Game research by design in project management and beyond

Freese, Maria; Bekebrede, Geertje

DOI
10.1016/j.plas.2024.100174

Publication date
2025

Document Version
Final published version

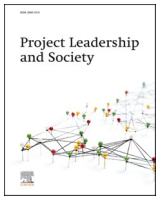
Published in
Project Leadership and Society

Project Leadership and Society 6 (2025) 100174

Contents lists available at ScienceDirect

Project Leadership and Society

journal homepage: www.sciencedirect.com/journal/project-leadership-and-society



Novel Research Practices

Game research by design in project management and beyond

Maria Freese [a,*], Geertje Bekebrede [b]

[a] Otto von Guericke University Magdeburg, Faculty of Mechanical Engineering, Universitaetsplatz 2, 39106, Magdeburg, Germany
[b] Delft University of Technology, Faculty of Technology, Policy and Management, Jaffalaan 5, 2628 BX, Delft, the Netherlands

ARTICLE INFO

Keywords:
Project management
Complex systems
Mixed methods
Serious game
Research approach

ABSTRACT

Projects are complex systems as they consist of different elements interacting with each other considering a certain degree of uncertainty. Serious games - defined as those that are not primarily intended to entertain - can be used to better understand, analyse, or design projects in such complex socio-technical systems. They are a powerful research method because they provide data and insights into people's behaviour in relation to their environment. They do this in an engaging way in a safe environment, making them suitable for testing hypotheses and gathering data on choices, decisions, and interactions of people. In addition, serious games provide an environment that allows for mixed methods data collection. This article introduces the Game Research by Design - Approach about the development of serious gaming research set-ups, which addresses three cycles - *theoretical, design and empirical one* - when conducting research using serious games. This article illustrates the choices researchers need to make when developing research design and experiments based on serious gaming. Further research is needed to elaborate the different steps and to fine-tune this approach.

1. Introduction

Management and leadership in projects are a balancing task. Project managers must focus on all criteria of the project management triangle (Kuster et al., 2015) - time, money and quality - under consideration of more 'soft' skills such as communication, collaboration, and negotiation (Thomas and Mengel, 2008). Projects themselves enable changes and improvements by addressing challenges, objectives or innovations within complex socio-technical systems. Complex socio-technical systems consist of different elements (technical and economic, social, political, or organizational) interacting with each other considering a certain degree of uncertainty. These uncertainties and interacting elements need to be part of the project management approach as well (van Marrewijk et al., 2008).

To train (future) project managers, games are used for project management education (Calderón and Ruiz, 2015; Rumeser and Emsley, 2019). These games provide a simulated environment where the intended target group (e.g., students) learn both 'hard' as well as 'soft' project management skills (e.g., Shehab et al., 2024). The research into these games focuses on their design, embedding in education (Jaccard et al., 2022) and their effectiveness in improving decision making (Rumeser and Emsley, 2019). According to Winter et al. (2006) and Ackermann and Alexander (2016), new research approaches in the context of project management are needed.

2. Serious games as a research method

Serious games are games that "[…] have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement. This does not mean that serious games are not, or should not be, entertaining" (Abt, 1987, p. 27). Serious games can vary in different aspects, such as the type of a game (analogue, digital, hybrid), the number of players (single- or multiplayer), and/or the genre (e.g., action, puzzle, strategy, etc.). According to different scholars (e.g., Bellotti et al., 2013; Gatti et al., 2019), the purposes of serious games can range from theoretical learning, knowledge acquisition, skills development, competency-based training, awareness creation, problem solving, supporting decision making, behavioural change, to the use of such games as a research method.

In 2003, Washburn (p. 185) discussed the role of computer games to be used in psychological experiments and highlighted that "[…] In contrast to the sterility, simplicity, and artificiality that characterizes many cognitive tests, game-like tasks can be complex, ecologically valid, and even fun." However, Yiannakoulias (2022, p. 1207) concluded that "[…] research games remain uncommon outside of economics and social psychology […]", "[…] but technological developments have made

* Corresponding author.
E-mail address: maria.freese@ovgu.de (M. Freese).

https://doi.org/10.1016/j.plas.2024.100174
Received 16 December 2023; Received in revised form 6 December 2024; Accepted 24 December 2024
Available online 26 December 2024

them more accessible than ever" (p. 1218). Also, Monteiro-Krebs et al. (2024) emphasized that (board) games have not yet been widely explored as a research method. According to Gómez-Maureira et al. (2022, p. 2), "[…] studies of games used for research purposes are sparse." However, Greenblat and Duke already stated in 1975 that it has characteristics of being one and also Yiannakoulias (2022, p. 1207) mentioned that "In recent years, games have emerged to offer new opportunities for studying socioenvironmental systems […]".

According to Lieberoth and Roepstorff (2015), the use of a single measurement method while a game is being played leads to a loss of information. They (p. 271) call for a mixed-method approach when "[…] we are interested in both players and games, as well as the moments where they merge into play […]". The successful use of a mixed methods approach in project management has already been demonstrated by Bosch-Rekveldt (2015), whereby they made no use of serious gaming. Serious games can enrich mixed method research by providing a dynamic and interactive tool that supplements traditional data collection methods by offering a more fundamental understanding of complex socio-technical systems through experiential learning and behavioural insights of human beings (Klabbers, 2006). David and Winter (2021, p. 127244) revealed in their study "[…] that a game-based research approach, can not only answer core questions […], but uncover reasons why decisions are made." Also Levy et al. (2018) concluded that games have the advantage of reducing possible experimental cofounds by integrating an assessment into a game environment, but also that scenarios can be included into games whose examination in real life would be resource-intensive. Slegers et al. (2015) showed that the use of a board game gives broader feedback on user experience testing. This is supported by Lukosch et al. (2015, p. 2) stating that "[…] there is a strong potential for simulation games to be used as a research method since games produce an abundance of data related to user experience, decision-making, human behaviour and skills." In comparison with non-gaming experiments, serious games create an engaging atmosphere in a safe environment (e.g., Wang et al., 2019), in which players get direct feedback on their actions and do not need to expect any negative consequences regarding their shown behaviour. Based on the dynamics and experiences in the game and discussions about these dynamics and experiences, it is possible to get more insights into the behaviour of human beings. Serious games are seen as a participatory research method (Gugerell, 2023). According to Grogan and Meijer (2017, p. 4), a research "[…] game acts as a model of the real world to support observation, hypothesis generation, and hypothesis testing or, alternately, a platform on which to evaluate the efficacy of other artifacts". Because of these reasons, serious games are very capable in analysing, designing, and researching socio-technical systems and provide an environment to enable data collection using mixed methods, however, there are no "[…] established frameworks for the use of games as research tool […]" (Lukosch et al., 2018, p. 284).

According to Andrade (2022), research games are a special form of serious games. Grogan and Meijer (2017) discussed the potential of games as a research method, their work does not focus on practical implications for those who aim to design and use research games. In addition, Lukosch et al. (2015) stated that design principles for games to be used as a research method are rather undetermined. In their work, Gómez-Maureira et al. (2022, p. 1) introduced the term academic games defined as "[video] games that are used and developed within academic institutions for the generation, evaluation, or dissemination of knowledge." They propose four fundamental reasons for the use of video games in research contexts: stimuli, intervention, incentive, and modelling. As part of their derived research agenda (p. 8), they highlight that future research should focus on "The formulation of development guidelines, frameworks, and tool-kits that are aimed at academic games." Monteiro-Krebs et al. (2024, p. 6) made use of the Serious Game Design Assessment framework for the development of a research game. They defined several lessons learned, whereby the key lessons relevant to this paper are that "The quality of board game should be assessed from both a research and a game perspective […] [to] Adjust the game mechanics in light of your data collection […]". They (p. 7) also concluded that "Future studies could include new ways to analyse data from research board games, or creating a new framework for research games ideation." Wetzel et al. (2019, p. 329) mentioned in their article that "Research games are challenging to design as they seek to fulfil a research agenda as well as work as a game." This is also confirmed by Levy et al. (2018, p.1-2) who stated that "[…] games designed as research tools have a unique and challenging set of considerations so that they meet both the requirements of a scientific protocol, while also maintaining an acceptable gaming experience." In detail, one of the biggest challenges is "[…] engaging and appropriate game design." In addition, Cooper and Klein (1980, p. 41) concluded that "With careful scenario design it should be possible to satisfy the requirements [for research purposes]".

