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Gamifying and evaluating problem structuring: A card game workshop for generating decision objectives

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ABSTRACT

Serious games, gamification, or game-based interventions are increasingly used as tools to aid participatory decision-making processes, but their evaluation is often not very rigorous. Therefore, it is still unclear whether game-based interventions are really beneficial. We focused on the following overarching question: how effective are game-based interventions specifically designed to support decision-making processes. We used an illustrative case to reflect on this question. Using a published framework proposing that design processes of game-based interventions and their evaluation are intertwined, we designed simultaneously (1) a game-based intervention, specifically a card game and a workshop structure in which this card game is to be used, and (2) its evaluation procedure, formulating evaluation questions and proposing measure instruments based on the literature. We pre-tested the evaluation procedure in a small pilot study with 10 students. We illustrate the use of the design framework for an intervention to generate objectives in a decision-making process about sustainable wastewater management. Through our illustrative case, we identify future research opportunities about designing game-based interventions and evaluating their effectiveness. We found that it is possible to address the dual challenge of game-based interventions for participatory decision-making processes: (1) designing an informative and engaging game-based intervention without telling participants what to think and (2) designing a tailored evaluation procedure. Designing the game-based intervention and its evaluation simultaneously is valuable, because both are strongly intertwined. However, conducting the evaluation is demanding and requires the collaborative efforts of scientists, including across disciplinary boundaries. For instance, the data collection effort could be distributed among different research groups to increase sample size. This would allow including control treatment(s) and covering the variation span of the confounding factors more broadly. All material is made openly available to foster collaborative future research.

1. Introduction: the dual challenge of game-based interventions supporting decision-making processes

In recent years, game-based approaches have increasingly been used for participatory decision-making processes related to sustainability issues (e.g. Flood et al,. 2018; den Haan et al., 2018; Aubert et al., 2019; Bakhanova et al., 2020). Recent papers have reviewed the use of game-based approaches in the related fields of water governance (Aubert et al., 2019; Furber et al., 2018; Medema et al., 2016), decision analysis (Aubert et al., 2018), and water systems planning and management (Savic et al., 2016). Game-based approaches encompass many concepts, such as serious games or playful interactions (Deterding et al., 2011) (Fig. 1). The definitions of these concepts are still evolving in the various fields (Deterding et al., 2011; Seaborn and Fels, 2015), and the boundaries between them are blurry. The following definitions are generally agreed. Serious games are usually defined as fully-fledged games that have another purpose than solely entertainment (Abt, 1970). Gamification is commonly defined as the use of game design elements in non-game contexts (Deterding et al., 2011) to stimulate a psychological response and thus a desired behavioural outcome (Deterding, 2012, Landers et al., 2018). At one end of the continuum of game-based approaches, some authors simply use playfulness or playful interaction, such as humorous moments in group decision support workshops, without adding game elements (Deterding et al., 2011, Burger et al., 2018). The present paper does not enter the definition debate and uses the encompassing term of game-based approaches.

Game-based approaches supporting real-world decision-making processes have several commonly cited rationales. First, game-based approaches can provide a safe trial environment for stakeholders to freely express their thoughts in a group in a way that will not be judged

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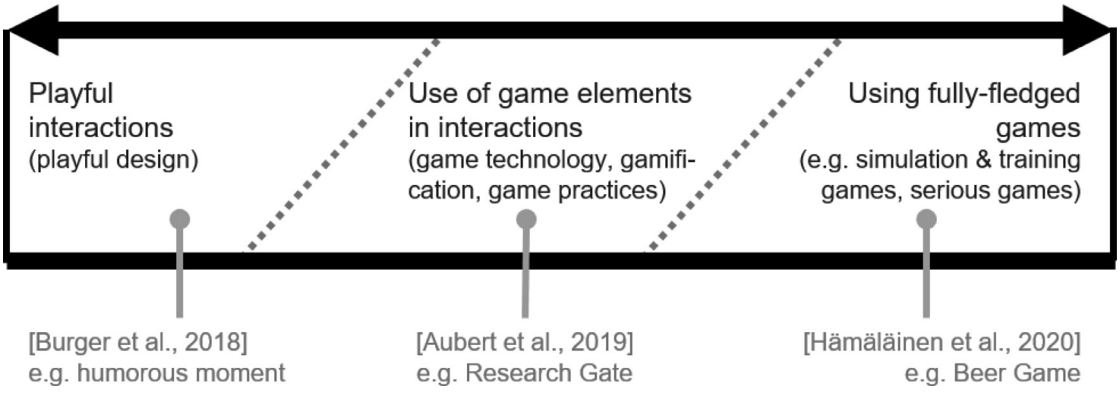

