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POSITIONING GAME SCIENCE FOR GAMING AND SIMULATION: A REFLECTION ON THE RESEARCH PHILOSOPHICAL UNDERPINNINGS

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ABSTRACT

This article provides an integrated epistemological and ontological frame of reference for scholars and practitioners in the field of gaming and simulation. This frame lies the foundation for an advancement in the field by developing a definition of game science. The article defines what games are (artifacts consisting of rules, roles, and resources), how they contribute to knowledge creation ('knowing' as doing) and how they connect the analytical and design sciences. Gaming and simulation are means to understand and design complex realities and therefore are an important means for actors to deal with the complexities of our world. However, we experience a stagnation of the science level in our discipline in a fast-moving world. To enable future and emerging gaming and simulation researchers to practice game science in a rigorous way, we have formulated statements and used an existing science framework to define game science as discipline.

1 INTRODUCTION

Since the 1950s, *gaming and simulation* as method of research and design have successfully evolved in many fields of application, which eventually have established their own research communities. *Gaming and simulation* as a term includes all notions of including humans in the act of a simulation through a playful, engaging interaction. At the instrumental, practical level the method has made tremendous progress in dealing with complex and uncertain, dynamic issues. Within the simulation community, the interaction of humans and (computerised) simulation models of sociotechnical and complex systems consists of different methods like gaming simulation, human-in-the-loop simulation, interactive and hybrid simulation and immersive methods. Tracks for these methods have been part of WinterSim over the past years.

This paper is born from the observation that young researchers successfully start using gaming and simulation and publish on their case-specific findings and on the method but tend to stagnate in academic development towards more senior positions and in establishing stronger theoretical reflection towards the method. This is a problem for the growth and sustainability of the field of *gaming and simulation*. There is still unclarity about what this field means as a science, here following the definition of Merriam-Webbster: "*…a system of knowledge covering general truths or the operation of general laws especially as obtained and tested through scientific method."* In this paper, we approach the 'system of knowledge' of *simulation and gaming* as consisting of Ontology, Epistomology, Theory and Methodology. This way, we provide a research philosophical underpinning for the development of *game science*.

Simulation games, human-in-the-loop simulations, interactive simulations, gaming simulations and games and/or simulations are words used to address a special case of games. In this publication, we do not address special cases, however limit ourselves to the tradition in simulation and gaming. Therefore, in the context of game science, we will use "game(s)"as the most generic term and focus on the related methodological issues (see Klabbers 2009b).

From a historical perspective, game science is evolving through varying foci of interest. More recently, understanding systems and complexity has gained influence (Bekebrede et al. 2015; Klabbers 2009a (chpt. 4); Meijer et al. 2023). The development of game science as embodied in the ISAGA (International Simulation and Gaming Association) community has remained remarkably constant over time, while more recently several developments such as gaming in formal teaching and gamification (Aldrich 2009; Bekebrede et al. 2011; de Castell & Jenson 2007; De Gloria et al. 2014; Egenfeldt-Nielsen et al. 2011; Hallifax et al. 2019; Squire 2003; Swacha 2021; Zhonggen 2019) have emerged, with representatives forming their own communities over time, such as the Higher Education Video Game Alliance (HEVGA) or the Games and Learning Association (GALA).

The *gaming and simulation* community mostly deals with the design and analysis of games in relation to complex systems and their uncertain and dynamic nature (Lukosch et al. 2018; Olejniczak et al. 2020). In the typology of Ståhl (1983), the field deals with the types of games that are called experimental games (testing hypotheses), research games (obtaining empirical material), and operational games (aiding decision-making). On the periphery of gaming and simulation we find educational games (with long-term learning benefits), dependent on the learning goal (e.g., if it is a skill or knowledge related to complex systems). Training games and assessments are excluded from the scope of this paper, as they presuppose an outcome that can be predicted and pre-defined objectives of what learners have to learn (Leigh & Spindler 2004; Peters & Vissers 2004).

Scholars in the field of gaming and simulation come from a wide array of disciplines, from engineering to social sciences, from management to architecture. This often leads to a multidisciplinary perspective in which fields overlap and comply to the complex reality the gaming simulations are aimed at. This variety poses one challenge to the field - an agreement on common epistemology, and a frame of reference for simulation and gaming methodology is missing. “Game scholars talk past each other precisely because we do not explicitly state our foundational assumptions” (Stenros, 2017:500).

2 CURRENT UNDERSTANDING OF GAME SCIENCE

Through presenting and discussing a set of five interlinked statements in the following, we aim to synthesize the different traditions and perspectives on game science in gaming and simulation, as precursor to an ontological and epistemological positioning. The statements were developed by a Special Interest Group from the ISAGA community. The SIG members were recruited through an open invitation, and a stable core group of senior researchers in the field of gaming and simulation remained after the first iteration. The statement generation processes followed 3 steps: generation of statements by the SIG members, a collective structuring of the long list of statements into theory-supported and distinct statements, and then a substantiation and specification of each statement through a collective, serial writing process. In total, 5 statements have been developed that passed the collegial review of being distinct and in line with current insights as well as dealing with the philosophical underpinnings of simulation and gaming as a science.

2.1 Statement 1: Games Consist of Interconnected Actors, Rules and Resources.

Interconnected actors, rules, and resources constitute the generic structure of simulation games (Abt 1970; Avedon & Sutton-Smith 1971; Klabbers 2006; Salen Tekinbas & Zimmerman 2003; Suits 1978). This definition, applying to single actor- as well as to n-actor configurations, presents games as *forms-of-play*. The actors express the play element, while the rules and resources represent the game element. Together, actors, rules, and resources define the form of play. A game is only a game, if being played (Ståhl 1983). The process of play is vital to the understanding of simulation and game science (Myers 1999).