Doing research to projects considering a socio-technical approach, project management and related topics require both a quantitative and qualitative focus. Both have its own advantages and disadvantages; however, mixed method research seems a valuable approach to provide more understanding (Locatelli et al., 2017; Jiang et al., 2022). Serious games can be used in project management to enable engaging data collection during a realistic simulation of complex scenarios. This makes it possible to familiarise oneself with new and innovative perspectives in project management and to develop new methodological approaches. To the best of the authors' knowledge, no research has been conducted regarding the design and use of games for research purposes in the context of project management. For this reason, this more practice-orientated article focuses on the general design and use of serious games as a research method, but derive examples for the project management context. First, we focus on the design of games for research purposes. We will not dive into the general game design process and all types of choices that must be made as these can be read in many other publications about game design. We focus on what makes the design process different or how does the research objective of a game influence design choices. This results into the following research question: *What are specific requirements when designing serious games for research purposes?* Second, we dive into the use of games as a research method and discuss what kind of data can be collected and in which way. The corresponding research question is: *How to collect and analyse data by using a serious game for research purposes?*

The aim of this article is to illustrate design features of research games based on the Game Research by Design-Approach by addressing specific requirements for the development and use of research games, showing the potential of research games for analysing human behaviour in project management, illustrating examples of how data is collected and analysed when using research games, and providing best practices for researchers, designers as well as practitioners. Although the value of games as a research method is widely accepted, the question of how games are developed as a research tool has gained increased prominence. Without a structured approach, this potential remains merely a promise, perceived as playful rather than being taken seriously.

3. Game research by design-approach

Serious games can be used as a research method when the research questions are related to the interaction between people, organizations, and the physical environment (e.g., Yiannakoulias, 2022) and where other methods are not sufficient to answer the research questions. According to Kurapati (2017), doing research by using serious games means going through a so-called design and an empirical cycle.

Based on our experience of using serious games as a research method over the past 15–20 years within national and international research projects, we have expanded Kurapati's initial ideas. This is summarised in the *Game Research by Design*-Approach presented in this article. This approach consists of three cycles (see Fig. 1). Each cycle pursues a goal. The theoretical cycle should end with the derivation of (a) research

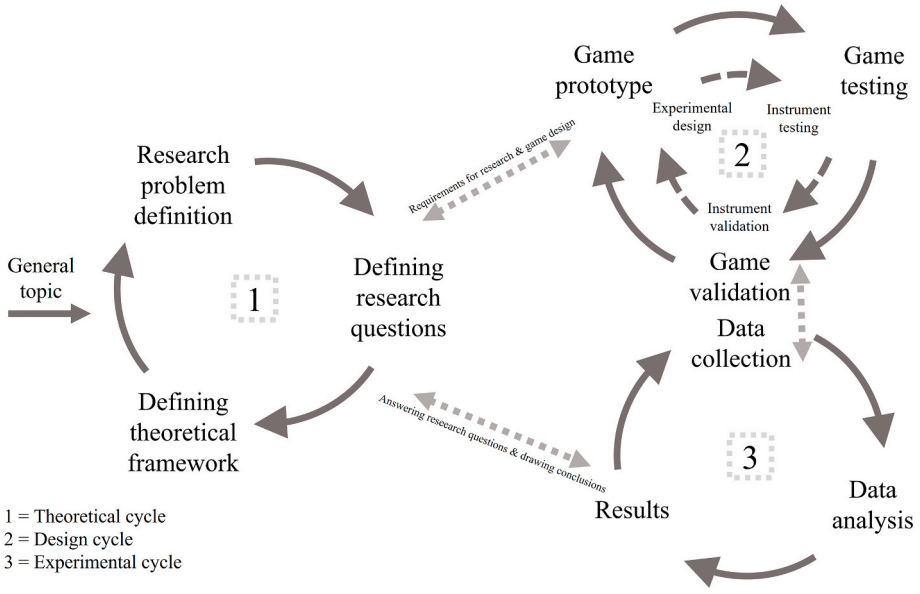


Fig. 1. Overview of Game Research by Design-Approach (own figure based on Kurapati, 2017).

question(s) (and corresponding hypotheses). The design cycle with the development of a research game (research question 1) and research instruments (research question 2) and the empirical cycle, in which data collected in experimental settings are analysed to draw conclusions and link the results back to the theoretical cycle (research question 2).

The following chapters emphasises the three cycles, in which aspects will be highlighted that are particularly relevant to games for research purposes in the respective phase.

4. Theoretical cycle: defining (a) research question(s)

The first cycle is called the theoretical cycle. According to Waern and Back (2017), the main objective is "To answer research questions […], and must supersede making a good game." Although there are many different approaches to construct research questions (Sandberg and Alvesson, 2011), in serious gaming research it is common to describe the problem statement (and later purpose of the game) based on a state-of-the-art analysis, the analysis of the theoretical background, and the identification of a research gap or even several research gaps. At the end of the theoretical cycle, the researcher has derived (a) research question(s) and a framework including a list of requirements for the research game and the experimental set-up to begin with the empirical research. As this step is comparable with other research approaches, we will only highlight aspects that are relevant for the design and/or use of a research game.

One of the important steps is to find the right research method to answer the research question. Many questions can be answered without designing or using games, however, for some questions, games could have an added value in comparison to simulations (quantitative approach) or questionnaires and interviews (qualitative approach). General research questions for game research are about how a system reacts to different actions of (multiple) stakeholders. With respect to project management in complex socio-technical systems, the following questions (to name a few) may be addressed:

a. What do project managers do when there is a delay in part of a process?
b. How do project managers communicate with clients or stakeholders?
c. What are the consequences when project managers take certain risks?
d. How will the project develop under different leadership styles?

What these questions have in common is that there is a link between the stakeholder's actions and the reactions of other stakeholders or the physical environment in the short and long term. Pure simulations can give insights in the physical development of the environment and, decisions of a stakeholder can be added as input, however, there is no feedback to the stakeholders' decisions. When the question is more about the stakeholders' actions and what they would do, interviews or questionnaires can be used, but again stakeholders will not receive feedback about the consequences of their decisions nor from the system or from other stakeholders. Games create an environment where stakeholders receive direct feedback from the simulated physical environment as well as other stakeholders in the game. If the stakeholder takes risks or lies to others, the stakeholder will experience the consequences later. In this way, a game can create a more realistic environment to research the behaviour of stakeholders.

"[…] Translating research questions into engaging gameplay elements […]" has been identified as a source of tension in the context of research games (Wetzel et al., 2019, p. 354). Also, Levy et al. (2018, p. 1) emphasized the need to pay attention to "[…] what game mechanics precipitate the kinds of data that would answer the research questions". This means that when designing research games, particular attention must be paid to the design of elements of the game and the mechanics, because they can all trigger different reactions in the players when they play. As Levy et al. (2018, p. 3) emphasized "Games present an exciting opportunity to be both highly valid and reliable scientific methods and tools. However, their design and use in this role is drastically different than their normal operation […]".

5. Design cycle: development of a valid research game

After the definition of the research gap(s), derivation of (a) research question(s), and the conclusion that gaming is the most suitable method to answer the research question, the design cycle starts.[1] The goal of this cycle is to develop a valid research game that can be used as part of the experimental set-up. Research games differ from other games in that the transfer of knowledge from the players acting in the game to the

[1] For this article, we assume that you are planning to develop a new game, however, in some situations, a (serious) game that fits is already available, so it is worthwhile to at least spend some time searching for existing games (state of the art analysis).

researchers is carried out through quantitative and/or qualitative data collection and does not remain exclusively with the players (Peters et al., 1998). The design of research games consists of an outer and inner circle with three steps each. The outer circle refers to the development of the (research) game. The inner circle refers to the design of the experimental set-up. Based on the analyses as part of the theoretical circle, a list of requirements for the research game and the experimental set-up should be available. The game design starts with developing prototypes, testing different prototypes, validating your prototypes and checking the requirements again and start a new cycle until the game design is perceived as valid as a research method. You go through the design cycle several times. Over the years, many different design approaches have been applied (for more information on game design research see also Lankoski and Björk, 2015). Several design approaches started from a *simulation perspective*, where a game designer tries to grasp real world simulation in a game (e.g., Duke and Geurts, 2004; Klabbers, 2006, 2009). We also see design approaches starting from the perspective of different *game elements or mechanics* (e.g., Hunicke et al., 2004; Winn, 2009). From an educational perspective also design approaches are developed with a strong link between *games and learning* (e.g., Westera et al., 2008; Faber et al., 2018).

