Chapter 1
Simulation and Gaming as Instrument for Social Design

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Abstract In gaming, games can be treated as instruments implicitly. However, due to the ambiguous nature of the notions of "game" and "gaming," the academic current of simulation and gaming studies, which has come out within the last 50 years, displays truly extensive and ambiguous polymorphism.

In this chapter, titled "Simulation and Gaming as Tools for Social Design," the author describes the characteristics of problem-solving oriented simulation and gaming, mainly with our social design in the twenty-first century in mind, going back to Richard Duke's arguments of the Gestalt communication. The author also explains the common process structure of gaming techniques. Moreover, also describes gaming as a scientific method, and looks at gaming simulation for social design through comparison with game theory, conflict analysis, and agent-based social simulation, which are operational models of multi-agent systems.

1.1 Introduction

Gaming means "playing a game," which implies treating the game as an implicit instrument. The ambiguous definition of the notion of a "game" is a common topic of discussion in the field of analytical philosophy. While the focus has shifted away from both gaming as a technique and its utility, it has great variety due to varying degrees of instrumentality. Possibly, for this reason, the academic current of simulation and gaming studies, which have emerged within the last 50 years, displays truly extensive and ambiguous variety. In this chapter, simulation and gaming are observed as instruments for social design.

Considering social design as we know it in the twenty-first century, the basic principles of simulation and gaming, especially those directed at problem solving, are described. Also, perceived reality and its shared communication as basic principles are reviewed. Besides, an effort is made to organize gaming techniques from the

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process structure point of view together with a thorough investigation into the peculiar structures of these techniques. Further, perspectives on gaming-simulation for social design are reviewed through studying the relationship between gaming and the traditional scientific method, along with the mutual comparison among game theory, conflict analysis, and agent-based social simulation (ABSS) in contemporary multi-agent systems theory.

The Japanese version of this chapter, titled "Shakai Dezain no Shimureishon to Gemingu (Simulation and Gaming for Social Design)" was published by Kyoritsu Shuppan in 2005. The following sections are a translation of a revised and improved version of the first chapter, which was originally titled "Simulation, Gaming and Social Design."

1.2 Gaming as Instrument

1.2.1 Gestalt Communication

Richard Duke's "Gaming: The Future's Language," published in 1974, outlines the basic principle of gaming as a problem-solving technique (Duke 1974).

Quoting the position of philosopher R. F. Rhyne (1972), Duke argues that one such principle is "to stimulate exploration of the means whereby appreciation of complex wholes may be more quickly and more reliably told to others." Rhyne's position can be summarized in today's world due to the complex interconnectedness of multiple issues, the objects of investigative action among decision makers, and those that help in decision-making can only become more vast and complicated. The methods of knowledge that are required today are those that provide an understanding of the whole, rather than minor details. This is the same for citizens, leaders of the industry, government, and researchers. Traditional empirical methods make it difficult to gain a deep understanding of issues, primarily because of time constraints. Therefore, a novel approach is necessary. Even today, many situations are observed in which the whole cannot be understood if not through aggregation work, such as city censuses.

In this regard, Duke presents a new mode of communication, so-called "multilogue," along with new means for such communication, which he calls "future's language." He includes gaming and simulation in the category of future language, along with maps, videos, 3D models, flowcharts, and operations analysis rooms.

Actual problem situations stem from composite realities. If we take the present condition of metropolitan areas as an example, we will find complex systems within complex systems, and option after option, which leads to a situation that blocks our view and goes beyond our understanding capacity. Whether or not such an environment is difficult to manage, it definitely is complex to an extent that it needs to be managed from various points of view. As a result, people gain a "perceived reality" that is different for every individual, and in order to communicate this reality they need to structure it into concepts. However, the way this structure is formed may vary from person to person. For instance, let us imagine asking a sociologist, an economist, a geographer, a policy scientist, an engineer, and an urban planning specialist for their opinions on the issues that a large city faces over time. The way each of them expresses their views, the major points will most likely vary broadly according to their specialization. The reason is although there is actually only one reality, there are multiple different ways to represent it based on nonidentical perceptions and structures.

When people participate in gaming-simulations that have been appropriately “modeled” on actual problem situations, their perceived realities are intentionally combined at the debriefing stage. Through this process, participants are able to share a closer “Gestalt” as it relates to the problem situation. Duke calls this kind of communication “gestalt communication,” and presents gaming techniques as tools that stimulate the multilogue with this function. The “future’s language” mentioned by him in the book’s subtitle can be interpreted as the language that holds this intention.

1.2.2 Why Now Gaming in Contemporary Information Society?

What then can we demand from gaming considering problem situations in twenty-first-century society from the perspective of social design? The answer is outlined in the six points as follows:

1.2.2.1 A Technique to Understand and Share a Complex Reality as a Whole

In contemporary society, to recognize specific problems, it is essential to understand the problem situations as a whole and to communicate among concerned parties. However, actual problem situations stem from complex realities and might be impossible for people to understand or express at some times. Gaming is a promising instrument to stimulate the gestalt communication required to understand the whole, as has been mentioned by Duke. Visions of the future and “composition” can also be included among the types of realities to be pursued.

Today, the use of a wide variety of digital data such as behavior sensing data has been made available and as new aspects of reality in social systems and urban spaces grow we could probably state that a System of Systems is emerging. However, the situation in which we find ourselves—confronted with a messy reality—has not essentially changed from that of the fields within fields argued by Rhyne.