Explanatory remarks: **Actors** in games have agency (Nguyen 2020; Tanenbaum & Tanenbaum 2009). Dependent on the level of aggregation, in games they can be individuals, groups, institutions etc. Guided by rules (laws, customs), they assume roles, interact with each other, and build social networks resulting in temporary social organizations, and in wider terms, social infrastructures. Game science needs to make a distinction between player and participant – in the sense of Myers (2003), requiring emotional engagement to enjoy winning.

Rules are the guiding principles, defining how the actors intervene with the resources. The rules and (perceived) constraints of the game structure players' behavior (Aarseth 2007), which consists of actions and strategies. The game tells the players to take up and pursue a defined goal, and needs to differentiate between the goals of the game and the players' purpose in playing it (Nguyen 2020). Or, in other words: "Playing a [simulation] game is the voluntary attempt to overcome unnecessary obstacles" (Suits 1978) while the goal can be learning for participants, researchers and other actors involved. Rules can also work at different levels of groups and between groups and can be both explicit and tacit.

Resources or objects refer to the physical and technological infrastructure (eco-systems included). In game science, a range of media of representation is in use to map the resources. For example, analog game boards, digital models running on computers, gross anatomy atlases, scale models, and other representations are used (Klabbers 2018; Klabbers 2009a). The instruments and game mechanics applied should be dependent on the goals of the simulation game, and the context of its use.

Practical implications: We recommend that studies in the game science domain include Actors, Rules and Resources in their game description, to create a generically recognizable structure to the methods section.

2.2 Statement 2: Games Have a Meaning, Expressed in Constructs

Games represent cognitive (related to mental processes) and conative (related to intended actions) constructs and are therefore most appropriate for the study of human action in a social or societal context. Even those with only one player or actor refer to a social context, as actors do not operate in a social vacuum (Klabbers 2009a). Such games foster the development of identity when the learner transforms into a member of a community of practice through play (Lainema 2009). Gaming and simulation allows actors to experience the simulated world and create meaning through social interaction with its cognitive and conative constructs.

Explanatory remarks: Human action in a social or societal context presupposes an action space that allows making choices. Without such an option the artefact – the game - excludes players from the autonomy to decide, becoming a zero-actor simulation instead of a playful learning environment in which players can experience agency.

Games have the specific power to make conventional use of signs and symbols in unconventional ways (Myers 2006). That said, gaming and simulation can be positioned in and act as a representation of a real referent system. The design of simulation games creates valid experiences. However, unconventional, surprising, and even unexpected elements, situations and scenarios can be created combined with such valid experiences that allow players to experience what cannot be experienced in a real-world situation for various reasons (van Lankveld et al. 2017). Knowledge gained via play can contribute to understanding complex social systems behavior. Players should have a certain autonomy to make choices how to react and act within a game. Simulation and gaming remain a simulation of human sign and symbol systems.

Practical implications: To properly understand a game science study, the action space, the meaning of constructs and symbols used needs to be documented. Given that players co-create meaning, a game science study needs to describe the combination of game and players to be scientifically valuable.

2.3 Statement 3: Play Happens in Games

Games enable forms of play, and in game science, numerous forms of play exist. Play is an activity that is desired and enjoyed for its own sake. *Play* is subjectively grounded in the player, while *game* is objectively grounded in the game rules and resources. Therefore, in practice both terms are intertwined in the term *playful gaming* (Klabbers 2009b).

Explanatory remarks: Games, as playful activities, find utility across various contexts and demographics. Altering the setting of a game doesn't necessarily alter its design, rules, or structure.

However, the context can profoundly shift the interpretation and significance of the play itself. Playfulness primarily stems from the mindset of the players rather than solely from the game's design, although the game can support this mindset (Stenros 2015). If players perceive a social intervention as play, it is play in their minds. The playfulness of rigid-rule games (games with rules that apply equally to all players, whose actions are goal-oriented) is more constrained compared to that of free-form games (that put players in an open situation, allowing for self-organizing learning). Yet, in assuming roles within a free-form simulation game, the actors still have the freedom to interpret the roles, in a way they see fit. If games no longer are played, their form still exists as text and images. However, the rules and resources only receive meaning if the game is being played. Game science needs to address the sometimes-paradoxical distinctions between rules-bound and rules-free systems (Klabbers 1996) because each one renders a completely different type of simulation game environment that has an impact on their potential results.

Practical implications: The act of play is an essential component of game science studies. Play needs to be captured as element of the player's creation of meaning. Further study is needed on how to best capture and design rules-bound and free-form games for scientifically valid studies within game science

2.4 Statement 4: Games Support Both Design Science and Analytical Science

Game science builds upon two distinct approaches: the design and the analytical sciences (Klabbers 2009a). The design science approach focuses on human-action-in-context. Its purpose is changing current situations into more preferred ones. Therefore, the design science approach surpasses (mono)disciplinary approaches, and operates as a meta-discipline, and includes a community of participants. The analytical science approach studies human behavior independent of context. Its goal is to develop and test (mono)disciplinary theories, bringing forward universal knowledge. For that reason, from the perspective of game science, the analytical science approach applies reductionist and functionalist methodologies, bringing together a community of observers.