Fig. 1. Continuum of the diversity of game-based approaches. Adapted from Deterding et al. (2011), including examples from the operational research literature and well-known examples.

(Hämäläinen et al., 2020; Mendler de Suarez et al., 2012). Second, game-based approaches offer the potential to motivate and engage stakeholders in a task, in turn promoting thinking about the topic and triggering learning. Increased stakeholders' motivation can lead to active engagement and better performance at the task (Ryan and Rigby, 2019). For instance for a brainstorming game, they can generate more ideas. Third, game-based approaches can enhance individual learning for decision-making at three levels (Aubert and Lienert, 2019): learning facts on the topic, constructing individual preferences, and understanding the decision process. Group settings exhibit a fourth learning level: social learning, which is learning from others, for instance about their worldviews (Yamori, 2012). This literature raises the expectation that game-based approaches can enhance the process and output of participatory decision-making interventions.

However, game-based approaches supporting participatory decision-making processes face at least two main challenges. First, game-based approaches that support decision-making processes should not advertise a specific solution but merely enable participants to express themselves freely or inform them generally about multiple possible trade-offs. Thus, game-based approaches in a decision-making process differ from many serious games on sustainability, which usually emphasize a specific solution (Aubert and Lienert, 2019). We reviewed literature on the state-of-the-art for designing game-based approaches appropriate for participatory decision-making processes in Section 2.1. Second, evaluating the effectiveness of game-based approaches is rarely rigorously done. We reviewed literature on the state-of-the-art for evaluating game-based approaches in Section 2.2. To tackle these two challenges, we formulated our overarching question: "how effective are game-based interventions specifically designed to support decision-making processes". Concretely, in an illustrative case, we applied a recent framework to design a game-based intervention and its evaluation concurrently (Aubert et al., 2019).

This paper presents a procedure for designing and evaluating a game-based intervention using an illustrative case. Our illustrative case is an intervention for generating objectives in the opening-up phase of problem-structuring workshops (Franco and Montibeller, 2010; Marttunen et al., 2019). After presenting state-of-the-art knowledge on both challenges (Section 2), the result section reports on operationalizing a framework from literature (Aubert et al., 2019). As results, there are (1) the game-based approach (Section 4.2), and (2) its evaluation procedure (Section 4.3). Finally, we discuss on the effectiveness of game-based interventions specifically designed to support decision-making processes, and reflect on the major difficulties of evaluating game-based approaches (Section 5). We conclude by pointing to future research for supporting complete evaluation, which will require multiple studies ranging across several disciplines.