1.2.2.2 Potential of Gaming Models to Flexibly Convey Reality

By taking advantage of the diversity of "games" that gaming can handle and the flexibility of model representation, it is possible to pursue model representations of problem situations that are desired in problem solving but cannot be adequately described by conventional abstract models that are overly conscious of universality. If the "aim" is well defined, the gaming model is appropriately prepared, and the gaming is conducted in the "context" of the problem situation, then the attempt will be very effective in solving the problem. However, models that are specific to a problem situation often have a significantly narrower scope of application when compared to abstract models. Therefore, in order to use gaming techniques for problem solving, a detailed check of the "problem situation," "context," and "aim" is required. This means that gaming techniques need to be positioned from a broader perspective.

1.2.2.3 Experience-Based Participation Tools—Healthy Relationship Between Civic Values and Social Design Practices

A wealth of prior research works demonstrate that gaming techniques are powerful dialogue tools to stimulate communication through the sharing of simulated experiences. In addition, when sufficiently developed and applied, gaming may turn to be a productive tool for positive participation in public design in the fields of civil society as well. For instance, with a design game aimed at resident participation, it would be both necessary and possible to create a "barrier-free" design that treats everybody—young or old, male or female, abled or disabled—equally.

Arai (1988) calls this a healthy relationship between education and research. In recent years, progress in the practical application of gaming has been accompanied by a tendency to develop a code of practice that relies on the "morality" of group actions and the "spontaneity" of participants.

1.2.2.4 Reality Composition in Information Society Design

Nowadays, as the Internet and other such information technologies continue to progress, active members of society are confronted with an information environment that did not exist in the past. Most likely, this information environment will continue to change in the future. This has a significant influence on the way people organize reality as it relates to actual society. Having this in mind, designing an information environment can be a central issue in social design today.

It is important to point out here that model design is essential in designing the desired information environment, and for this reason, the approach of bringing in existing games as models of information environments has been used in social networking sites, for example, with the motivation of introducing user-friendly interfaces. This is even the “new normal” that continues to evolve through the explosive spread of SNS in recent years.

1.2.2.5 A Model Representation Form as Multi-Agent System

There are several known operational model forms with multi-agent system that are expected problem-solving techniques for dealing with social problem situations, and gaming technique is one of them. In general system theory, multi-agent system is a system of interaction among multiple decision-making agents. In Sect. 1.5, in addition to gaming-simulation models, game theory models, conflict analysis models, and ABSS models are discussed as model representation forms of the multi-agent system. All of these research fields have been developing in recent years and their interchange with simulation and gaming studies is growing as well. Another popular trend is constituted by rigorous attempts to combine gaming techniques with other existing techniques.

1.2.2.6 Contribution for Social Design Science

When not only gaming models but also multi-agent operational models are used for problem solving, a way of approaching social design that uses these models efficiently and effectively according to the aim and situation, in other words, the social design science becomes significant. Under this science, it is desirable that gaming techniques and other problem-solving techniques using multi-agent models be positioned appropriately.

1.2.3 Three Directions of Gaming for Enhancing Instrumentality

Since it relates to simulation and gaming for social design, in this chapter, the aims of gaming techniques are presented in the following three categories, focusing on the directionality intended by the organizers.

- Those oriented to the composition of the target problem situation and the search for solutions to the problem situation.
- Those oriented to the generation of theoretical models or the scientific testing of hypothetical models.

Those oriented toward providing learning opportunities for participants, i.e., knowledge and skill acquisition and experiences sharing.

Other directions such as mere transmission of messages or pursuit of pleasure may also exist, but they are beyond the scope of this chapter.

Hereafter, the three above-mentioned directions will be referred to as "Problem Solving Oriented," "Scientific Theory Oriented," and "Learning Opportunity Oriented," respectively. Assuming that there are "aims" that are shared by two or more of these directions, these can be represented as a three-sets Venn diagram. For example, some "aims" may be present in the Problem Solving Oriented and the Learning Opportunity Oriented, or absent from Problem Solving Oriented and Scientific Theory Oriented. Gaming is thus classified according to its "aims." This interconnection is shown in Fig. 1.1 along with specific examples of each theme. The majority of the simulation and gaming for social design that is discussed within this chapter belongs to the Problem Solving Oriented category. However, there might be cases that do not fit clearly within any single direction, and we do not have to exclude ambiguous cases from their problem awareness, as will be addressed below.

Rather, regardless of the specific "aim," what current researchers are emphasizing is the common effect of gaming on "manipulative and experiential understanding of models" and "communication of models." In understanding large, complex, and incomprehensible models, people not only look at them from various angles but also recreate or deconstruct them. In the case of gaming, one can "immerse" oneself in a game that represents the model and experience it. Such manipulations and experiences form an internalized reality for each participant, and by encouraging their interplay in discussions among participants, the understanding of the model in question can be shared among many people. It is mainly due to these effects that gaming simulations can be useful in exploring social design and problem solving.