Explanatory remarks: The distinction between the design and analytical science approaches refers to different methodologies and different criteria of success. In game science research, that distinction is often blurred (Klabbers 2009a, ch.7). Many approaches and studies in the field focus on the instrumentality of games (Lainema 2009), with questions like: *Do they actually confirm an intended effect, how are they experienced?* Keeping the distinction between design and analytical science in mind, game science in its capacity of a meta-science will benefit from their cross-fertilization. We should keep in mind that it is very difficult - often impossible - to validate a game in terms of the analytical science methodology (Klabbers 2009a, ch. 7). Yet, it can be very `usable` from the design science perspective. Both perspectives add value when developing and applying game science and should not be considered in isolation or contradiction, but as complementary set of perspectives (Van den Hoogen & Meijer 2015).

Practical implications: A study within game science can encapsulate goals of both design science and analytical science nature, but we recommend addressing the explicit scientific assumptions of both approaches for each study.

2.5 Statement 5: Games are Succinct Abstractions from the Real-World Reference

If a game is used to intervene in any form in a referent system, for example, to change current situations into more preferred ones, game science makes a distinction between the requirements of two levels of design: design-in-the-small (DIS) – the game design, and design-in-the-large (DIL) – the organizational design (Klabbers 2009a). Although both levels are closely connected, they tap different professional competencies and need active transfer management (Raghothama & Meijer 2018).

Explanatory remarks: game design and organizational design are linked realms, with important interplay. The linkages can take various forms. For example, the outcome of design-in-the-small may be used as input to design-in-the-large. Different knowledge domains are needed for DIS and DIL – e.g. contextual and scientific knowledge to understand the organizational/societal context for DIL, and game design and simulation/modeling knowledge (and experience) for DIS (Lukosch et al. 2018). Furthermore, different methods of analysis are needed for example, to learn about the effects of SG on design-in-the-large, and to experience the usability in a game. For instance, to make a model or representation of a real organization, steps of aggregation and abstraction must be made in DIS and this requires that the game designer knows how certain mechanics generate specific leverages for learning or creating insights at the meta level (Klabbers 2009a; Kriz & Hense 2006). We design to learn, and we learn from the design.

Beyond the players themselves, characters or roles in the game, as well as a game facilitator are crucial to contribute to the social experience of a game. Facilitation both in the form of facilitation design (for instance the design of reflective learning loops throughout the gameplay session) as well as a facilitator with personal traits influence the outcome of the simulation game possibly in a positive and/or negative way (de Wijse-van Heeswijk & Kriz 2023; Leigh & Spindler 2004).

Practical implications: A game in a game science study is, by definition, an abstraction of reality. The way this abstraction is made, both in the design of the game and in the roles and facilitation of the game needs to be documented to increase the scientific rigor of a study. Facilitation is needed to create linkages between the two levels of design related to gaming and simulation.

3 SYNTHESIS: POSITIONING GAME SCIENCE

The SIG members subjected the combination of the statements in the previous section to a review against a series of textbook approaches to the sciences, with the aim to find the best possible fit with current frameworks in the philosophy of science. The statements show both social science and natural science characteristics, as well as analytical and design science perspectives. However, game science includes a particular duality of observers and observing, which cannot be covered by existing knowledge systems. In gaming simulation, multiple communities of observes act – outside observers such as researchers, but also active, 'inside' observers, the players. Both communities contribute to the process and result of play. No currently existing science, like social science, design science, etc., can fully function as a system of knowledge covering general truths or the operation of general laws as obtained and tested through the scientific method of gaming and simulation.

While many frameworks found could explain either the social or the natural science perspective, the number that can bridge both is much more limited, and include Nuijten (2011), and Richter et al (2022), which show that such synthesis between sciences need to be done for a domain. We found Moon and Blackman's "A Guide to Understanding Social Science Research for Natural Scientists" (2014), as the most useful canvas to position game science in the wider scope of the philosophy of science: ontology and epistemology. Their framework needed the fewest adjustments to position game science. We did consider alternative frameworks like Haberlein (1998) and Kline et al (2017) but found these to aim for interdisciplinarity in terms of scientific triangulation and use of social science to enrich the modelling approach in the natural sciences.

3.1 General Observations

Game science has some clear characteristics that distinguish it from the dominant natural and social sciences. For example, games can be designed that fit into almost all theoretical perspectives of Moon and Blackman's Guide. All theories mentioned in the guide can be a basis for game design. However, that notion doesn't tell us much about the essence of game science as it only provides a basis for theoretical development within the case-base gaming which we pointed out in the introduction. It does not accommodate for the dichotomy of outside observer on the one hand and actors within the game and game design on the other. We apply a similar hierarchy as Moon and Blackman, distinguishing four levels: Philosophy of science – covering ontology and epistemology -, a theoretical perspective, and we add a methodological level (Klabbers 2018). We focus on the first three, and do not discuss the methodological level in detail. We have adjusted the guide to make it fit with the requirements of gaming and simulation, see Figure 1. We pose that Figure 1 describes the full stack that constitutes a 'science', and given the argument that the guide in Figure 1 is unlike any other descriptions of already identified sciences, we name this combination of ontological, epistemological, theoretical and methodological stances 'Game Science'.