5.1. Game prototype and experimental design

The question whether specific design choices should be considered when designing research games and how this could deviate from games with other objectives will be discussed based on Harteveld's (2011) Triadic Game Design (TGD) philosophy. The TGD is used because this approach is a well-recognized and often cited procedure for generating general requirements and initial game concepts. The core of the TGD is to balance the three different 'worlds' of reality, meaning and play. The following sections explain these worlds in the light of research games.

5.1.1. Reality: Defining the 'right' system boundaries

Serious games are a simplified representation of a real-world system. A system is understood as "[…] one in which there are multiple interactions between many different elements of the system […]" [Ridolfi et al., 2012, p. 39]. To get a better understanding of such a system, a thorough analysis of its dynamics, actors, relations and challenges is required with the aim of obtaining a model that represents the basis for the development of a serious game. This is often already part of the overarching (research) project and theoretical cycle but needs a different approach to create a serious game for research purposes. Mapping out the complexity clarifies the challenges, but it can still be difficult to define the problem within the system that the game should address (Freese and Lukosch, 2024). What elements should be in the game, and which might make it too complex or confusing. While doing a thorough system and actor analysis, many elements and issues might come up, but choosing too many of them makes the game too complex and less efficient. It is therefore important to define the underlying problem the game should address (Duke and Geurts, 2004), as this will serve as a valid reference for the game design. To be able to make the 'right' decisions and focus on the relevant aspects only, iterations and back and forth loops are recommended. During these phases, aspects of the TGD-World of Reality and related questions (Harteveld, 2011) as well as methods to approach a certain specificity (Freese and Lukosch, 2024) can be used. This is a balancing procedure and must be done in consultation with the target group or subject-matter experts. The use of an adequate model of a simplified reality is of utmost importance to guarantee a valid research game, which allows conclusions to be drawn (Klein, 1985; Peters et al., 1998).

5.1.2. Meaning: Defining the game objectives

The objectives should be described very precisely. As the goal(s) *of* the game and the goal(s) *in* the game are often complex, overlapping and might change over time, this might become a challenge. The objective of a research game is to answer the research question(s) by collecting data about the behaviour of the players and the system. Other researchers and (commercial) partners within a (research) project have their own interest(s) in the project and game. They might have non-research related objectives in mind which could potentially conflict with the objectives of a research game. For example, to make it interesting for players to join, often a secondary learning objective is added. Although these objectives could overlap, it is very important to define the non-research and research objectives separately to avoid diffusion in game play and data collection.

5.1.3. Play: Creating a game prototype

The idea for a research game probably arose before the system analysis was done. That is what probably initiated the analysis in the first place. There is no correct sequence of the steps of analysis, design, and development. The best process is a mixed and iterative one, where you start with one aspect, which feeds into the other, after which you return to the first because more information is needed to continue with the second. The minimum requirement to be able to start designing your game is defining the system and the problem. Once you have done that, you can start defining the right type of game that fits with your chosen system and problem. Selecting the right type of a game can be understood in multiple ways and presents different choices to make. They are very important as all these choices influence the complexity of the development process and the resulting game experience and data collection. There is no black or white solution; a game can be realistic or use metaphorical elements only, can be both digital and analogue, and can have single- or multiplayer elements. According to Levy et al. (2018, p. 3), the design of research games differs from conventional design processes, since "There exists a balance between having "enough" of a game that engages the player and produces the desired data, but where the design does not interfere with the validity of using the game as a scientific instrument." To reduce 'noise', the implementation of for instance luck by rolling a die requires careful consideration. In deciding for or against any of the above forms, a researcher must always consider the research objective and derived relevant system components.

High and low degree of realism: Games are models of reality, and these models can be represented on different levels in terms of abstraction from reality. A distinction is made between social and physical realism. Regarding social realism, the focus is on the behaviour of players, while physical realism says something about the representation of the physical system. The focus and the identified boundaries of the TGD-World of reality gives insights in what is important for the research. For some questions (e.g., What are the consequences of selecting a specific type of material for the strengths of the construction?), the representation asks for a high level of physical realism, while communication might be less important. On the other hand, research about trust between competing companies, requires a high level of social realism, while the physical representation might be less important. This leads to different types of games and different levels of realism. Cooper et al. (1980) warn that experts in a field will bring an additional realism from their experiences into the game, which affect game play and game outcomes. Gralla and Szajnfarber (2018) concluded that inexperienced participants have more difficulty with translating medium fidelity games to reality, while experienced participants can deal with medium-fidelity settings.

We conclude that research games can be abstract, however, the right characteristics of the reference system (reality) need to be present. Van den Hoogen et al. (2016) state that when you miss these characteristics of the reference system, you may endanger the transfer of causal claims made within the gaming simulation to the real world.

Digital, analogue, and hybrid games: An analogue game is a game that does not use digital support. In these games, the 'physical' system is represented in the story, the cards, and other game elements. A digital game can be played on consoles, PC's, mobile devices etc. With these digital forms, the physical world can be represented in simulations and virtual (3D) environments. In other words, you can reach a higher level

of (physical) realism. Third, hybrid forms of games use digital tools to support calculations and changes in the physical system, but players communicate directly to each other. The different forms of games have many implications for the experience of players and the choice depends on the objectives in the game and other game design choices.

Doing research with a digital, analogue or hybrid game highly differs depending on the type of data collection and how relevant concepts have been operationalized as part of the theoretical cycle. Cooper and Klein (1980) stated that it is important to think about data collection as this has to be done without disturbing the game play. Digital games can easily track player's choices and can have larger player bases, resulting in reliable, quantitative data. Collecting data with analogue games is much harder, as tracking in-game data is more challenging. This can be compensated by using separate questionnaires, making observations and doing recordings which will result in much more qualitative data. The advantage of interactions in analogue games goes hand in hand with the challenge of keeping analogue settings and the variables to be studied controllable, however, once the focus is on human behaviour and human-human interactions, the social and emotional components in analogue games are especially important to emphasise on.

Developing digital games is very often underestimated. Designing the game, creating the back- and front-end, art and doing the testing, tweaking and bug-fixing for such a game can take a lot of time. Sometimes it might be possible to already start doing research with a working prototype. This might save a lot of development time, like making detailed artwork and production materials. On the other hand, research might require complex (digital) models in the game, and this will result in more work. Similarly, creating databases and other back-end features to track players actions for research purposes will also result in a heavier workload in the development, however, it can save time in data collection. Especially if a high number of respondents/players are expected it could be worthwhile to invest in digital support.

The question of the extent to which the investment in developing a digital game is worthwhile should also be linked to the extent to which the game should be played with whom and in which environments. This should be the result of the requirement analysis. The same applies to the question of the degree of realism to be implemented, which then has an influence on the decision as to whether an analogue or digital game should be used.

Singleplayer or multiplayer games: Another design choice is the question regarding the development of a single- or a multiplayer game. A singleplayer game is a game where one player is playing against the 'system'. In multiplayer games, two or more players are playing together or against each other. The choice for or against a singleplayer or multiplayer game depends heavily on the defined objectives as well as on the boundaries of the previously analysed system. The guiding question should be in what form the system studied can best be presented under consideration of the research purpose. The choice between a singleplayer or multiplayer game from a research perspective is therefore often easily made, but there are situations in which it is not very apparent. In situations where getting people together is challenging (due to external resources, or availability of players), you could replace human players with computer-simulated players, or, in the case of a board game, consider several characters as part of the storyline of the game. The other way around, a game that might seem obvious to work as a singleplayer game might benefit heavily from multiple players, in the least to compare scores, but in the best case to discuss and interact about the core matter of the game.