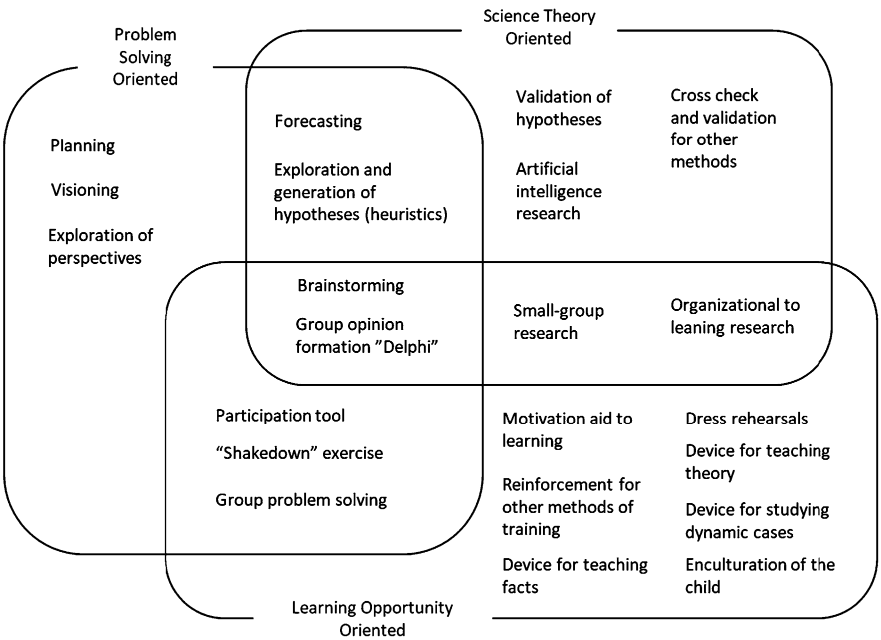

Fig. 1.1 Directions of gaming techniques

1.2.4 Competition and Role-Playing: Two Typical Society Models in Gaming

In gaming for social design, a game can be considered as models of society. The variety of games stem from a high degree of freedom in model representation. Here, an explanation will be given for two different types of society models that can be featured in gaming, concentrating on competition and role-play responding to the player's actions.

1.2.4.1 Competition Society Model

This society model takes the form of a setting in which players are explicitly given goal functions (goals) and constraints on their behaviors (rules). It is a model to which the metaphor of a competitive situation, i.e., rules in a sports competition, applies, and is the first thing many readers associate with the word "game." The zero-sum game theory model is one of the purest forms of a competition society model. This society model is characterized by the fact that each player is expected to behave competitively under the given rules of the game, independent of the "context" of the problem situation. Thus, the "thinking" of players in this society model is detached from the real problem situation that constitutes the target of the model.

1.2.4.2 Role-Playing Society Model

On the other hand, a role-playing society model is as follows. First, a role is given for each of the participants in the form of words and symbols. From the information presented, each evokes his or her internalized role norms and interprets his or her role during gaming. After that, the participant recognizes a given situation and performs the role action under it. At this time, the participant depends on the "context" for action selection, as mentioned above. It is important to note that unlike the competition society model, the existence of norms, interpretations, and cognitions characterizes the behavior of players in this society model.

In some of these society models, the role actions of each agent are periodically mutually evaluated among the others. In other words, the agents carry out their roles by referring to the evaluation information of other agents. On the other hand, each agent presents to the others the results of its evaluation of its role-playing behavior in light of the norms of the expected roles that it has formed and has internalized under the circumstances it has recognized in gaming.

This kind of mutual evaluation mechanism is one typical case of this role-playing society model. Since the mutual evaluation mechanism generates "mutual control" among agents, this mechanism acts as a coordination principle. Obata's (1992) waste treatment gaming is a positive example of this mechanism.

1.3 Common Process Structure in Gaming Techniques

1.3.1 Process Structure

Here, we will call gaming with instrumentality a gaming technique. In general, techniques and methodologies should be characterized by their process structure. Although there are a wide variety of actual gaming techniques, the author would like to explain gaming techniques formally by showing the following process structure.

Process 0: The following Processes, *1* to *5*, will be implemented to aim for beneficial effects such as exploring solutions appropriate to the problem situation or some knowledge related to social design. These processes are pre-designed to operate under a certain aim and "context."

Process 1: Before the implementation of gaming, a "game" should be prepared. This game is a representation of a "model" that in some way simulates a (social) problem situation. The model and the game may be newly created for this purpose, or they may be adapted or modified from what already exists.

Process 2: At the time of gaming, the players choose their actions while following the "rules" of the game. The state of the game progresses as an accumulation of the mutual actions of the players. However, the actions chosen by the players are influenced not only by the game rules but also by the "context" in which they find themselves.

Process 3: Through the experience of gaming, each player acquires a "reality" on the model from his/her point of view. In addition, people observing their gaming play acquire a "reality" on the model as well.

Process 4: Each participant (including players and observers) should have a reality on the problem situation from before the gaming. In the post-event "debriefing," participants compare the reality on the model described in *Process 3* with the reality they originally had about the problem situation.

Process 5: In "debriefing," participants intersect their own "realities on the model" and the "realities on the targeted problem situation" in order to explore a comprehensive reality that can be shared.

An illustrating example of this process structure is BARNGA (Thiagarajan and Thiagarajan 2011). The organizer sets the aim (*Process 0*) and designs a card game with a seed to be revealed at the end (*Process 1*). The participants engage in the game, genuinely believing that the intent of the game is the playing card competition itself (*Process 2*). However, an unexpected turn of events leads them to start thinking about the meaning of this gaming. Through gaming, the participants acquire some kind of impressions (*Process 3*). Someone begins to say that this experience is somewhat similar to a cross-cultural situation. Everyone recalls their own impressions of the experience and compares them with the impressions of the gaming experience (*Process 4*). This is indeed very similar among the participants and they may discuss as such with each other. Through this discussion, participants understand the implications of BARNGA (*Process 5*).

Further, Policy Exercise introduced by Toth in the 1980s can also be interpreted through the lens of this process structure (Toth 1988). The organizer prepares a fictional game with a system model that structurally imitates the problem situation, and invites stakeholders to participate in a "structured dialogue" between them about the problem situation through some kind of reality sharing. It should be noted that Policy Exercise also follows the process structure of *Processes 0* through *5*. However, in Policy Exercises, the model needs to be abstract and the game needs to be intentionally made unrelated to the real problem situation in order to avoid the recurrence of straightforward conflicts of interest among them during gaming.

