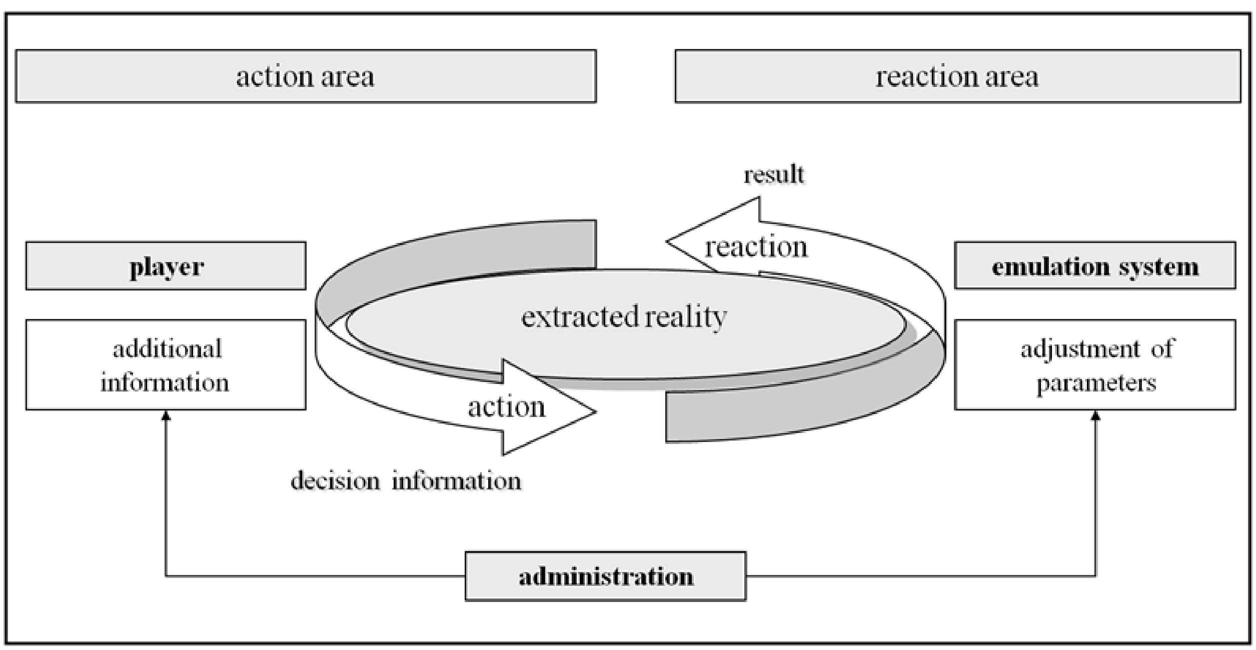
These relationships are also, among other sources, found in the VDI (The Association of German Engineers) guideline "Simulation of logistics, material flow and production systems", in which simulations are understood as the emulation of a system with its dynamic processes in an experimental model to achieve insights which can be transferred to reality (VDI 3633-1, 2010).

Simulations can be classified as follows: a) examination method, b) medium of representation, c) intended purpose and d) transition of state (Page, 1999). In summary, the term simulation describes the precise emulation of a real situation with the aim to gain insights, but without the intention to serve as teaching method directly - in contrast to educational games.

Apart from the term educational game itself, numerous other terms are in existence, e.g. action plan game, management game, business game, educational game, simulation game, planning game, simulation exercise (Steffens, 1972; Rohn, 1964; Bollermann , 1975; Scheitlin, 1975; Kaiser, 1976; John & Walter, 1981; Schmidt, 1988; Manthey, 1990; Anderson & Lawton, 2008). Accordingly, there are equally numerous definitions which, due to their varying background, lead to partly synonymous, partly conflicting perspectives and viewpoints. Nonetheless, it appears to be common understanding that educational games primarily pursue teaching aims.