Even though Levy et al. (2018) focused in their article on video games, they provide, in addition to co-creation in interdisciplinary teams, a number of design choices for games to be used as a scientific tool (experimental games). The game should motivate the players to play the game in an engaging way and should elicit the actions from the participants that generate the data relevant to answering the research question. The game should be "[…] good enough […]" (p. 9) to fulfil these requirements, but it doesn't have to be perfect. Understanding and exploring the game (rules) already represents a learning process. To minimize the learning curve, it is recommended to refer to "[…] elements or interfaces that the target demographic is already familiar with, either from real life […] or from well-known game tropes […]" (p. 9). This is in line with the guidelines of Cooper and Klein (1980) which recommend simple or easy to learn rules, for example by using rules from the real-world system. In contrast to serious games, which are related to learning or education and thus inevitably initiate some kind of change process, be it on a cognitive or behavioural level, research games focus on answering research questions by analysing an actual state. Levy et al. (2018, p. 9) expressed the need for players to "[…] play the right way […]" by providing a "[…] careful design and subsequent testing […]" to ensure that players can only play in the intended way. When developing research games, the research objectives must be defined and taken into account from the very beginning of the development.

5.1.4. Experimental design

In addition to the development of a playable prototype of a research game, the development of the experimental design is also important. When serious games are used as a research method, they can be described as "[…] rule-based, interactive environments, where players learn by taking actions and by experiencing their effects through feedback mechanisms that are deliberately built into and around the game" (Mayer, 2009, p. 825). Researchers can make use of these environments to plan and set up their experiments including modelling of processes, data gathering and testing hypotheses. Serious games provide an experimental environment to gather data according to a specific research question. Yiannakoulias (2022, p. 1213) stated that "Online computer games can also accommodate longitudinal research designs […]" which "[…] might offer new opportunities for research that could be particularly useful for understanding changes in perspectives or behaviors […]".

Gaming can be seen as a mixed method research approach, where different sources of data, quantitative and qualitative (Monteiro-Krebs et al., 2024), can be collected and combined. Monteiro-Krebs et al. (2024, p. 7) described as an example of quantitative data "[…] the moves of the players, the associations between different cards and the socio-demographic characteristics […]" and for instance letting "[…] players to express their thoughts on the decisions they are making […]" as qualitative measurement. This approach can have an exploratory, an explanatory or a convergent design (Creswell and Plano Clark, 2011). In the design of your experiment, an important step is how to operationalize the main research concepts, which is part of the theoretical framework (cycle 1). A next step is to design the research experiment and identify how the necessary data must be collected.

There are several options for the research design. To measure changes in knowledge or attitudes of the participants, pre- and post-test design is recommended (Bellotti et al., 2013). For research games, it is often more relevant to look at the game play itself. The game environment is the simulated world in which players take decisions. A researcher can observe this behaviour and translate this to the reference system. This can be a more explorative study as well as a more experimental one. In the explorative study, the questions and observations are more open, which also requires a broader data collection approach not to only measure effects but also to explain the behaviour of players. In an experimental study, the focus is more on testing hypothesis or comparing different scenarios. In this type of study, a game can be played with different starting situations/scenarios and the outcomes can be compared.

A second part of the design of the experiment is the design of the data collection tools. Smith et al. (2015) found the following mostly used instruments: interview, focus group, questionnaire, direct and indirect observations. had an even more extended list of data collection in where video and audio recording, biometrics and logging of game data is also mentioned. Questionnaires are used to collect opinions of the process and game outcomes. Other instruments for qualitative data collection

are interviews or focus groups. The debriefing is also a source of information, just as observations during game play. Quantitative data are for example in-game data, such as specific key performance indicators based on scores in the game but also time-related aspects and decisions that can be scripted. This in-game data collection can be integrated in the game design, for example in digital games where specific variables are saved or where players write things down.

Before designing your game, it is important to know what the process of development entails in terms of time, cost, and people that might be needed. It is important to find the right people to design and develop the game and research set up. Some options of developers include commercial (serious) game design companies, freelancers, (graduate) students or, if you have the right skills, you yourself. Try not to involve developing parties too late in your process, because their skills determine what you can and cannot have in your game and of course it is strongly recommended that researchers and designers work closely together from the very beginning. This co-creation process has also been highlighted by Wetzel et al. (2019) and under the term of trans-disciplinary teams by Levy et al. (2018). For a good integration of the game design and design of your experiment, it is advised to design this in parallel. One of the limitations of games is that only a limited number of sessions can be played due to time constraints and availability of participants. Therefore, a triangulation of data is recommended to increase the reliability of the results.

5.2. Game and instrument testing

The only way to prove that your game experience is effective is by testing this interaction. This should be done very early on and on many occasions after that, because testing is the backbone of game development (see Schell [2008] for different types of testing).

Testing your game with experts and especially with your target group will positively influence the development. It is necessary to validate your design choices and to make you throw away ideas that might have seemed good but really do not work. It can be a challenge to find testers, especially if you test often and want to constantly get new perspectives. Playing your game with colleagues, friends, and acquaintances always works and will be useful. Use them to test your game on usability and quality assurance especially, however, your game needs to be played by the target group to do the real playtesting as well. If the target group is small, you might want to find people with similar backgrounds and ask them to empathise, for example students. In this case, it can be an opportunity to train students and familiarise them with the subject matter at least to a certain level (Freese et al., 2022).

Next to testing the gameplay, it is important to test the experimental set-up, data collection approach, and instruments to be used as well. The measurement validity is part of the next step, in this step we mean to test how the data collection is part of the gameplay. The idea of games is that players step into a magic circle (Klabbers, 2006, 2009) and become in such a flow that they forget the world around them (Csikszentmihalyi, 2002). Adding all kinds of data collection instruments can interrupt this immersion. As player you can feel you are assessed when cameras are recording or when observers take notes of your actions. Another distraction is when players must do administrative tasks to collect data, without any relation with the game. As designer and researcher, you need to design the research instruments in such way that they are part of the game play. Players can take notes if this has a function in the game, observers can ask questions from the perspective of a role. For example, an observer is playing a journalist and is collecting data for an in-game news article. In this way, players stay immersed, and data can be collected about the reasons of the actions. Therefore, it is important to also test your research instruments and see how these instruments are part of the game or could affect the immersion of the players.

5.3. Game and instrument validation

Validity is defined as the extent to which one can translate the findings to reality. In the context of games, validity is understood as "[…] the degree of correspondence between the reference system and the simulated model thereof" (Peters et al., 1998). This is highly relevant especially when talking about research games, because the data collected by using a research game and analysed form the basis for drawing conclusions. If the method itself is not valid, the conclusions based on it must be questioned. The link between realism and validity in serious games lies in the extent to which the game represents and simulates real-world scenarios, contributing to the effectiveness of the intended objective. According to Raser (1971) and Peters et al. (1998), there are four different aspects that characterise validity: psychological realism, structural validity, process validity, and predictive validity.

Other researchers talk about fidelity which describes a games' resemblance of the real system, and can be described by the dimensions of physical, functional, psychological, and social fidelity (Lukosch et al., 2019). Both validity and fidelity make a distinction between different ways in which a game can be abstract representation in terms of processes (process validity or functional fidelity), interactions (structural validity or physical fidelity), which describes the degree to which a game simulates the physical properties of its reference system, and tasks to be carried out in real systems and in a game. And both talk about psychological validity and fidelity describing the cognitive and psychological dimensions of a game (Alexander et al., 2005) and finally, social fidelity refers to how well social interactions and social reality are represented in a game (Galloway, 2004).

The validation step also requires the instrument validation, which means that it must also be ensured that the instruments measure the intended constructs. As earlier described, a researcher can collect different types of data in different ways, both qualitative (observations, questionnaires) and quantitative (in-game data, game output). Van den Hoogen et al. (2016) explain that the instrument or measurement validity contains three categories - construct, criterion and content validity and that there are linked with the validity of the game. In the design of the game, choices are made about the main characteristics of the system under study, these main concepts are translated in game elements. These game elements have a specific meaning in the game and this needs to be considered in the use of game data and analysis of the data and how this translates back to the system under study.

6. Empirical cycle: conduction of a study by using a research game

After the development of a valid research game and research instruments, the empirical cycle begins. The goal of this cycle is to collect data to be able to answer the previously derived research questions and to be able to draw conclusions. The empirical cycle consists of three steps: data collection, data analysis, and results.