1.3.2 Dealing with Reality

As explained above, "reality" plays a vital role in gaming techniques. Here, reality is defined as "an image of experienced and perceived reality." In a certain sense, gaming techniques are nothing other than the derivation of insights or findings by participants via comparisons among each own internal realities as well as the realities of other participants. Whether by experiment, operational understanding, or by communication of the model, in any case, these techniques appear as manners to mediate reality.

In the above explanation of the process structure, the "reality of the model" and the "reality of the problem situation" have been presented as two different types of reality. Let us explain both using the example of BARNGA. The first reality is the impression of being tricked in the card game experienced by participants. The second reality refers to the past personal experience impressions of individual participants in cross-cultural business situations. BARNGA takes on the meaning when each of the participants connects these two realities inside him or her.

Process 1 and *Process 4* are conversion processes that are essential to preserving compatibility between the "reality of the model" and the "reality of the problem situation." *Process 1* is a forward conversion by organizers and designers moving from the "reality of the problem situation" to the "reality of the model." In contrast, *Process 4* is an inverse conversion by participants, moving from the "reality of the model" to the "reality of the problem situation." These two processes correspond to the encoding and decoding that occur in communication theory.

Further, variance in gaming techniques can be considered through a reinterpretation and simplification of part of this process structure. The assisted negotiation proposed by Susskind et al. (1999a, b) and known as support techniques for environmental conflict resolution are not generally referred to as gaming techniques but can be interpreted as such. Assisted negotiation is a scheme whereby stakeholders concerned with a problem situation are made to experience "experimental new rules," in an attempt to stimulate substantial agreement among concerned parties through high-quality content of mutual actions that are thereby produced. This can be identified as an example of replacing the reality of the model with the powerful reality acquired through a social experiment (introduction of rules). In this case, it is essential for each concerned stakeholder to hold a reality and it is not necessary to combine the realities of concerned stakeholders afterward. Therefore, *Process 5* of the process structure is omitted. Besides, in relationship building workshops (e. g., Elliott 1999) it may be necessary to define the meaning of games and models more ambiguously. Still, these can certainly be seen as cases of variance in gaming techniques.

Incidentally, we should not forget that the game itself provides a special kind of reality to the life world. For example, we need to take into account the fact that the word “game” may conjure up images of the realities of sports, play, and gambling. This may be a merit or a demerit. For instance, when addressing a problem situation that requires a serious attitude, the adoption of a game that is interpreted as “playful” would clearly have an adverse effect. On the contrary, strategies with precise “aims” may be efficacious. These outcomes are closely connected to the “context” such as the time and place of gaming, the theme, the aim, and so on.

1.3.3 Is Gaming a Mapping or a Metaphor?

As for “model,” some people may think of this word as a kind of formal theory that produces rigorous science. Here, the model, which is also called a “gaming model” in this chapter, relies basically on the concept of system model in system theory established in the mid-twentieth century. In such models, the description of the problem situation can be comprehended as “one system” and the writing of the model can be understood as “another system.” Under such a premise, the concept of homomorphism in system theory becomes key for a set of mapping relationships between the components and internal structure of the two systems, the problem situation, and the model. Hence, the system model can be referred to as “model as a mapping.” In the system model, the mapping relationships between the problem situation and model can be condensed analytically through a point-by-point examination. Through this operation, consistency between the “reality of the model” and the “reality of the problem situation” yielded through gaming is ensured by logically connecting the two.

Simulation is formed according to this explanation of system model. In simulations, the “reality from the present to the future” yielded through the simulation is superimposed on the “reality from the past to the present” of the problem situation. In other words, the reality gained as a result of the simulation is regarded as an extension of the reality of the present situation. This type of operation is called “extrapolation.” Through such operations, insights and future visions supported by reality, the composition made up of various elements, or something that is missing is sought.

The credibility of the interconnection of consistency between the two realities depends on the consistency between the problem situation and the model. Hence, what simulation refinement heads for is an introduction to scientific theory.

Gaming-simulation is a technique that features the characteristics of both gaming and simulation. Gaming-simulation also attempts a "composition" of various aspects of reality by all participants through combining the realities each had yielded during gaming at the debriefing stage. Gaming wherein the theme has to do with future visions can also include operations whereby this composite reality is superimposed with the reality of the problem situation. In social design gaming featuring this kind of simulation, the introduction of system models with multi-agent is extremely significant.

Regarding that, the model can also be comprehended as a type of "metaphor" of the problem situation. Here, metaphor is defined as an expression aimed at calling attention to a hidden property of the object by using words that hint at something unanticipated. In the case of gaming techniques, a metaphor is something that calls attention to the hidden peculiarities of the problem situation via gaming experience, which presents a simple but surprising model. For instance, in BARNGA the act of playing a game of cards without speaking is used as a metaphor for business situations. In this case, the "card game" can be considered as a model for "business situations."

Now, let us observe the changes in the mental images of participants after encountering the metaphor. As soon as an impression of the model is gained through the experience of gaming, it is rapidly connected to one of the various aspects of reality held by participants about the world of their daily lives. This might produce a hearty laugh or a feeling of surprise. "A is like B"—the speed and surprise of this connection are the sources of the metaphor's efficacy.

In this sense, the "model as a metaphor" is considerably different from the "model as a mapping." In this model, although a connection is comprehended to exist between the model and problem situation, there is no meaning to be found by considering each as a system and carefully examining the mapping relationships among its components. It is enough, at least, for a matching to exist between a part of the reality of the model and a part of the reality of the situation in the eyes of the participants. Homomorphism between the model and the problem situation is not necessary. Instead, the "model as a metaphor" is meant to scheme participants' intuitive recall of realities applicable to the "context" of the field of gaming. The above-mentioned BARNGA is a gaming using metaphors, although it cannot be called a simulation per se. The "model as a metaphor" exemplified by BARNGA needs to properly apply the "aim" and "context." This means that such a model cannot essentially be detached from its context.