EXHIBIT 1

FLOW CHART OF AN EDUCATIONAL GAME/ SIMULATION



DIFFERENCES AND SIMILARITIES BETWEEN SIMULATIONS AND EDUCATIONAL GAMES

Comparable to simulations, educational games should also appear as realistic as possible, with the difference that the depicted environment is based on assumptions only (Geuting, 1992; von Fürstenberg, 1993). This hypothetical and virtual world dominantly provides conflict and problem settings in which participants need to prove themselves depending on the specific objective target (Rebmann, 2001). Hence, educational games emphasize the activities and decision taking (Blötz, 2005) and thereby the experiencing of consequences arising out of the decisions and the general conduct of the real persons in charge (Taylor & Walford, 1974). All in all, an educational game is primarily a teaching and learning method which allows participants to gain experience by (collaborative) action in conflict and problem settings within a virtual, but realistically emulated excerpt adopted from reality.

The educational game is supposed to describe learning content, e.g. processes within a marketing oriented corporation. As these are usually highly complex and not easily accessible for noninvolved persons, only selected relevant sections are focused. This modeling follows the principle of isolating abstraction (Kosiol, 1961), in which the relevant section is isolated from the overall concept of reality and intentionally simplified but without altering the significantly influential elements of reality. When developing educational game models, it is important to depict these elements in the right scales and with the correct reciprocal effects. It has to be conveyed to the target group in how far the individual factors affect proceedings and how they influence each other.

The vast range of variation in the existing models offers a remarkable incentive for the participants, because even though certain rules set a firm framework, the participants can navigate and act without constraints within it. Here the aspect of playing a game gains significant meaning. By taking over the position of an entrepreneur, the players enter a competitive situation and confront the other groups of players. Therefore this teaching and learning method has specific advantages, e.g., the advancement of social aptitudes and the pooling of arguments and facts to reach the best possible result (Fortmüller, 2007), examination of the own perspective as well as the improvement of the own decisiveness (Anderson & Lawton, 2008). Several different areas exist within the course of both an educational game and a simulation (fig. Flow chart of an educational game/ simulation). In the following section , the main differences and similarities between educational game and simulation will be described from the varying perspectives within the different areas.

Starting from the perspective of an educational game, the default starting point is the action area, in which every player or each group of players is informed about the initial situation. After the screening of this information, the first round begins. Each round consists of an action phase and a reaction phase. In the action phase, the player groups develop their desired course of action according to the situation at the beginning of each round and communicate their taken decisions to the system, using the available input and command options and facilities (e.g. verbal or written to the administrator/ trainer who will enter the data into the system or directly by the participants into an electronic device). After the decision information has been related to the system, the reaction phase begins. Now the emulation system uses the parameters preconfigured by the game supervisors to evaluate the received player's decision information and delivers the result information back to the players.

From the perspective of a simulation, a common aspect of simulation and educational game is the existence of an action and a reaction area. The decisive difference is the allocation of the two areas. A simulation does not only display the event information in the reaction area, but also (and this is the crucial point) autonomously processes the tasks of the virtual agents in the simulation and generates their decisions based on e.g. historical data, stored expert opinions or probabilities. This means that within the simulation, not only the emulated environment but also the future decisions of the virtual stakeholders have to be modeled during the design process, whereas in the educational game, the decisions will be entered each round through the participants. These relationships make on the one hand, the modeling of decision based simulations difficult, and on the other hand, they also lead to undesired interference.

To sum up: The system of an educational game only

EXHIBIT 2
DIFFERENCES BETWEEN EDUCATIONAL GAME AND SIMULATION

educational game	simulation
main purpose learning	main purpose research
extract of reality to gain experience	exact emulation of reality for knowledge gain
places event information	autonomously processes results and actions
decisions have to be considered and taken by real players	generates decisions independently

places the event information at the disposal of the users, the decisions have to be considered and taken by the real players themselves (action area). The reaction area is mainly influenced by mathematical equations and adjustment of parameters by the administrator. A simulation acts autonomously in both areas. It simulates the decisions of the virtual agents as well as calculates the results almost completely independent (If the administrator does not perform parameter changes in the system at discrete times during the simulation process.).