6.1. Data collection

The data collection takes place around the game session. The researchers need to organize these sessions and make decisions how this takes place. In the previous cycle, the gaming session is already designed, which will differ per game. Some games will be part of a workshop, others are distributed online. Yiannakoulias (2022, p. 1207) stated that especially "[…] online games […] offer a low-cost option for collecting rich data from diverse populations." In addition, online computer-based games, in particular, have the advantage that they can run for a long period of time and that they are accessible to a large part of the population (Yiannakoulias, 2022). An exemplary overview of different qualitative and quantitative approaches in relation to games can be found in Lankoski and Björk (2015). In this phase, the sessions need to be prepared to ensure the three-goodness criteria *objectivity*,

reliability, and *validity*. Guarantying all three criteria is one of the main challenges when using games as a research method because of the dynamics of a game.

A gaming session normally consists of a briefing (giving background information, explanation of rules), game play, and a debriefing (making a connection between game play and real world). During all these phases, it is possible to collect different types of data. You can collect data about the game play itself or collect data in the context a game is played (Lukosch and Cunningham, 2018). A singleplayer online game does maybe not have a briefing and/or debriefing, still data can be collected during game play and the context it is played. To be able to know how many sessions should ideally be organized, tools such as G*power (Faul et al., 2007) make it possible to estimate the minimum number of the sample. In the preparation of a session, the researcher decides on the following points:

a. Target group: who will be your players, are they also the target group of the research or do they maybe need to be prepared;
b. Facilitators and observers: the facilitator can have a large impact on the game play, so they must be briefed how to facilitate the game and how to reduce the impact on the gameplay;
c. Location: the location requires enough space to play the game in a good atmosphere;
d. Ethical committee: as this research is done with people, you need to get an approval of the ethical committee to collect data;
e. Informed consent: this often involves obtaining participants' consent to their data being used for research purposes.

Research games have the huge advantage of being able to collect data by providing participants a meaningful experience in comparison to other forms of data collection (Yiannakoulias, 2022). The benefit of serious games - the focus on human beings - is at the same time a big challenge as well. Gaming sessions create many variables that can hardly be controlled, which makes it difficult to repeat the experiment under the same circumstances, however, protocols and checklists can help to guarantee a standardized research set-up up to a certain extent. For an experimental setting it is possible to write down the complete introduction that needs to be read out loud to avoid differences in the starting situation and thus, to guarantee a standardised procedure.

A gaming session ends with a debriefing, where in serious games the experiences in the game are discussed in line with the (learning) objectives. As in research games, the learning is not the main objective, the debriefing focuses on the validity and reliability of the results in the game and translation to the reference system (Van den Hoogen et al., 2016). The debriefing also provides the opportunity to let the participants cool down, to protect the instrument of gaming simulation and to validate the researcher's interpretation of simulation outcomes (Peters and Vissers, 2004).

6.2. Data analysis

Different sources of data, as discussed above, requires different ways to analyse the data and to combine the data. The more common analysis are descriptive analyses, such as median, mean, standard deviation, etc. More advanced analysis are causal analysis and regression analysis or *t*-test to measure differences, in some cases it is even possible to do some structural equation modelling if sufficient data is available. For more details about how to do statistics or how to code interviews we refer to the existing literature about these instruments.

From previous experiences, we would like to share some of our experiences. One of them is that is not only interesting to look at the average of the group, but especially focusing on the outliers. For example, when a player is doing something different than the average player, this can give insides in extreme situations, or it can start follow-up research of what the consequences could be for the system under study. What happens when somebody else takes the lead? Or what if some stakeholders are treating? All these unexpected results could give interesting information about the resilience of the system.

As mentioned earlier, it is sometimes difficult to get enough data for statistical analysis, therefore triangulation of data can increase the validity of the results, as you use multiple data sources to study the concepts. Next the researcher needs to reflect on all kinds of surrounding variables that could influence the results or that makes comparison between different sessions complicated.

The possibilities of data analysis are large and highly dependent on the collected data. It is recommended to also look in other fields what can be used for the analyse. For instance, van den Hoogen et al. (2016) used event-structure analyses or Lukosch and Cunningham (2018) made use of Bayesian analysis technique. The latter ones argue that this technique is designed for open and uncertain systems such as games.

6.3. Results

In the final step of the empirical cycle, the results must be discussed in the light of the hypothesis (accept or reject) or theoretical framework to give meaning to the results in more explorative studies. As this step is not specific for gaming research and highly depend on the data collection and research questions, we will not go into detail about how to do this. One important part of the discussion is the translation of the game to the real world. As the games are seen as a representation of the real world, it is easy to say that the results in the game world can be translated to the reality, however, this must be done with care as also games are a model of reality and during the design, choices have been made to develop a playable game. An important part of the discussion of the results is to be critical about this translation and discuss the limitation of the game.

7. Applied game research by Design-Approach – serious game "where to move"

To put the previously mentioned cycles into a practical context, we will provide an example of a serious game entitled Where to Move (van Leiden, 2023). This game has been developed at Delft University of Technology and was part of a research project about flood prevention in province of Limburg, the Netherlands.

7.1. Theoretical cycle

Due to climate change, the change of flooding increases and the existence of public flood measures only (such as dikes) are expected to be insufficient in the future. House owners should also take private flood protection measures to reduce the risk of flooding or reduce the damage, but this is rarely done. The research question therefore was: Do house owners take private measures and if so, what type of measures and what are their reasons to act (or not). A serious game was selected as research method as players could experience the consequences of their choices and observe the behaviour of their (in-game) neighbours. Regarding the theoretical cycle, the associated analyses resulted in the derivation of the following questions: What are the preferences of houseowners for flood protection? Are these preferences influenced by information and flood experience? Two theoretical models, the Protection Motivation Theory (Rogers, 1975) and the Tiebout Model (Tiebout, 1956), were used as frame of reference.

7.2. Design cycle

Reality: The researchers wanted to collect the preferences for flood protection of house owners. In the analysis many different boundaries had to be determined. For example, a limited boundary with focus on flood risks or a broader boundary including other risks for house owners as well (e.g., fire, droughts, etc). Only focusing on floods would mean a research focus on different types of flood protection. While considering

different types of risk, the research shifts to identifying which risks are more important to house owners and the type of protection they prefer to invest in. Both could give a valid representation of the real-world system, but they contribute to answering different research questions. This example shows the importance of the relationship between research objectives and design choices, and the need to make them carefully.

Meaning: The objective of the game was to research the preferences of house owners and their willingness to invest in flood protection measures. To make it more interesting for players (the 'respondents'), a learning goal could have been added. In this situation, this was a conflict, as the research was on existing behaviour, and in a learning game, participants are supported to change their behaviour. The researchers decided not to focus on a secondary learning objective. At the same time, they were aware that while playing Where to Move, players will learn about flood protection and its measures.

Play: Where to Move is a board game due to limited resources. To learn about the preferences of house owners, the players represent house owners and could decide where to buy a house and how to adapt the house. As the future is uncertain, just as the available measure and it effects, the decision was made to somewhat realistically represent the public and private flood measures, effects and prices. The measures not mimic reality exactly, but on a scale of high, medium, low impact. As one of the assumptions based on theory was that peer pressure could play a role in decision making, Where to Move was developed as a multiplayer game, even though the research focus was on individual preferences. In this way, the decision-making process and social realism could be high, while the physical realism was lower to increase playability, but still has the main characteristics of the reference system. As consequence, data about the measures can say something about the type of measures households prefer, but do not give insights in the exact prices of the measures or the exact reduction of damage costs after a flood.

The design of the Where we Move gives an illustration of several (of the many) choices that have to be made by designers and researchers. For each choice, the research objectives are leading and validity of the instrument is important. This could negatively influence playability, which is more important for entertainment games and learning games than for research purposes. The mechanics of the game worked well, but testing showed an administrative burden for players. As the researchers wanted to play the game more often, they decided to invest in a supporting digital tool to facilitate data collection.

7.3. Empirical cycle

The Where to Move game has been played several times by students interested in water management and from people of a municipality in the Netherlands (Van Leiden, 2023). Both groups are slightly different from the real target group (home owners). An introduction of the role was part of the briefing of the game. What was excluded on purposes was the focus on public and private flood measures to avoid framing the participants. After the game play, participants were told about the research objective (approved by Human Research Ethics Committee).