Now, the question would be "Is the model a mapping or a metaphor?" Investigations into gaming models by simulation and gaming researchers have certainly been marred by this polarized way of thinking. Here, I would like to share my own views on the matter with social design concept in mind. First, as for the relationship with the real problem situation, one of the necessary conditions required by gaming models is system models. This is particularly effective in cases characterized by a large scale. However, when attempting to compose a real problem situation into a model or game, the challenge would be producing something hard for participants to understand, either in the operation process or at the stage of gaming. While modeling, reality may unintentionally be distorted. To avoid this situation, it is necessary to simultaneously apply techniques using a bold metaphor that evokes the "holistic essence" of things in the real experience.

1.3.4 Importance of Contexts

Some readers may have noticed that in the above-mentioned process structure there is a discrepancy in the meaning of the context used in *Process 0* and the context used in *Process 2*. In fact, the context in *Process 0* is the context in which the problem solver plans to gaming, or in other words, the problem situation itself, while the context in *Process 2* is the context in which the player considers his or her own behavior during the gaming.

The former discussion of context is linked to the discussion of the validity of the implementation of gaming techniques for problem situations. This is because the implementation validity of gaming should be discussed in terms of the fit among the problem situation, the aim of gaming, and its implementation. However, this is related to the content rather than the form. In gaming practices, context and background are used about the circumstances of specific fields. In a few chapters of my previous book (Kaneda 2005), I have discussed the concepts of negotiations, conflicts, disputes, social organization, community development, and environmental policy formation as well as various aspects of gaming exercises and their background, i.e., "context."

Next, the context in the *Process 2* will be discussed. This relates to whether the game is a competition or a role-play. Let us imagine a game in which players are given only role norms and behave in their roles according to these norms. In other words, players are required to role-play. In this case, when choosing how to act within the game, human beings will probably bring some implicit "context"—aside from the provided rules—into their behavior. Human players may choose how to act by calling to mind real situations that they link with the gaming situation.

Provided this example, while action choices in competitive situations are independent of context, action choices in role-play situations are characterized by their extent of dependence on the context. Further, context dependency is a desirable characteristic in gaming-simulation. This is because context dependency is an important contributing factor to gaming-simulation, which establishes the ability to address a variety of interpretations by participants as well as the manipulation of abstractness on symbols as the model elements by the organizers.

Is the game a competition or a role-play? In other words, are players called for making decisions independently or depending on the context? This hinges on the design principles of the gaming model. At this point, gaming techniques can allow for great freedom and flexibility.

1.3.5 Prototyping

How shall we design a gaming model that represents a problem situation? Below is an explanation of the method known as “prototyping.”

The answer to the above question is to first create a gaming model, then implement and gradually improve the game while establishing “aims” through communication among organizers, designers, and participants, and finally grow closer to social design and problem solving as a result. The approach of realizing games with partially incomplete forms, ambiguous models, or undifferentiated “aims” is referred to here as “prototyping.” A prototype is created and improved with version updates so as to be more and more effective according to the “aim” of the gaming. Throughout this process, it is vital to make incremental improvements that are sufficient to the “growing degree of depth” of the reality addressed by designers and participants.

In prototyping, the aphorism of the “Procrustean bed” is used with a nuance of self-admonishment, referring to the problem situation being forced to fit within an established model of understanding. As this form of prototyping takes root, Piaget’s structuralism, which recognizes targets as undifferentiated elements and develops successive distinctions of these elements, becomes significant. Besides, in the improvement of Problem Solving Orientated gaming models, it is essential to instead plan both prototype and version updates in accordance with the depth of reality awareness reached by designers and participants.

1.4 Gaming as Scientific Method

1.4.1 Is Gaming an Empirical Science?

This section contains a brief discussion of the interconnection between gaming and the traditional scientific method in the form of questions and answers. The first question is whether the whole-system behaviors observed as a result of gaming can be considered valid as an empirical science. To answer this question, a prior explanation of gaming as a science by system theorist, Russell L. Ackoff (1962), is introduced below.

Ackoff divides this question into two parts: the validity of gaming models and gaming design, and the validity of making inferences about the problem situation based on the results of gaming.

As for the first part, according to him, “Gaming is essentially experimentation in which the behavior of decision makers is observed under controlled conditions. It differs from most psychological and social experimentation only in that the conditions under which the “play” is observed represent some situation outside the laboratory about which knowledge is sought. The experimental situation, then, is deliberately constructed as an iconic or analog model [a homomorphic or isomorphic model] of a type of situation of interest." Further, "In cases where a completely specified course of action or decision procedure cannot be derived from a model, but a partially specified action or procedure can, the effect of the action or procedure may be determined by gaming."

As for the second issue, "The fundamental weakness of current gaming is being incapable to draw strong inferences from the play of the game to decisions in the situations that the game models." This is specifically due to "the inferences that are drawn are weakened by the complexity of the game. A model, whether an equation or a game, is always a simplification of reality, and for this reason only it is useful in science. It is vital, however, to understand the nature and significance of the simplification because only then can we justify inferring from the model to reality."

However, "The more aspects of reality are represented in a game, the more difficult it becomes to analyze its structure, i.e., to represent it by a mathematical model. On the other hand, unless enough of the relevant aspects of reality are included it cannot be an adequate model of reality. The gradation between excessive simplicity and complexity can be attained only by experimenting with the game itself." Ackoff concludes that "[Gaming] has been used primarily where large complex systems are involved, systems where structures are not thoroughly understood. Under such situations, the principal use of gaming is the exploration of structural relationships. Results obtained from the game should be treated as suggestions or hypotheses which should be more rigorously tested." Further, "Gaming should not be considered as a substitute for analytic model construction. On the contrary, it should be viewed as a way of obtaining information that can be used to generate models where analysis of or experimentation on the "real" situation is impractical or impossible."