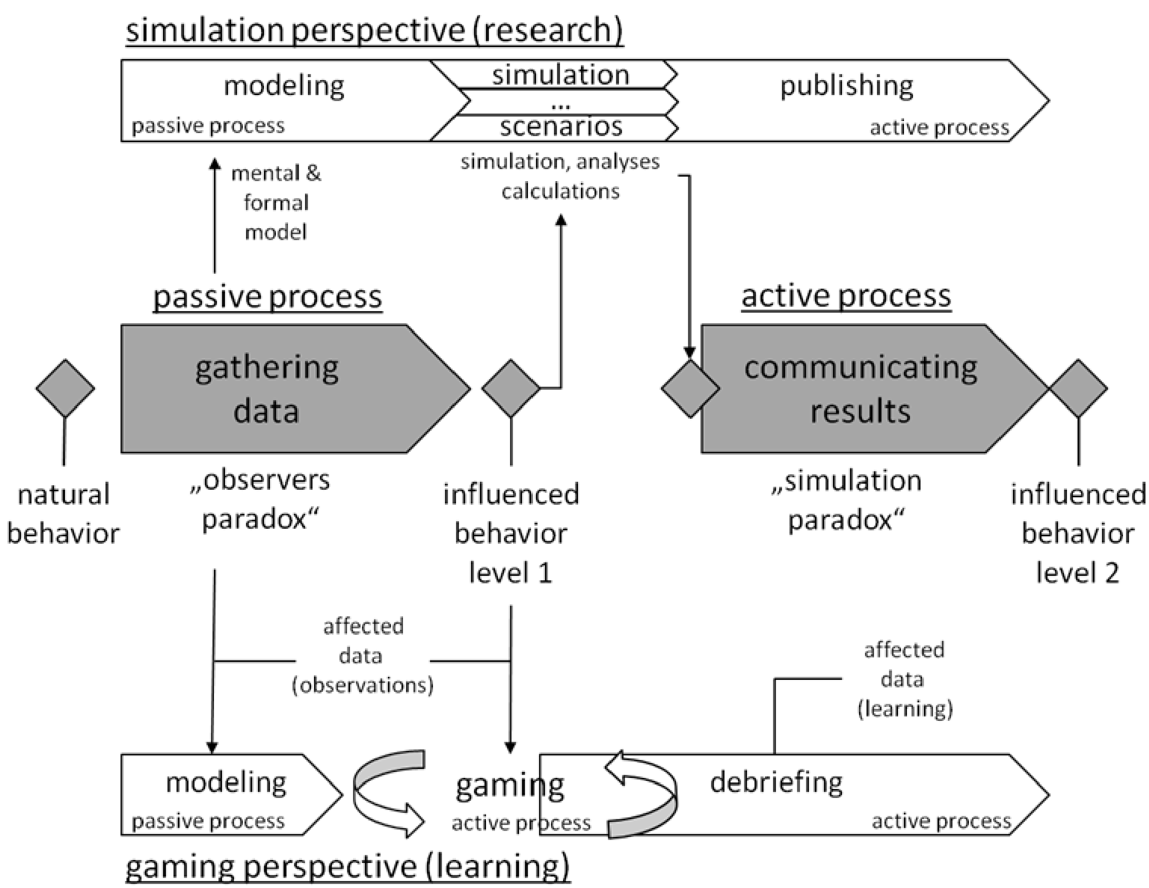
THE SIMULATION PARADOX

The theories and the assumed interdependencies on which a model is based are valid until the derived hypotheses and findings are empirically refuted (Picot et al., 2008).