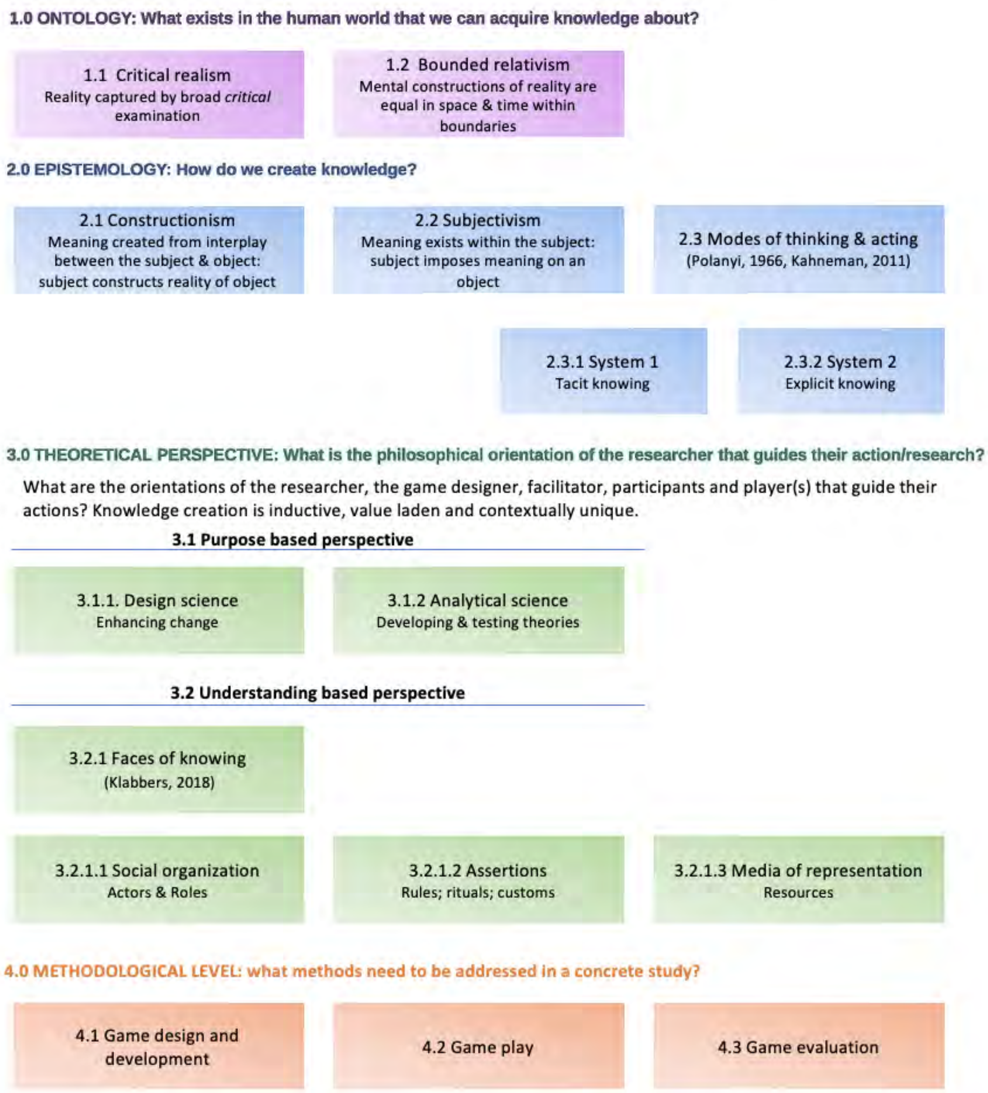

Figure 1: Guide to position Game Science.

Game science is the umbrella that covers the related disciplines, each producing different sorts of knowledge and results. In game science we need to deal with a dual position: the position of the outside observer – the classical researcher – and the position of the inside participant – the player(s) in their capacity of reflecting actors who exercise agency, and the game designers, facilitators and debriefers. Both encompass different realities as they make meaning of reality from different positions. The communities of observers apply analytical science theories and methodologies. Their purpose is to develop and test theories to explain and predict future outcomes. Knowledge creation is deductive, value-free, and generalizable (context free). In game science, simultaneously we need to include knowing-in-action by the players, in a temporary learning community, a process that is inductive, experiential, value-laden and context-dependent (situated). Moreover, we need to include the roles of the designer and facilitator in addressing knowledge creation about what exists in the world.

3.2 Philosophy of Science Level 1: Ontology

We approach the ontological stance of game science with the questions: *What is a game?*, and *What exists in games?* that the players can construct implicit and explicit knowledge about.

"A game is a form of play. It is an activity involving one or more players who assume roles while trying to achieve a goal. Rules determine what the players are permitted to do, or define constraints on allowable actions, which impact on the available resources, and therefore influence the state of the game space. Games deal with well-defined subject matter (content and context)." (Klabbers 2009a, p. 24).

We observe that most approaches to game science recognize that multiple realities exist or are produced within the setting of a game (Klabbers 2009a; Kriz 2010; Kriz & Hense 2006). This aligns with the predominant use of games: to understand and to contribute to changing the inside and outside of complex social systems. This is in stark contrast with studying the behavior of complex natural systems from the outside observer position alone.

Regarding rigid-rule games, critical realism, and bounded relativism are viable ontological options, as the combination of natural science systems in interaction with social systems does not qualify for full relativism, and neither for structural nor naïve realism. The motivation for choosing gaming and simulation, and not choosing a purely quantitative simulation, excludes the naïve realism position from game science.

Free-form games, the players' self-organization of reality via co-constructing situated knowing-in-action, fit well the conditions of bounded relativism. The game designer, the facilitator, and the players may rely on different ontological positions. If this is the case, then it is worthwhile that the facilitator – taking a boundary position between the outside observer and inside participants - will bring their different positions to the surface, because they may cause varying appreciations of the facts, the experiences and lessons learned, especially in the phase of debriefing (Crookall 2014; Kriz 2010).

3.3 Philosophy of Science Level 2: Epistemology

On an epistemological level, we position games along the question: *How can game science create knowledge and enhance knowing-in-actio*n?