Today, gaming can be regarded as a means to gain useful "heuristics." For instance, when hypothetical models of future environments and states of emergency need to be "extrapolatively" constructed from the expertise of environmental scientists and disaster prevention scientists, or when a comprehensive investigation into social issues is not progressing sufficiently as new and complex problems arise.

In summary, the utilization of gaming as an instrument for empirical science is a means to test hypotheses based on other experiences or theories, which is both possible and practical. However, the most significant characteristic of gaming is not being a means to test simplified hypotheses, but rather to structurally investigate complex realities. When applied to large-scale complex targets, gaming is effective in allowing participants to heuristically obtain previously "unimaginable scenarios," "verifiable hypotheses to pursue," and a "narrowing of the elements eligible for composition." To a certain extent, gaming can be appropriately positioned as an instrument for social design science as is the theme of this chapter. Going forward, gaming combines the aims of not only the scientific theory oriented but also the problem-solving oriented and the learning opportunity oriented, which may lead to greatly significant practical applications.

1.4.2 Does Gaming Rely on Game Theory?

The next question is whether gaming has its foundation in game theory. The research of Harvard Negotiation Project scholars (Fisher et al. 2011) and the succeeding current of negotiation gaming can be cited as examples of models relying on game theory as their foundation. However, many other examples of gaming that by far surpass them do not rely on game theory.

In addition, gaming has historically been studied since well before game theory. Within the scope of simulation and gaming studies except for the activity of researchers such as Shubik (e.g., Shubik 1975), the connection with game theory is not particularly strong when compared to other fields of study. Given the mathematical space in which models can be described, the space of "playable" gaming models is large, including the space of game theoretic models. In the early days of game theory, there were attempts to experiment with actual human players in model situations such as the prisoner's dilemma. Some of these experiments were conducted to find solutions to social problems, while others were conducted by game theory researchers to explore theoretical developments.

In addition, among the aforementioned types of the society models, it may be possible to introduce game theory as the basis for the competition society models. On the other hand, some of the role-playing society models do not have explicit preferences or utilities as rules of the game, and it is not possible to introduce such models as found in game theory.

1.4.3 Testing the Validity of Gaming

In the field of econometrics, there are formal procedures to verify the validity of a built model. However, gaming-simulation models undergo no such procedures. Here, the question is, how shall we test the validity of gaming? This section discusses this question and possible answers by dividing it into two parts: the formal validity of gaming models, and the implementation validity of gaming.

As it relates to the formal validity of gaming models, the first condition these models must fulfill is to borrow a term from the mathematical system theory and homomorphism in relation to the target reality as discussed earlier.

Second, the author thinks that the modeling approach for large-scale systems that leads to this formal validity should be a constructive approach (model analysis by model synthesis). Constructive modeling here means to construct a model of a large and complex object by combining partial models whose properties are already clear, and then comparing the behavior of this model with that of the object. While constructing an artificial social model, we can deepen our understanding of the social system by comparing the behavior of the social model with that of the real world. This approach is the basis for the prototyping already mentioned.

In a broad sense, the constructive approach satisfies the condition of falsifiability. In other words, the appearance of the same behaviors at one time is not enough to immediately regard the model as correct. Moreover, if the constructed model behaves differently from the target system, that model is rejected. When a model is rejected, we try again by changing the partial model or, in some cases, by recombining the partial models. This process has an important meaning. One model that has not been rejected should be constructed, and if more than one model is possible, the models should be narrowed down by using various supporting evidence.

As for the implementation validity of gaming, this is an issue that involves the entire gaming application effort including the setting of gaming models and contexts. Therefore, the validity of gaming must be tested while accounting for the existence of context dependence and intersubjectivity. In addition, as emphasized in *Process 4* above, in the problem-solving-oriented gaming, a fitting relationship between the reality of the problem situation that participants have and the reality they get from the gaming experience should be emphasized. Therefore, one of the criteria for validity evaluation is how to appropriately provide the participants with materials (environment) to reconstruct the reality of the target problem situation or problem structure. In this way, unlike the concept of formal validity of a model, this validity should be judged by people who are deeply familiar with the real problem situation and problem structure, and who mix their subjectivity in the debriefing session after participating in the gaming.

1.5 Gaming Model as Multi-Agent System

Various system concepts have continued to play crucial roles in simulation and gaming studies since the 1950s. In recent years, research on a system theory of multi-agent system as a system underlying Gaming Simulation Models and Multi-Agent Social Simulation Model has made significant progress (e.g., Kaneda and Kitani 1994, 1995, 1996, 1997, 1998; Kaneda 1999, 2005, 2007, 2012). Nowadays, multi-agent system concept has attracted attention as the common form for model representation of social situations. In this section, gaming techniques are positioned as model representation forms of multi-agent systems within the problem-solving techniques, and their characteristics are compared.

Furthermore, the introduction of the concept of multi-agent system was one of the directions in the refinement of gaming model. The hybrid to the other problem-solving techniques with the multi-agent models that feature forms of models is also connected to new possibilities in gaming.

1.5.1 Multi-Agent System as Complex System

Multi-agent system is also known as “complex system that includes agents.” This means that macro-phenomena of the whole system emerge via the accumulation of mutual actions by individual agents. Four characteristics of a multi-agent system as complex system are outlined below.