Hence a model is only valid until the gained hypotheses and insights are proven on empirical basis. This means that the gained results do not necessarily have to be true, whether due to analytical, formal or fact-based logic relationships. Both the units deemed relevant for the model and the links among these are subject to assumptions of at least one individual. Therefore it is true for such models as well, that wrong premises in form of units and/or erroneous deductions in form of links between the units may imply wrong conclusions. Strictly spoken, a model can only be accepted as true after it was definitely verified. Usually this would suggest an empirical study in form of a long-term observation of real relationships and behaviors, the results of which can be juxtaposed to the results of the simulation afterwards.

This logical relation alone offers the basis for a potential disruptive effect, named by the author as simulation paradox. A quite similar phenomenon appears in social sciences, too. The challenge sociolinguists face while doing fieldwork in linguistic research referrers to the so called observer's paradox (Labov, 1972). This paradox deals with the observation of an event or an experiment which is influenced by the presence of the observer or investigator itself. Before the experiment starts (or rather before the subjects knew about the experiment), the observed individuals act unaffected, they will show their natural behavior. However, if the experiment begins it cannot be excluded that the involved subjects adjust their

EXHIBIT 3
PASSIVE AND ACTIVE INFLUENCE OF BEHAVIOR FROM DIFFERENT PERSPECTIVES



behavior. In that case, gathering data is undermined by the researcher's existence. While this paradox influences the phase of gathering data in which the observer takes a passive role, the simulation paradox takes into account the phase thereafter: The active influence through communicating the results of a data analysis after a simulation (fig: Passive and active influence of behavior from different perspectives) which possibly leads to an adjusted behavior of the simulated individuals in reality.

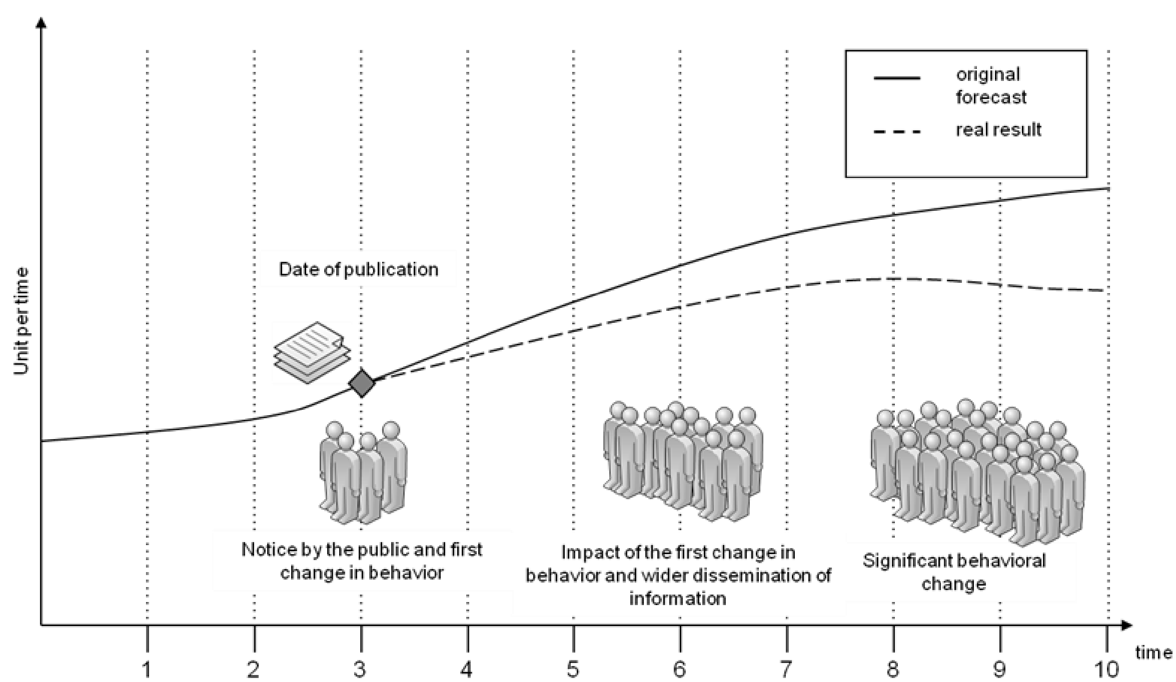
The observer's paradox is not within the focus of this paper; nevertheless it could be a further aspect that should be considered while doing research on human behavior and decision-making, especially in educational gaming and experiential learning. As already introduced, if certain predictions or trends, based on simulation results, are forecasted and published, these can influence the behavior of the otherwise simulated individuals in the real world. In both cases, before and after the publication, the two results might be true. Under this precondition, it may be impossible to verify at the end of an examination or observation period whether the result of the simulation is coherent (and consequently the underlying model of the simulation) or whether it was the publication of the results which intervened and thereby influenced future developments.