Games are artefacts, consisting of linked actors, rules, and resources. From a broader perspective, games encompass the interplay between the social organization and the physical, technological infrastructure of social systems (Klabbers 2018). From an epistemological perspective, those notions align with constructionism: meaning is created from the interplay between the subject & object: subjects constructing the reality of the object. The actors co-construct reality through the interplay with the resources and among each other.

Constructionism conditions constructivism: knowledge creation of the object through (social) constructivism: meaning making of reality is an activity of the subjects, the individual and the group. Care should be taken of stretching the constructivism within the game (DIS) to designing rules or declaring generalised scientific theories outside the game (DIL), as a game is an abstraction of reality in which the abstraction has changed the context from real-world to game context.

In the setting of game science, we need to distinguish between the noun knowledge and the verb knowing as two different ways of knowledge construction (Klabbers 2009a). In this regard, Sfard (1998) referred to the acquisition and participation metaphor. The mind - in the view of the acquisition metaphor - is a mental container of knowledge, and learning is a process of concept development, of filling up that container. Such knowledge is a capacity of the individual mind. It is a process of gaining possession over some commodity. Learning, in this view, is a matter of acquisition, construction, and application of new knowledge in new situations. Knowledge is treated as an integral, self-sufficient substance, theoretically independent of the situations in which it is learned and used (Brown et al. 1989). Brown et al. pointed out that knowledge is situated. Games offer situated learning environments (Kirk & MacPhail 2002). In that context we propose to replace the noun knowledge with the verb knowing, which indicates action.

The acquisition metaphor is strongly entrenched in the rationalist tradition in science. In this tradition, knowledge is composed of abstract, context-independent, formally interconnected domain-specific concepts. Knowledge acquisition tends to be deductive and context independent. The participation or interaction metaphor tends to be more inductive, value laden and contextually unique.

The next question to address at the epistemological level is: *How does meaning making happen, which modes of thinking & acting apply?* Referring to Polanyi (1966) and Kahneman (2011), we distinguish two modes of thinking and acting: System 1 (tacit knowing), and System 2 (explicit knowledge). As pointed out by Klabbers (2009a Figure 3.3), tacit knowing is embodied, stays in the background and is 'silent'. However, while being subjective, and difficult to explicate, tacit knowledge is important for actions, decisions, and strategies to be transferred from a gaming simulation into the real world (van Haaften et al., 2021). Explicit knowledge on the other hand is in the focus of attention. Players simultaneously use System 1 & 2. The personal knowledge of the players combines and integrates both systems.

These understandings at the epistemological level have serious consequences for the science and the application or practical level. Regarding the science level, System 1 (tacit knowing) is to a certain extent not fully observable. Yet at the practical level, System 1 plays a vital role in gameplay, in the embodied gaming experience, and in figuring out the meaning of the game. This has widespread ramifications for the analytical science branch of game science, for developing and testing theories, and for validating games. The analytical science branch overwhelmingly limits its scope to System 2, focusing on explicit, conceptual knowledge. Regarding the design science branch of game science, facilitating, and especially debriefing games becomes crucial for the success of game sessions (Meijer 2009; Van den Hoogen & Meijer 2015). The DIS/DIL loop, offers adequate opportunities for dealing with the combined impact of System 1 and 2.

3.4 Level 3: Theoretical level

These views on the ontology and epistemology condition the science level of game science, and pose the question: *What are the orientations of the researcher, the game designer, facilitator, and player(s) that guide their actions?* To better understand the ramifications of theorizing in game science, we first pay attention to a well-known game theory, exploring the scope of both.

3.4.1 Characteristics of the Mathematical Theory of Games

One area of application within game science concerns the mathematical theory of games (Von Neumann & Morgenstern 1944), commonly known as "game theory". Providing the three-level approach to game science presented here, mathematical theory of games selects a particular form of play that fits into economics reasoning, choosing a typical configuration of actors, rules, and resources. Game theory covers narrowly instrumental views on ontology and epistemology of game science. The mathematical rigor of von Neumann's game theory in essence transmuted humans into mathematical objects, their decisions driven by their self-interests. Clancy (2024, p. 95) argues that von Neumann eventually "abandoned his dream of building an unassailable fortress for mathematics and traded it for the hope of building "synthetic rationality"- now known as artificial intelligence. Nobel Prize winning economist Sen (1977) pointed out that "we would hardly consider this "rational" agent, based on the consistency of their choices, meaningfully intelligent. Intelligent choices don't fall into a single fixed ordering; they depend on context" (In Clancy, 2024, p. 104-105). Game theory presents a so-called zero-actor model (Klabbers, 2009a). A game-theoretic agent is equivalent to a mathematical equation: generating context independent "behavior". In game science, game design and use are based on empirical observations and on rules of correspondence with referent systems. Therefore, most game theoretical games can be transformed into a gaming activity, but only few gaming activities can be transformed into game theoretical studies (Roungas et al. 2019)

3.4.2 Characteristics of the Design Science and Analytical Science Theory of Games

Providing the various orientations of the researcher(s), the game designer, facilitator, and player(s) the question is: *what is driving them?* It is reasonable to assume that they think and act differently regarding the notions about knowledge and knowing, mentioned above. Moreover, we distinguish two purposes of game science; design science: enhancing change and development, and analytical science: developing and testing theories. Both branches benefit from one another and cross-fertilize each other. Knowledge in action (relating to design sciences as in this is what should be done/these processes should be shaped) differs from knowledge on action (Schön 1995; Visser 2010). When putting both knowledge in action and knowledge on action in practice the game functions as tool that opens up realistic meaningful processes connecting theory and action. As pointed out by the statements above, in the design science approach we pay attention to the interplay between design-in-the-small (DIS) and design-in-the-large (DIL) (Klabbers 2009a; 2018).