1.5.1.1 System of Medium Number

Medium number systems indicate the domain of numbers that are not covered by either mathematical analysis, which studies heterogeneous specimens of small numbers or statistical analysis, which studies homogeneous specimens of large numbers. The mathematical analysis used in traditional science can only study two to several agents, primarily due to limitations in the computational complexity. Statistical analysis, on the other hand, leads to the abstraction of agent individuality and the considerable simplification of interaction among agents. In medium number systems, which exist in the gap between these two domains, substantial changes, irregularities, and discrepancies with all theories often occur regularly. According to complex system scientist John Casti (1996), the domain of medium number systems should be studied as a system and simulation should be actively used to that end.

1.5.1.2 Local Information, Bounded Rationality, and Adaptation Function in Decision-Making

In contemporary society, nobody has all the information. On the contrary, each agent cannot directly know the thoughts or actions of other agents, and normally bases their decision-making on limited local information. Decision-making situations like those of drivers in a traffic jam or traders on the stock market are in fact a daily occurrence. Local information is one of the characteristics of social situations as multi-agent system. In turn, local information is one of the sources of bounded rationality in an agent’s decision-making.

In addition to bounded rationality, the function of adapting to one’s environment is sometimes assumed in models of decision-making agents in multi-agent systems. An example is the study of the classifier system implemented for the El Farol problem presented by economist Brian Authur. Casti called multi-agent systems that fulfill this assumption “complex adaptive systems.” In regards to multi-agent systems, many theorists insist on the emergence of macro-phenomena of the whole system via agents’ micro-behaviors with both bounded rationality and intellectual adaptation functions.

1.5.1.3 Contingency

Let us consider a decision-making agent who decides what action to take based on rules expressed with the situation-action pair. At this time, their decision-making will be contingent on the situation in the sense that their decisions will be made in response to the situation. This type of situation-dependence is called "contingency." For instance, if given the situation of agent X, agent Y takes action on this situation and the subsequent action of agent X will be contingent on the action of agent Y. The uncertainty that agent X faces with such a contingency is a considerably different concept than the uncertainty due to noise as explained in probability distribution including models of natural phenomena.

In addition, if the actions of agent Y were also contingent on the actions of agent X, none of the agents would be able to choose their actions spontaneously. In social systems theory, such a situation is called "double contingency" and the introduction of social roles is explained as a way to reduce this kind of uncertainty.

1.5.1.4 Micro–Macro Linkage

As discussed earlier, a necessary condition of multi-agent system is causation from micro to macro. However, multi-agent system can also be considered as established by causation from macro to micro. For example, the El Farol Bar problem fits within this pattern. In an information society, individual agents are flooded with information about the entire societal situation and are strongly influenced by such information in their decision-making. In this sense, the interconnectedness of micro and macro is a common characteristic of multi-agent system as a complex system.

1.5.2 Operational Models with Multi-Agent System for Social Design

With problem-solving techniques that deal with multi-agent systems in mind, the following four models are addressed, overviewed, and compared:

- Game Theory Model
- Conflict Analysis Model
- Agent-Based Social Simulation (ABSS) Model
- Gaming-Simulation Model

The first criterion for comparative arrangement is the difference in the implementation form of the model—mathematical formula, computer algorithm, or flesh and blood human—and the second criterion is the ability of the model form of the multi-subject system to depict the reality of the problem situation.

1.5.2.1 Game Theory Model

The category of game theory model primarily focuses on the game theory founded in the 1940s by John von Neumann and Oskar Morgenstern. A typical example of this model description of multi-agent system is the zero-sum game theory as the standard version. This theory features three main components:

(1) A game with a simple mathematical structure, featuring “player set,” “strategy set,” and “payoff functions.”
(2) Players’ decision-making principles are expressed by a formula known as the “Maximin principle.”
(3) Equilibrium solutions for the whole system, derived logically by premises (1) and (2).

Here, (2) is the agents’ decision-making model, and (1) is the rule that regulates their interactions. Therefore, noncooperative zero-sum games are a model of multi-agent system.

Characteristic of the game theory is the concept of (3) equilibrium solutions. A wealth of examples of this can be produced via on-paper calculations with the logical stringency that is the foundation of utility theory. Game theory provides the opportunity for valid insight for those facing complex problem situations. However, this appears to be caused by the vividness of models as metaphors encouraging the simplification of problem awareness and by the strong message of the concept of rationality itself rather than by the ability of the model to represent the reality of the problem situation.

1.5.2.2 Conflict Analysis Model

This is a general term for models of multi-agent systems developed for conflict analysis, and is a problem-solving-oriented system mathematics that starts from a game theory description. In meta-game analysis, as introduced by N. Howard in the 1970s (Howard 1970), the strategies of decision-making agents are rephrased in if-then form, i.e., as reactive strategies so as to identify and categorize new equilibrium solution concepts. First introduced by graph theory, the idea of metagames developed into one-shot games to study conflict analysis. In contrast, P.G. Bennett’s hypergames (Bennett 1980), which redefine whole-system games as the “normal form game” expand the game description to express the internal model of each agent with the “normal form game” thereby analyzing subjective perceptions by decision-making agents and how they are influenced by misconceptions.

These are unique in that the problem situation is mainly represented and calculated by a model that extends the game theory notation. In addition to written calculations, computer programs are often used for calculations. Further, these models emphasize counter-intuitivity, which is another characteristic of the complex system.

1.5.2.3 Agent-Based Social Simulation Model

Multi-agent system simulations that implement decision-making agent models via computer programs have long fascinated researchers. Sample examples are projects that substitute part or all of the players with machines to offset the excessive time and cost required by the operation of a gaming-simulation involving massive numbers of human players as decision-making agents within the game. In the well-known Agent-Based Social Simulation (ABSS), agent models are implemented as computer programs with memory and learning functions. In such agent models, the assumption of bounded rationality is sometimes insisted. Progress in computer science, particularly improvements in computer performance and program productivity were essential for the realization of ABSS.