For a comparison between informed and less informed home owners, the researchers had two instances of the game: one with complete information about the effects of the measures and one where the effects are only visible after implementation. Assuming other variables can be considered as constant, the outcomes can be compared. Data analysis has been limited to descriptive analysis due to the limited number of sessions. From the descriptive data, we learned that households prefer the 'old' grey measures, such as dike protection and one of the reasons was the lack of information about the private measures (Van Leiden, 2023).

Although this example is not directly related to project management, the outcomes could be used in the development of flood management projects for municipalities. The gaming sessions provided information about the preferences of inhabitants, which can be used in a strategy to inform the public.

8. Discussion

New research approaches in project management focusing on both "[…] human factors and intricate relationships between project components […]" are needed (Ackermann and Alexander, 2016, p. 891). It is precisely these components and their relationships, highlighting the role of the human factor, that can be understood under socio-technical systems. Research on complex socio-technical project management requires both a quantitative and qualitative focus (mixed method). Serious games are a useful and meaningful tool for analysing and designing these (Klabbers, 2006; Lukosch et al., 2018).

Serious games can be used in project management to enable rich data collection while proving an engaging and meaningful experience. Using games as a research method, comes with several advantages. They provide a more fundamental understanding of complex socio-technical systems, considering the role of human beings (Klabbers, 2006) and represent a safe environment (Wang et al., 2019) addressing scenarios whose analysis in the real world can be very resource-intensive (Levy et al., 2018). They enable a rich collection of data (Lukosch et al., 2015), while at the same time providing a meaningful and fun environment for the participants and high ecological validity (Washburn, 2003; Yiannakoulias, 2022). In addition, serious games can help to reduce experimental cofounds by integrating assessments as part of the game (Levy et al., 2018). These results show a number of crucial advantages in comparison to other methods, but to the best of the authors' knowledge, there is no holistic and structured approach that focuses on the development of research games. Although the value of games as a research method is widely recognized, how games are developed as a research tool has become an increasingly important question, which leads to the call for structured approaches (Lukosch, 2018; Gómez-Maureira et al., 2022; Monteiro-Krebs et al., 2024). The Game Research by Design-Approach meets this demand. The present article provides guidance on design decisions that will have a significant impact on the use of games as a research method.

Careful design and implementation are important regarding the use of serious games as a research method in project management. This can be initiated by the structured approach presented in this article. When used as a research method, serious games are a valid tool for generating rich quantitative and qualitative data in project management. This is possible because serious games themselves are simplified models of reality to simulate complex project management systems and their real-world challenges. However, the success of this approach also depends on the careful consideration of some limitations.

A research game has many degrees of freedom, which means that the game creates a space in which players can interact. Through actions and interactions, the game can move in directions that are not always controllable in advance. According to Waern and Back (2017, p. 159), "The player experience does not arise from the game as such, but from the game session in which the player has participated." In addition to game design, there are many cofounding factors, such as "[…] how players were recruited to the study and with whom they are teamed up" (Waern and Back (2017, p. 159). Furthermore, the influence of the facilitator on the interaction of the player and between the players must be considered. All this leads to research game sessions with a "large number of variables that are hardly to be controlled in a dynamic situation of game play" (Lukosch et al., 2018, p. 284). In order to use games as a valid research tool, it is important to control and standardize session parameters as much as possible. Our advice is therefore to use a triangulation of data collection and apply a mixed method approach to increase the validity and reliability of the collected data. Further, we mainly focussed on games that are played in a (semi-)controlled environment with a facilitator. If you are developing a game for research purposes that will be distributed online and needs to be played by many participants in order to collect enough data, additional attention needs

to be paid to promoting the game and keeping participants involved. Lieberoth et al. (2014) used the behavioural chain for online participants based on Fogg and Eckles (2007) to design the game approach.

Another challenge is the alignment of data collection and game play. For realistic behaviour, participants need to be immersed in the game play and stay in the magic circle. Asking them to complete questionnaires or other forms could break this ambiance. Data collection using in-game parameters and game outcomes (e.g., log files) is generally easier to implement in digital or hybrid games. One idea for analogue research games might be to define the process of data collection as part of the game play. Therefore, it is recommended to design the game and experimental set-up integral. Another point of discussion related to the behaviour of players is that participants are aware that they are playing a game and act in a safe environment. Therefore, they could behave in a different way, by for example taking more risks, or do something different than normal just to explore the effects. The debriefing can be used to validate these actions, and this feedback can be used for the interpretation of data (van den Hoogen et al., 2016).

Generally, games are a relative expensive research method in comparison to interviews or questionnaires. The development of the game itself costs time and money, also organising sessions and the time investments of the participants is higher. Compared to real world experiments and living lab kind of methods, games have the advantage of being less expensive and in a safe environment, however, researchers need to have the resources to make it possible. Using existing serious (or entertainment) games and adapt the game slightly for the research purposes, reduces the investment in the design cycle. Another option is to add a learning objective to the research game, but this must be done in a balanced way so that the learning objective does not interfere with the research associated with the game. In research games, you want to simulate reality as it is or to explore a future situation, in learning games, you want to steer the participants to apply new knowledge or practice specific skills, which is maybe not their natural behaviour. Finally, in some situations it is already useful to use a playable prototype of the game to collect data. The finishing touch of the game is very time consuming and contribute maybe less to the objectives of the research. As the design team is involved in the sessions, the game could be good enough for the research purpose.

The discussed Game Research by Design-Approach is another tool in the researchers' toolbox to collect and analyse data, but also provides best practices for designers as well as practitioners.

9. Conclusions

The Game Research by Design-Approach provides a holistic and structured approach focusing on three cycles. In addition to the research problem definition, the aim of the *theoretical cycle* is to derive requirements for the game and experimental set-up. In the *design cycle (*research question 1 and 2), the development of a valid research game, but also the preparation and associated testing of all elements of the experimental set-up (e.g., use of quantitative and qualitative measurement) is done. This forms the basis for use in various sessions as part of the *empirical cycle* (research question 2) to enable data analysis and interpretation of results so that research questions can be answered and conclusions drawn. The Game Research by Design-Approach offers a structured way that can be used by researchers, practitioners and designers.

By considering all steps of the structured Game Research by Design-Approach, specific requirements for the development and use of research games can be derived.

9.1. Theoretical cycle

At the end of the theoretical cycle, the research question must be derived. If this is not the case, the theoretical background and the definition of the research problem need to be further explored (iterative procedure). In accordance with Levy et al. (2018), it is essential to know what the research question is before developing or adapting a game. Translating the results from the theoretical (research questions) into the design cycle (game elements, mechanics, and/or interface) is one of the biggest challenges, but must be done with absolute care (Levy et al., 2018; Wetzel et al., 2019). It is important to consider which variables to measure and how to answer the research question, and to what extent the data can be collected through certain elements or mechanics in the game.

9.2. Design cycle

At the end of the design cycle, both the research game and research instruments must be developed and elaborated. The aim should not be to develop a perfect game. The game just has to be good enough to motivate the participants to play it and at the same time enable the collection of data (Levy et al., 2018). In addition to the development of the research game, the development of the experimental design must be completed and well-integrated in the game design. As gaming can be understood as a mixed method research approach, not only in-game data, but also qualitative data can be measured (Monteiro-Krebs et al., 2024). When transitioning from the design to the empirical cycle, it is important that the variables are precisely operationalized and that the game has been checked for validity. A test session is also recommended to familiarise yourself with the game and session procedures.

9.3. Empirical cycle

The empirical cycle ends with collected data and their analyses to be able to link drawn conclusions back to the theoretical cycle.