The following hypothetical result of a simulation serves as an example: The CO_2 emission is predicted to increase rapidly in the near future (maximum of 10 years) and cause a massive deterioration of the general living conditions for both humans and animals, up to irreparable damage to the nature and environment in the worst case. Provided that this prediction – being of high interest for the masses without any doubt – would be published, this could cause the involved individuals in reality to change their behavior to counter the predicted development (fig: Simulation paradox). In this example, motivations could be manifold, e.g. the urge for self-preservation, interest in nature and environmental protection or other reasons.

The above mentioned example demonstrates how limited the verification or falsification of simulation models can be, even with the help of long-term observations – especially when the simulation is not of a purely technical nature, but dominantly or exclusively dependent on individual decisions. Conversely, it could be stated that valid simulations can basically only be implemented with technical systems, because of the fact, that human behavior and decision making plays no role in it. Similarly strict is the conclusion to prevent a publication of the simulation results in any case to counter just this effect of the simulation paradox. Both ideas appear logical, but lack feasibility due to their radical nature.

More importantly, simulation models need to be supplied with updated data continuously, especially when they depict the behavior as well as the decisions of individuals and comprise a long-term period of observation. This way it could be ensured that potential changes of behavior in the real world have access to the model. Beyond that, however, a verification or falsification of the simulation model would generally not be possible before the end of the planned period of observation. This point shows the decisive advantage of the link between simulation and educational game, which can be

EXHIBIT 4
SIMULATION PARADOX



accomplished through a method introduced in the following.

SYNERGISTIC MODELING

The reasonable and meaningful combination of simulation and educational game requires a more differentiated consideration of the main aspects which both concepts have in common. The synonymous use of the terms simulation and educational game may partly be traced back to different reasons. One general reason could be based on the acceptance of gaming as a serious scientific area of research. It seems that research under the name of "simulation" lead to higher recognition instead under the term “game”. Another reason could be, that authors i.e. Geilhardt (1995) stated, that an educational game always includes a simulation.