One of the precursors of ABSS is the Repeated Prisoner's Dilemma Competition by Axelrod (1984). In this competition, participants prepare computer programs or multiple agents that output strategies depend on the game situation and they also participate in a computer experiment in which the agents are asked to calculate the results of the game many times. Many of the attempts of this competition are scientific theory oriented, and attempts to explore new theoretical horizons through this competition approach have become more popular in recent years. It is often discussed together with complex systems science.

In general, ABSS is often understood as a scientific theory oriented experiment. However, several adaptations to the problem-solving oriented have been reported in prior studies in the fields such as crowd control, evacuation guidance, disaster management, stock trading, public auctions, and so on.

1.5.2.4 Gaming-Simulation Model

This refers to models for simulations in which human players play one or more agents as components of a multi-agent system. Gaming-simulation allows for a high degree of freedom and flexibility in multi-agent system model construction. However, it should be noted that gaming-simulation has constraints about "playability." Playability refers to the ease of play for human players, and is a concept that defines the scale and content of models that human players can and should participate in, such as games that were once too large and time consuming for anyone to use. Since the advent of gaming software and online games, this playability has continued to expand.

Another advantage of Gaming-Simulation Models compared to the other models is that they allow us to observe by "entering" the game, as humans participate in the actual gaming as one of the constituent agents in a multi-agent system. It is also possible to examine contextual factors in an agent's decision-making.

1.5.3 Comparisons Among Operational Multi-Agent Models

The differences between the game theory model and Gaming-Simulation Model were illustrated by the game theorist Martin Shubik in the 1970s (Shubik 1975). Over more than half a century the concepts of non-complete information, imperfect information, learning, and bounded rationality were introduced into game theory, which has caused substantial changes. However, very little has changed in the basic framework. A comparison among techniques that address multi-agent system models in addition to Conflict Analysis Model and ABSS Model is shown in Table 1.1. In a gradation of the four types of models side by side, comparisons are made for each of the following characteristics, positioning the two models of Game Theory Models and Gaming-Simulation Models at each end of the spectrum: homogeneous or heterogeneous agents, complete or incomplete information, learning, dynamic or static models, role-play, problem symbolization, fixed/unfixed payoffs and utility, and explicit or implicit rules. In summary, the major peculiarity of gaming-simulation models occurring in multi-agent system models is that they provide human players with decision-making situations that are rich in variety, individuality, and complexity. Therefore, they demand from human players the ability to interpret the problem situation.

There is also potential for new techniques to combine these four types of models, and there are known reports of scientific theory-oriented reports that attempt to complement the findings by cross-checking the results of different models on the same target. In addition, there is a problem-solving-oriented use of gaming, which is a heuristic search for possible scenarios. In this case, only the model form used in the completed model is shown as a result, and the contribution of the gaming simulation may not be apparent to the public.

1.6 Conclusion: Gaming as Primary Instrument for Social Design

In this chapter, simulation and gaming are observed as instruments for social design and their basic principles are described considering our social design as understood in the twenty-first century. The two concepts of game and gaming are both polymorphic, so to speak, with a variety of concrete examples, but gaming is characterized by its "instrumentality," its awareness of its uses.

Section 1.2 presents the writings of R. Duke, who emphasizes the role of gaming as a medium for sharing and communicating a complex reality as the basic principles of gaming. Furthermore, considering the issue of social design, the three directions of problem solving, scientific theory, and learning opportunity are outlined. However, there could still be more directions such as entertainment.

Section 1.3 begins with a step-by-step description of the process structure that characterizes gaming as an instrument. The concepts concerning reality, a model as a

Table 1.1 Comparisons among multi-agent models

	Game theory models	Conflict analysis models	Agent based-social simulation models	Gaming-simulation models	
Homogeneous agents	←	←	→	→	Heterogeneous agents
Complete information	←	→	→	→	Incomplete information
No learning	←	←→	→	→	Learning
Primarily static	←	←	→	→	Primarily dynamic
No role playing	←	←	←→	→	Role playing
Game formulation is independent of problem situation (Context-independent. No coding problem)	←	←	←	→	Game recognition depends on each player's problem situation recognition (Context-dependence. Coding problem)
Clearly given payoffs and utility functions	←	←	←→	→	Player's implicit, ambiguous, and changing payoffs and utility functions
Explicit rules of the game	←	←	←	→	Implicit rules of laws and customs of society

mapping and a model as a metaphor as well as context are put into question and a prototyping approach that constitutes the first step of multi-agent system modeling is outlined from the viewpoint of an undifferentiated part of directional consciousness.

Section 1.4 introduces the traditional discussion on the relationship between the scientific method and gaming, whereas Sect. 1.5 introduces the game theory, conflict analysis, and ABSS as different model representation forms of multi-agent system in contemporary system theory and identifies the peculiarities of gaming-simulation by comparing it to these techniques.

In my opinion, social design takes the form of a kind of trans-relational science. When defined narrowly, social design science can be characterized as a problem-solving-oriented multi-agent systems science. Elsewhere, the author had once mentioned soft systems methodology, policy science, and planning theory as examples of advanced research topics that will lead to the coming social design science (Kaneda 2005). Here, however, I have omitted details mainly due to a lack of space. As for specific examples, the author had already discussed the reports of action research and gaming exercise proposed by soft systems methodology in another article (Kaneda 2019; Kaneda et al. 2020). In our social design science, a discipline characterized by a constant back-and-forth interaction between the wisdom of theory and the wisdom of practice simulation and gaming can be expected to become a primary instrument of social design science.

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