The use of games as a research tool has great potential as games are the only method that can combine people's behaviour and reaction in a simulated environment based on a reference system. The immersive environment encourages participants to behave realistically, and feedback from the game and other participants in a multiplayer game also provides insight into how people take this feedback into account. This is interesting for project management when it comes a) to acquiring soft skills as well as conceptual knowledge (Geithner and Menzel, 2016), b) to promoting systems and critical thinking (Barnabè et al., 2023), and c) to training how to react to and in unpredictable situations (risk management; Annunziata et al., 2024). Often, students are tested in these studies. In future research, and taking into account the approach defined in this paper, more research with experts from the field of project management would be desirable. Several examples also demonstrate the added value of using games as a research method (Meijer, 2009; Kurapati, 2017; Freese et al., 2020). Although the potential of serious games is recognized by several researchers and more examples are becoming available, the use of games for research purposes is still an unexplored area. This article is a first step to a holistic and structured approach and further research is necessary to make use of this approach in project management and give more detailed guidelines about setting different design choices and empirical steps. Step-by-step more knowledge and experience are needed to improve the quality of data collection and to combine results from different instruments. In the future, each step of each cycle could be further elaborated and the results made available in the form of a checklist.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Maria Freese: Writing – review & editing, Writing – original draft, Visualization, Methodology, Conceptualization. **Geertje Bekebrede:**

Writing – review & editing, Writing – original draft, Visualization, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

References

Abt, C., 1987. Serious Games. University Press of America, Maryland, USA.

Ackermann, F., Alexander, J., 2016. Researching complex projects: using causal mapping to take a systems perspective. Int. J. Proj. Manag. 34 (6), 891–901.

Alexander, A.L., Brunyé, T.T., Sidman, J., Weil, S.A., 2005. From Gaming to Training: A Review of Studies on Fidelity, Immersion, Presence, and Buy-in and Their Effects on Transfer in PC-Based Simulations and Games. Darwars Training Impact Group. Aptima, Woburn, MA. Available at https://www.cs.uky.edu/~sgware/reading/papers/alexander2005gaming.pdf [26.11.2023].

Andrade, P., 2022. Sociological (Re)search Games: play and transfer cultural knowledge among social sciences, museum staff and publics. In: *Proceedings Of the 10th International Conference On Digital And Interactive Arts* (ARTECH '21). Association for Computing Machinery, New York, NY, USA, pp. 1–12. https://doi.org/10.1145/3483529.3483660. Article 16.

Annunziata, G., Lambiase, S., Palomba, F., Ferrucci, F., 2024. Serge – serious game for the education of risk management in software project management. In: *Proceedings Of the 46th International Conference On Software Engineering: Software Engineering Education And Training* (ICSE-SEET '24). Association for Computing Machinery, New York, NY, USA, pp. 264–273. https://doi.org/10.1145/3639474.3640085.

Barnabè, F., Armenia, S., Nazir, S., Pompei, A., 2023. Critical thinking skills enhancement through system dynamics-based games: insights from the project management board game project. Systems 11 (11), 554.

Bellotti, F., Kapralos, B., Lee, K., Moreno-Ger, P., Berta, R., 2013. Assessment in and of serious games: an overview. Advances in Human-Computer Interaction 2013, 1.

Bosch-Rekveldt, M., 2015. Applying mixed methods for researching project management in engineering projects. Designs, methods, and practices for research of Project Management 26, 327–340.

Calderón, A., Ruiz, M., 2015. A systematic literature review on serious games evaluation: an application to software project management. Comput. Educ. 87, 396–422. https://doi.org/10.1016/j.compedu.2015.07.011.

Cooper, D.F., Klein, J., 1980. Board wargames for decision making research. Eur. J. Oper. Res. 5 (1), 36–41.

Cooper, D.F., Klein, J., McDowell, M.R.C., Johnson, P.V., 1980. The development of a research game. J. Oper. Res. Soc. 31 (2), 191–193.

Creswell, J.W., Plano Clark, V.L., 2011. Designing and Conducting Mixed Methods Research, second ed. Sage, Los Angeles.

Csikszentmihalyi, M., 2002. Flow: the Psychology of Optimal Experience, second ed. Harper & Row, New York.

David, N., Winter, P.L., 2021. Plant your street! A research game exploring tree selection and placement in an urban neighborhood. Urban For. Urban Green. 64, 127244. https://doi.org/10.1016/j.ufug.2021.127244.

Duke, R.D., Geurts, J.L.A., 2004. Policy Games for Strategic Management: Pathways into the Unknown. Dutch University Press, Amsterdam.

Faber, T., Dankbaar, M., Van Merriënboer, J., 2018. Applying an instructional design method to serious games-Experiences and lessons learned. In: Presented at *9th International Conference On Information, Intelligence, Systems And Applications* (IISA). IEEE, pp. 1–3.

Faul, F., Erdfelder, E., Lang, A.-G., Buchner, A., 2007. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav. Res. Methods 39 (2), 175–191. https://doi.org/10.3758/BF03193146.

Fogg, B.J., Eckles, D., 2007. Mobile persuasion: 20 perspectives on the future of behavior change. STAND: Stanford Captology Media.

Freese, M., Lukosch, H., 2024. The funnel of game design – An adaptive game design approach for complex systems. Simulat. Gaming 55 (2), 323–341. https://doi.org/10.1177/10468781231222524.

Freese, M., Lukosch, H., Wegener, J., König, A., 2020. Serious games as research instruments – Do's and don'ts from a cross-case-analysis in transportation. European J. Trans. Infrastruct. Res. 20 (4), 103–126. https://doi.org/10.18757/ejtir.2020.20.4.4205.

Freese, M., Zürn, B., Lukosch, H., 2022. In: Alf, T., Hahn, S., Zürn, B., Trautwein, F. (Eds.), Planspiele: Erkenntnisse aus Praxis und Forschung, Vol. 13. Books on Demand GmbH, (ZMS-Schriftenreihe) Norderstedt, pp. 127–136.

Galloway, A.R., 2004. Social realism in gaming. Game Stud. 4 (1). Available at http://www.gamestudies.org/0401/galloway/[26.11.2023.

Gatti, L., Ulrich, M., Seele, P., 2019. Education for sustainable development through business simulation games: an exploratory study of sustainability gamification and its effects on students' learning outcomes. J. Clean. Prod. 207, 667–678.

Geithner, S., Menzel, D., 2016. Effectiveness of learning through experience and reflection in a project management simulation. Simulat. Gaming 47 (2), 228–256.

Gómez-Maureira, M.A., van Duijn, M., Rieffe, C., Plaat, A., 2022. Academic games - mapping the use of video games in research contexts. In: *Proceedings Of the 17th International Conference On the Foundations Of Digital Games* (FDG '22). Association for Computing Machinery, New York, NY, USA, pp. 1–10. https://doi.org/10.1145/3555858.3555926. Article 4.

Gralla, E., Szajnfarber, Z., 2018. Games and exercises for teaching and research: exploring how learning varies based on fidelity and participant experience. In: Proceedings of the ASME 2018 International Design Engineering Technical Conference. August 26-29, Quebec City, Canada. DETC2018-85827.

Greenblat, C.S., Duke, R.D., 1975. Gaming-simulation: Rationale, Design, and Applications. Sage Publications, New York, NY.

Grogan, P.T., Meijer, S.A., 2017. Gaming methods in engineering systems research. Syst. Eng. 20 (6), 542–552.

Gugerell, K., 2023. Serious games for sustainability transformations: participatory research methods for sustainability - toolkit #7. GAIA - Ecological Perspectives for Science and Society 32 (3), 292–295.

Harteveld, C., 2011. Triadic game design: balancing reality. Meaning and Play. Springer Science & Business Media, Heidelberg, Germany.

Van den Hoogen, J., Lo, J., Meijer, S., 2016. Debriefing research games: context, substance and method. Simulat. Gaming 47 (3), 368–388. https://doi.org/10.1177/1046878116651023.

Hunicke, R., LeBlanc, M., Zubek, R., 2004. MDA: a formal approach to game design and game research. In: Proceedings of the AAAI Workshop on Challenges in Game AI, vol. 4, 1.

Jaccard, D., Bonnier, K.E., Hellström, M., 2022. How might serious games trigger a transformation in project management education? Lessons learned from 10 Years of experimentations. Project Leadership and Society 3, 100047.

Jiang, Y., Yao, J., Gao, R., Chen, J., 2022. Why the "journey" of carbon neutrality is a long one—a mixed method research based on carbon emission trading in hubei province. Front. Environ. Sci. 10, 984434. https://doi.org/10.3389/fenvs.2022.984434.

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

Klabbers, J.H.G., 2009. Terminological ambiguity: game and simulation. Simulat. Gaming 40 (4), 446–463.