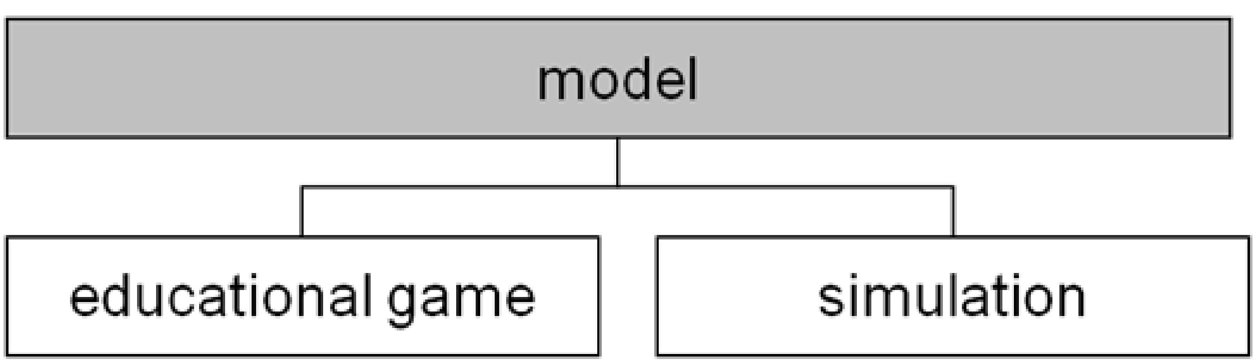
This general statement requires closer inspection: indeed, an educational game always includes a certain kind of simulation. This, however, is not due to an exact emulation of reality, but more because of a model which has been adapted to the educational game purposes and thereby allows to depict a specifically chosen extract of reality (For a clear distinction: An educational game emulates a relevant part of reality. Only a simulation – in the sense defined before – simulates.). According to Gehring (1992), the relationship of model and simulation is the following: the simulation illustrates processes of real systems in a model. Therefore the model, which can either be employed in a comprehensive or reduced form, is generally to be seen as integral part both of simulation and educational game (fig:Relationship between simulation and business simulation). Therefore, Geilhardt's statement needs to be clarified: Both a simulation and an educational game are based on a dedicated model. Therefore, the modeling claims a central position both in the conceptualization of simulations as well as educational games.

If, ideally, a game has been established in parallel to the simulation and is based on the mainly identical model, the time-lapse function of the game can help to form an empirical basis from the behaviors and decisions of the participants. A thorough analysis of the decisions made in the game form an empirical basis to assist in a first verification resp. falsification of the model. Hence, a falsification based on these premises can help to improve the quality of the simulation model as a whole but without the need to monitor the whole period of observation in real time. Further, debriefings at various points of time during the game will encourage the participants to reflect their decisions through the resulting consequences. This situation could be compared with the active communication of simulation results and the following change in behavior after a (longer) period of time. When the game is prepared accordingly, it will be possible to investigate the behavioral changes in more detail as if it were possible with the sole simulation – and that in a shorter time. It should be apparent, that the synergies from the combination consisting of simulation and educational game lead to many benefits. To make these benefits available, a common modeling process appears as a useful idea.

Such a synergistic modeling process (fig: Synergistic modeling process), in which one common model will serve for both a simulation and an educational game, can be supported by a joint predetermined entity library (For the needs of construction industry a fundamental modeling library based on the principles of system dynamics has been developed by the author. For details please refer to Karl, 2014). This library consists of a predefined set of entities including attributes as characterizing features and relationships between different properties; mainly expressed as mathematical functions. Using such a modeling library has many advantages.

This approach unites valuable expertise of two different and mainly solely operating scientific communities: Simulators and Gamers. Because of the fact, that both simulation designers and game designers will use entities out of the aforementioned joint predefined modeling library, knowledge synergies are created which enable the interdisciplinary development of simulations and educational games in the sense of a method which can be named synergistic knowledge absorption (abbr. SKA). Furthermore, predetermined entity libraries can be easily

EXHIBIT 5
RELATIONSHIP BETWEEN SIMULATION AND EDUCATIONAL GAME



integrated in existing frameworks for the development of educational games (i.e. Lynch & Tunstall, 2008; Karl, 2012).

CONCLUSION

The aim of this paper was a short introduction into the difference between educational game and simulation and how the combination of both could solve the simulation paradox through a synergistic modeling approach which can be used both in modeling simulations and educational games.

In the area of educational games, the introduced synergistic modeling approach and therefore the connection to simulations enable the application to explore and research human behavior – in addition to the classic use of a teaching and learning method.

Through this approach, multidisciplinary R&D teams of scientists from different domains have the chance to develop models from varying perspectives in both scientific communities. The approach introduced here can provide a valuable contribution to promote further developments. Additionally, it allows to tap the potential of the educational game method much more than before.