These viewpoints suggest a preference within the design science branch for the participation/interaction metaphor, whereas the analytical science branch leans toward the acquisition metaphor. Mixing up these epistemological approaches could lead to challenges in creating and assessing knowledge. The design and analytical sciences each employ distinct methodologies and criteria for success. Usability and fidelity serve as criteria for success in the design science branch, while validity and reliability are key in the analytical science branch. Essentially, these differing criteria don't align in principle.

Referring to constructionism, and constructivism, we should ask the question: *Which faces of knowledge and knowing are predominant in game science?* Klabbers (2018; 2009a) integrated the generic structure of games with Barth's (2002) three faces of knowing: social organization: (the composition of actors & roles); assertions (rules; rituals; customs, codes of conduct); and media of representation of the resources, resulting in a holistic view on what types of knowledge are generated within SGs.

3.5 Level 4: Methodology

To enable the gaming and simulation community to position much of the existing work on gaming methods in our identification of game science, we include the methodological level in our guide but limit ourselves to the major components of Game Design and Development, Game Play and Game Evaluation. The authors are aware of the massive body of scientific knowledge that each of these components entails but leave it for future work to deepen the discussion of the link to each of the methods and strands to game science.

4 DISCUSSION

We have adapted Moon and Blackman's Guide to make it fit with the field of gaming and simulation, and thereby define game science, outlined in Figure 1, which allows us to approach game science from multiple positions and with varying purposes, such as:

I. To learn and understand: Social constructivism during gameplay provides possibilities to understand phenomena and processes from the inside rather than the outside alone (Duke, 2014; Geurts et al., 2007; Klabbers, 2009a). Researchers can assume a specific role in game sessions, giving them an opportunity to learn-by-doing and reflect-in-action. They also can take the position of outside observer, focusing on reflection-on-action during the debriefing and assessing/evaluating the outcomes of a game.

II. To anticipate and predict: from a post-positivism viewpoint, games add value because they allow for pre-, process- and post-measurements with an array of different methods, running from observation and data-collection during gameplay to sense-making during the debriefing, to in-depth interviews and surveys after the debriefing. By using dedicated games as research method and applying different evaluation methodologies, related tensions between theory and practice and between DIS and DIL can be brought to the surface. Game science can help to uncover both generic and specific conditions that define how social systems act and move.

III. To emancipate: Particularly the participation metaphor is suitable to enhance emancipation, both during the design process (Ismail et al. 2019; Lukosch et al. 2012) and gameplay. Players learn about the inside working of complex systems and of the influence of their roles. Players recreate those complex systems, while the game – as a form of play - represents a chosen reference system. Especially during the modelling of the game new insights are born, and varying viewpoints may converge into a common understanding. In terms of Duke (1974), they converge into a shared Gestalt of the system involved.

IV. To (de-)construct: Post-modernism applies to unfolding multiple realities, existing in game design and use. Post-modernism deals with indeterminacy, which refers to the open-endedness of processes of change that can be represented in free-form games. Scientific knowledge not only depends on its degree of fit with nature, but also on its correspondence with social constructions of reality (Klabbers 2009a; Klabbers 2018). Those social constructions are being questioned, negotiated, and decided upon, while applying the DIS/DIL approach. It is an ongoing empirical process of deconstructing and constructing games as artefacts.

5 CONCLUSIONS

Game science is based upon the ontology of critical realism and bounded relativism, and the epistemology of constructivism and subjectivism. Meaning is created from the interplay between the subject & the object. Game science creates knowledge and enhances knowing-in-action through games as artefacts, consisting of linked actors, rules, and resources. This aligns with the epistemic position of constructionism, as meaning is created from the interplay between the subject and the object: the subject constructs the reality of the object. The participants co-construct reality through the interplay with each other, and with the resources, however there is a subjectivism stance to this as there is no guarantee that the players construct one (shared) reality, nor that the reality within the game transfers to the real-world reference system

Game science has some clear characteristics that distinguish it from the dominant natural and social sciences. In game science we need to deal with a dual position: the position of the outside observer – the classical researcher position – and the position of the inside participant – the player(s) in their capacity of reflecting actors who exercise agency, as well as the designer, facilitator and debriefer. Both positions encompass different realities as they make meaning of reality from different positions. Unfolding multiple realities are being questioned, negotiated, and decided upon, while applying the DIS/DIL approach. It is an ongoing empirical process of deconstructing and constructing games as artefacts.

Now that game science has been identified, we would encourage authors of scientific studies in gaming and simulation to position their work in the guide on all four levels, and to include ontology and epistemology in the positioning of their work. This would both strengthen the rigor in the field but would also test our guide to game science and could lead to improvements over time, and adjustments when the domain further develops.

REFERENCES

Aarseth, E. 2007. "Doors and Perception: Fiction vs. Simulation in Games' *Intermédialités* 9: 35–44.

Abt, C.C. 1970. *Serious Games*. New York: Viking.

Aldrich, C. 2009. "Virtual Worlds, Simulations, and Games for Education: A Unifying View". *Innovate: Journal of Online Education* 5(5).

Avedon, E. M. and B. Sutton-Smith. 1971. *The Study of Games*. Philadelphia, PA: Wiley

Barth, F. 2002. "An Anthropology of Knowledge". *Current Anthropology* 43(1): 1–18

Bekebrede, G. 2010. *Experience Complexity: A Gaming Approach for Understanding Infrastructure Systems*. Delft: Gildeprint.