Klein, J., 1985. The abstraction of reality for games and simulations. J. Oper. Res. Soc. 36, 671–678. https://doi.org/10.1057/jors.1985.124.

Kurapati, S., 2017. *Situation Awareness for Socio Technical Systems: A Simulation Gaming Study in Intermodal Transport Operations* (Doctoral Thesis). TRAIL Research School, Delft, The Netherlands.

Kuster, J., Huber, E., Lippmann, R., Schmid, A., Schneider, E., Witschi, U., Wüst, R., 2015. Project controlling. In: Kuster, J., Huber, E., Lippmann, R., Schmid, A., Schneider, E., Witschi, U., Wüst, R. (Eds.), Project Management Handbook. Springer-Verlag, Berlin, Heidelberg.

Lankoski, P., Björk, S., 2015. Game Research Methods: an Overview. ETC Press, Pittsburgh, PA.

Levy, L., Lambeth, A., Solomon, R., Gandy, M., 2018. Method in the madness: the design of games as valid and reliable scientific tools. In: Proceedings of the 13th International Conference on the Foundations of Digital Games, pp. 1–10.

Lieberoth, A., Roepstorff, A., 2015. Mixed methods in game research: playing on strengths and countering weaknesses. In: Lankoski, P., Bjork, S. (Eds.), Game Research Methods: an Overview. TC Press, Pittsburgh, PA, USA, pp. 271–289.

Lieberoth, A., Pedersen, M.K., Marin, A.C., Planke, T., Sherson, J.F., 2014. Getting humans to do quantum optimization - user acquisition, engagement and early results from the citizen cyberscience game Quantum Moves. Human Computation 1 (2). https://doi.org/10.15346/hc.v1i2.11.

Locatelli, G., Mikic, M., Kovacevic, M., Brookes, N., Ivanisevic, N., 2017. The successful delivery of megaprojects: a novel research method. Proj. Manag. J. 48 (5), 78–94.

Lukosch, H., Cunningham, S., 2018. Data analytics of mobile serious games: applying bayesian data analysis methods. International Journal of Serious Games 5 (1), 19–36. https://doi.org/10.17083/ijsg.v5i1.222.

Lukosch, H.K., Groen, D., Kurapati, S., Verbraeck, A., 2015. Using simulation games as research instruments: lessons learned from the transportation domain. In: Toyoda, Y., Kanegae, H. (Eds.), Proceedings of the 46th International Simulation and Gaming Association Annual Conference. ISOCARP, pp. 177–190.

Lukosch, H.K., Lukosch, S., Hoermann, S., Lindeman, R., 2019. Conceptualizing fidelity for HCI in applied gaming. In: Proceedings of International Conference on Human-Computer-Interaction, pp. 165–179, 26.- 28.07.2019, Orlando, Florida.

Mayer, I.S., 2009. The gaming of policy and the politics of gaming: a review. Simulat. Gaming 40 (6), 825–862.

Meijer, S.A., 2009. The Organisation of Transactions: Studying Supply Networks Using Gaming Simulation. Wageningen University. PhD-thesis.

Monteiro-Krebs, L., Geerts, D., Sanders, K., Caregnato, S.E., Zaman, B., 2024. Board games as a research method: a case study on research game design and use in studying algorithmic mediation. In: *Extended Abstracts Of the CHI Conference On Human Factors In Computing Systems* (CHI EA '24), May 11–16, 2024. ACM, Honolulu, HI, USA, p. 8. https://doi.org/10.1145/3613905.3637116. New York, NY, USA.

Peters, V.A.M., Vissers, G.A.N., 2004. A simple classification model for debriefing simulation games. Simulat. Gaming 35 (1), 70–84. https://doi.org/10.1177/1046878103253719.

Peters, V., Vissers, G., Heijne, G., 1998. The validity of games. Simulat. Gaming 29, 20–30.

Raser, J., 1971. Simulation and Society: an Exploration of Scientific Gaming. Allyn & Bacon, Boston, MA.
Ridolfi, G., Mooij, E., Corpino, S., 2012. Complex-systems design methodology for systems-engineering collaborative environment. In: Cogan, B. (Ed.), Systems Engineering - Practice and Theory. INTECH, New York, NY.
Rogers, R.W., 1975. A protection motivation theory of fear appeals and attitude Change1. J. Psychol. 91 (1), 93–114. https://doi.org/10.1080/00223980.1975.9915803.
Rumeser, D., Emsley, M., 2019. Can serious games improve project management decision making under complexity? Proj. Manag. J. 50 (1), 23–39. https://doi.org/10.1177/8756972818808982.
Sandberg, J., Alvesson, M., 2011. Ways of constructing research questions: gap-spotting or problematization? Organization 18 (1), 23–44. https://doi.org/10.1177/1350508410372151.
Schell, J., 2008. The Art of Game Design: A Book of Lenses. Elsevier/Morgan Kaufmann, Amsterdam; Boston.
Shehab, L., Malaeb, Z., Hamzeh, F., 2024. Harnessing LPS metrics for smarter resource allocation and project control through gamification. Lean Constr. J. 01–15.
Slegers, K., Ruelens, S., Vissers, J., Duysburgh, P., 2015. Using game principles in ux research: a board game for eliciting future user needs. In: *Proceedings Of the 33rd Annual ACM Conference On Human Factors In Computing Systems* (CHI '15). Association for Computing Machinery, New York, NY, USA, pp. 1225–1228. https://doi.org/10.1145/2702123.2702166.
Smith, S.P., Blackmore, K., Nesbitt, K., 2015. A meta-analysis of data collection in serious games research. In: Loh, C., Sheng, Y., Ifenthaler, D. (Eds.), Serious Games Analytics. Advances in Game-Based Learning. Springer, Cham. https://doi.org/10.1007/978-3-319-05834-4_2.
Thomas, J., Mengel, T., 2008. Preparing project managers to deal with complexity - advanced project management education. Int. J. Proj. Manag. 26 (3), 304–315.
Tiebout, C.M., 1956. A pure theory of local expenditures. J. Polit. Econ. 64 (5), 416–424.
Van Leiden, J., 2023. Understanding homeowners' preferences and motivations towards public-private flood protection (MSc Thesis). http://resolver.tudelft.nl/uuid:4a77645a-79a4-4d63-a845-e344dc63cda6.
Van Marrewijk, A., Clegg, S.R., Pitsis, T.S., Veenswijk, M., 2008. Managing public–private megaprojects: paradoxes, complexity, and project design. Int. J. Proj. Manag. 26 (6), 591–600.
Waern, A., Back, J., 2017. Experimental game design. In: Lankoski, P., Holopainen, J. (Eds.), Game Research Methods: an Introduction to Theory and Practice. ETC Press, Pittsburgh, PA, USA, pp. 341–353.
Wang, Y., Lukosch, H.K., Schwarz, P., 2019. The role of serious gaming in assisting humanitarian operations. Int. J. Inf. Syst. Crisis Response Manag. 11 (1), 20–34. https://doi.org/10.4018/IJISCRAM.2019010102.
Washburn, D.A., 2003. The games psychologists play (and the data they provide). Behav. Res. Methods Instrum. Comput. 35 (2), 185–193.
Westera, W., Nadolski, R., Hummel, H.G.K., Wopereis, I., 2008. Serious games for higher education: a framework for reducing design complexity. J. Comput. Assist. Learn. 24 (5), 420–432. https://doi.org/10.1111/j.1365-2729.2008.00279.x.
Wetzel, R., Bachour, K., Flintham, M., 2019. Tensions within the ministry of provenance: reflections on Co-creating a research game together with artists. Simulat. Gaming 50 (3), 329–358. https://doi.org/10.1177/1046878118818867.
Winn, B.M., 2009. The design, play, and experience framework. In: Ferdig, R.E. (Ed.), Handbook of Research on Effective Electronic Gaming in Education. IGI Global, Hershey, PA, pp. 1010–1024. https://doi.org/10.4018/978-1-59904-808-6.
Winter, M., Smith, C., Morris, P., Cicmil, S., 2006. Directions for future research in project management: the main findings of a UK government-funded research network. Int. J. Proj. Manag. 24 (8), 638–649.
Yiannakoulias, N., 2022. Games in socioenvironmental research. Ann. Assoc. Am. Geogr. 112 (5), 1207–1223.