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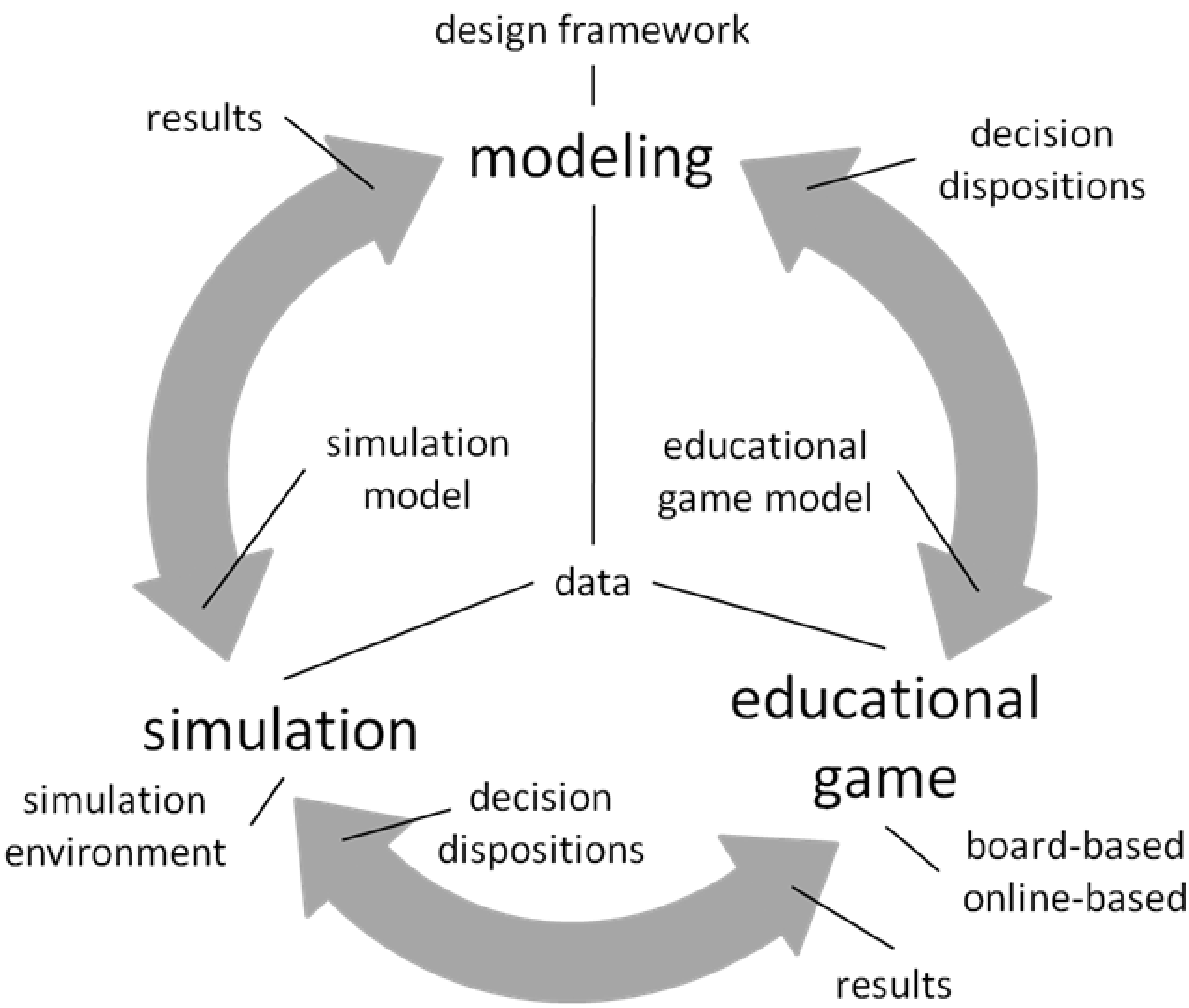
EXHIBIT 6
THE SYNERGISTIC MODELING APPROACH



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