Bekebrede, G., J.C. Lo, and H. Lukosch. 2015. "Understanding Complex Systems Through Mental Models and Shared Experiences". *Simulation & Gaming* 46(5): 536–562.

Bekebrede, G., H.J.G. Warmelink and I.S. Mayer. 2011. "Reviewing the Need for Gaming in Education to Accommodate the Next Generation. *Computers & Education* 57(2): 1521–1529.

Brown, J. S., A. Collins and P. Duguid. 1989. "Situated Cognition and the Culture of Learning. *Educational Researcher* 18(1): 32–42.

Clancy, K. 2024. *Playing with Reality: How Games have Shaped our World*. New York: Riverhead Books.

Crookall, D. 2014. "Engaging (in) Gameplay and (in) Debriefing". *Simulation & Gaming* 45(4–5): 416–427.

De Castell, S., and J. Jenson. 2007. "Digital Games for Education: When Meanings Play". *Intermédialités* 9: 113–132.

De Gloria, A., F. Bellotti and R. Berta. 2014. "Serious Games for Education and Training". *Int. Journal of Serious Games* 1(1).

De Wijse-van Heeswijk, M. and W.C. Kriz. 2023. "Design Science Perspective on Formative Evaluation in Simulation Games De Gloria, A., F. Bellotti and R. Berta. 2014. "Serious Games for Education and Training". In *A Generic Approach of Facilitation Applicable to a Broad Variety of Simulation Games*, edited by R. Angelini and M. L. Muniz, 215–251. Cham: Springer International Publishing.

Dubin, D., and J. Jett. 2015. "An Ontological Framework for Describing Games". In *Proceedings of the 15th ACM/IEEE-CS Joint Conference on Digital Libraries*, 165-168, New York: Association for Computing Machinery.

Duke, R. D. 1974. *Gaming: The future's language*. Michigan: SAGE Publications, Inc.

Egenfeldt-Nielsen, S., B. Meyer and B.H. Sørensen. 2011. *Serious Games in Education*. Aarhus:: Aarhus University Press.

Geurts, J. L. A., R.D. Duke and P.A.M. Vermeulen. 2007. "Policy Gaming for Strategy and Change". *Long Range Planning* 40(6): 535–558.

Heberlein, T. A. 1988. "Improving Interdisciplinary Research: Integrating the Social and Natural Sciences". *Society & Natural Resources* 1(1): 5–16.

Hallifax, S., A. Serna, J-C. Marty and E. Lavoué. 2019. "Adaptive Gamification in Education: A Literature Review of Current Trends and Developments". In *Transforming Learning with Meaningful Technologies: 14th European Conference on Technology Enhanced Learning: Proceedings* 14: 294–307. Cham: Springer International Publishing.

Ismail, R., R. Ibrahim and S. Yaacob. 2019. "Participatory Design Method to Unfold Educational Game Design Issues: A Systematic Review of Trends and Outcome". *5th International Conference on Information Management (ICIM)*, 24-27 March 2019, Cambridge, UK, 134–138.

Kahneman, D. 2011. *Thinking, Fast and Slow*. Princeton: Macmillan.

Kirk, D. and A. MacPhail. 2002. "Teaching Games for Understanding and Situated Learning: Rethinking the Bunker-Thorpe Model". *Journal of Teaching in Physical Education* 21(2): 177–192.

Klabbers, J.H.G. 2018. "On the Architecture of Game Science". *Simulation & Gaming* 49(3): 207–245.

Klabbers, J.H.G. 1996. "Problem Framing through Gaming: Learning to Manage Complexity, Uncertainty, and Value Adjustment". *Simulation & Gaming* 27(1): 74–92.

Klabbers, J.H.G. 2006. *The Magic Circle: Principles Of Gaming & Simulation*. Rotterdam: Sense Publishers.

Klabbers, J.H.G. 2009a. *The Magic Circle: Principles Of Gaming & Simulation: 3rd edition*. Rotterdam: Sense Publishers.

Klabbers, J.H.G. 2009b. "Terminological Ambiguity: Game and Simulation". *Simulation & Gaming* 40(4): 446-463.

Kline, J.D., E.M. White, A.P. Fischer, M.M. Steen-Adams, S. Charnley, C.S. Olsen et al. 2017. "Integrating Social Science into Empirical Models of Coupled Human and Natural Systems". *Ecology and Society* 22(3): 25-40.

Kriz, W. C. 2010. "A Systemic-Constructivist Approach to the Facilitation and Debriefing of Simulations and Games". *Simulation & Gaming* 41(5): 663–680.

Kriz, W.C. and J.U. Hense. 2006. "Theory-Oriented Evaluation for the Design of and Research in Gaming and Simulation". *Simulation & Gaming* 37(2): 268–283.

Kurapati, S., H. Lukosch, S. Eckerd, A. Verbraeck and T. Corsi. 2017. "Relating Planner Task Performance for Container Terminal Operations to Multi-Tasking Skills and Personality Type". *Transportation Research Part F: Traffic Psychology* 51: 47–64.

Kurapati, S., H. Lukosch, A. Verbraeck and F.M.T. Brazier. 2015. "Improving Resilience in Intermodal Transport Operations in Seaports: A Gaming Approach". *EURO Journal on Decision Processes* 3(3–4): 375–396.

Lainema, T. 2009. "Perspective Making". *Simulation & Gaming* 40(1): 48–67.

Leigh, E. and L. Spindler. 2004. "Simulations and Games as Chaordic Learning Contexts". *Simulation & Gaming* 35(1): 53–69.

Lukosch, H.K., G. Bekebrede, S. Kurapati and S.G. Lukosch. 2018. "A Scientific Foundation of Simulation Games for the Analysis and Design of Complex Systems". *Simulation & Gaming* 49(3): 279–314.

Lukosch, H.K., T. van Ruijven and A. Verbraeck. 2012. "The Participatory Design of a Simulation Training Game". In *2012 Winter Simulation Conference (WSC)*, 1–11, https://doi.org/10.1109/WSC.2012.6465218.

Mayer, I. S. 2009. "The Gaming of Policy and the Politics of Gaming: A Review". *Simulation & Gaming* 40(6): 825–862.

Meijer, S. 2009. *The Organisation of Transactions: Studying Supply Networks Using Gaming Simulation.* Wageningen: Wageningen Academic Publishers.

Meijer, S. 2015. "The Power of Sponges". *Simulation & Gaming* 46(5): 512–535.

Meijer, S., K. Olejniczak and J. Raghothama. 2023. "Public Policy and Engineering Systems Synergy". In *Handbook of Engineering Systems Design*, 1–24. Cham: Springer International Publishing.

Moon, K. and D. Blackman, 2014. "A Guide to Understanding Social Science Research for Natural Scientists". *Conservation Biology* 28(5): 1167–1177.

Myers, D. 1999. "Simulation, Gaming, and the Simulative". *Simulation & Gaming* 30(4): 482–489.

Myers, D. 2003. "The Nature of Computer Games: Play As Semiosis" *Digital Formations* 16: 1 - 200.

Myers, D. 2006. "Signs, Symbols, Games, and Play". *Games and Culture* 1(1): 47–51.

Nuijten, E. 2011 "Combining Research Styles of the Natural and Social Sciences in Agricultural Research". *NJAS - Wageningen Journal of Life Sciences* 57(3–4): 197-205.

Nguyen, C. T. 2020. *Games*. Oxford :Oxford University Press

Olejniczak, K., K.E. Newcomer and S.A. Meijer. 2020. "Advancing Evaluation Practice With Serious Games". *American Journal of Evaluation* 41(3): 339–366.

Peters, V.A.M. and G.A.N. Vissers. 2004. "A Simple Classification Model for Debriefing Simulation Games". *Simulation & Gaming* 35(1): 70–84.

Polanyi, M. (1966). *The tacit dimension*. New York: Doubleday.

Raghothama, J. and S. Meijer. 2018. "Rigor in Gaming for Design: Conditions for Transfer Between Game and Reality". *Simulation & Gaming* 49(3): 246-262.

Richter I., B.R. Roberts, S.F. Sailley, E. Sullivan, V.V. Cheung, J. Eales et al. 2022. "Building Bridges Between Natural and Social Science Disciplines: A Standardized Methodology to Combine Data on Ecosystem Quality Trends". *Phil. Trans. R. Soc*. B377: 20210487.

Roungas, B., F. Bekius and S. Meijer. 2019. "The Game Between Game Theory and Gaming Simulations: Design Choices". *Simulation & Gaming* 50(2): 180-201.

Salen Tekinbas, K. and E. Zimmerman. 2003. *Rules Of Play: Game Design Fundamentals*. Boston: MIT Press.

Schön, D. A. 1995. "Knowing-In-Action: The New Scholarship Requires a New Epistemology". *Change: The Magazine of Higher Learning* 27(6): 27–34.

Sen, A. 1977. "Rational Fools. A Critique of the Behavioral Foundations of Economic Theory". *Philosophy & Public Affairs* 6(4): 317-44.

Sfard, A. 1998. "On Two Metaphors for Learning and the Dangers of Choosing Just One". *Educational Researcher* 27(2): 4.

Squire, K. 2003. "Video Games in Education". *International Journal Intelligent Games & Simulation* 2(1): 49–62.

Ståhl, I. 1983. *Operational Gaming, an International Approach.* Oxford: Pergamon Press.

Stenros, J. 2015. *Playfulness, Play, and Games: A Constructionist Ludology Approach*. Tampere: Tampere University Press.

Stenros, J. 2017. "The Game Definition Game". *Games and Culture*, 12(6): 499–520.

Suits, B. 1978. *The Grasshopper: Games, Life and Utopia*. Toronto: University of Toronto Press.

Swacha, J. 2021. "State of Research on Gamification in Education: A Bibliometric Survey". *Education Sciences* 11(2): 69.

Tanenbaum, K. and T.J. Tanenbaum. 2009. "Commitment to Meaning: A Reframing of Agency in Games". *Digital Arts and Culture*. https://escholarship.org/uc/item/6f49r74n Accessed 20th April 2025.

Van den Hoogen, J. and S. Meijer, 2015. "Gaming and Simulation for Railway Innovation". *Simulation & Gaming* 46(5): 489–511.

Van Haaften, M.A., I. Lefter, H. Lukosch, O. van Kooten and F. Brazier. 2021. "Do Gaming Simulations Substantiate That We Know More Than We Can Tell?" *Simulation & Gaming* 52(4): 478–500.

Van Lankveld, G., E. Sehic, J.C. Lo and S.A. Meijer. 2017. "Assessing Gaming Simulation Validity for Training Traffic Controllers". *Simulation & Gaming* 48(2): 219–235.

Von Neumann, J. and O. Morgenstern. 1944. *Theory of Games and Economic Behavior*. Princeton: Princeton University Press.

Visser, W. (2010). "Visser: Design as Construction of Representations". *Art + Design & Psychology* 2: 29-43.

Zhonggen, Y. 2019. "A Meta-Analysis of Use of Serious Games in Education over a Decade". *International Journal of Computer Games Technology*, 1: 1–8.

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