2. State of the art of designing and evaluating game-based interventions

2.1. Designing game-based interventions supporting participatory decision-making processes

Game-based approaches supporting decision-making processes should not promote specific outcomes. Instead, they should primarily aim at creating a shared understanding of facts and values (Aubert et al., 2019; Medema et al., 2017). Consequently, they differ from most fully-fledged serious games. Most serious games are educational games promoting a known best option or given values (e.g. values that move beyond self-interest (Marini et al., 2018; Aubert et al., 2018)). In our view, game-based approaches for decision-making processes should mainly enable participants to learn about multiple unavoidable trade-offs and to express their preferences freely. Policy games and simulation games (Bakhanova et al., 2020; Aubert et al., 2018; Duke and Geurts, 2004) already support such complex decision-making processes. Often, they consist of analogue role-playing games, sometimes complemented with digital simulation, such as in the companion modelling approach (Barreteau, 2003) and participatory modelling (Voinov et al., 2018). However, if these policy and simulation games are not co-designed, stakeholders do not necessarily provide significant input: some stakeholders may wish to jointly set the outcomes of the intervention, i.e. co-design it (Aubert et al., 2019). To support decision-making processes, game-based approaches should be designed to be as neutral and open-ended as possible, by creating space for non-predetermined outcomes.

In addition, game-based approaches supporting decision-making processes about common resources and services are a means to involve all stakeholders: those making and/or influencing the decision as well as those affected by the decision (Reed et al., 2018; Dietz and Stern, 2008). At the least, game-based approaches can include the opinions and worldviews of all stakeholders. Additionally, game-based approaches can include how stakeholders value the objectives, and the trade-offs they are willing to make between achieving objectives may reveal conflicts of opinions (Lienert et al., 2013). For instance, some stakeholders may value income generation over environmental protection, while the opposite may be true of others. Acknowledging these conflicts of interest by making them explicit and transparent is a first step towards conflict resolution and finding a consensual decision. As early as 1992, Eden wrote that 'models can be toys that a group can play with together, enabling them to create knowledge' (Eden, 1992, p.199). However, the stakeholders' expertise on the topic and/or their knowledge of the local conditions may differ. Game-based approaches are a means to bring all stakeholders together in an equal setting. Thus, they can serve

as boundary objects to deal with conflict situations (Barreteau, 2003; Voinov et al., 2016; Redpath et al., 2018).

The design of game-based approaches supporting participatory decision-making processes is also influenced by general aspects of group decision-making (Aubert et al., 2019). Ideally, in addition to the points mentioned above, their design should enhance a commitment to the process of finding a (joint) solution to the problem (e.g. Aubert, 2018) and to the implementation of the consensual solution (if one emerged), create trust and/or a feeling of togetherness between the involved stakeholders (Lankford and Watson, 2007; Jean et al., 2018), and evoke a sense of ownership of the decision process (Jean et al., 2018). Well-designed game-based approaches should also flatten the hierarchical relationships between involved stakeholders (Zhou, 2014), enhance the internalization of extrinsic motivation to participate (Ryan and Deci, 2017), facilitate reflection (Jean et al., 2018), and create space for emotions (Aubert et al., 2019; Zhou, 2014). These aims are widespread in the literature on participatory decision-making processes (Reed et al., 2018; Gray et al., 2018), and not specific to game-based approaches. We have reviewed this literature in an earlier paper, and refer to (Aubert et al., 2019) for details.

The game design and its technical aspects are specific to the game-based format (Aubert et al., 2019). These include: creating an immersive experience through visuals and interactions (Zhou, 2014), including game elements as motivational affordances (Seaborn and Fels, 2015), finding the effective balance between challenges and skills needed to meet them and thus creating flow (Csikszentmihalyi, 2000), finding the effective balance between seriousness and playfulness (Lankford and Watson, 2007), finding the effective degree of verisimilitude by varying how much real-world complexity is integrated in the game-based approach (Wesselow and Stoll-Kleemann, 2018), and evaluating the effectiveness of in-game actions and decisions to determine future options or learning loops (Lankford and Watson, 2007; Zhou, 2014; Csikszentmihalyi, 2000; Plass et al., 2015). Some of these aspects of game design require trade-offs. They can be summarized as trade-offs between simplicity and complexity (Lankford and Watson, 2007). Both in OR studies and game design studies, the designers of the intervention or game are making these trade-offs, which influence the results.

Defining the 'right' balance is challenging, because it is context-specific (Aubert et al., 2019; Mayer et al., 2014). Answers to the basic questions of *what/which topic?*, *why/which purpose?*, *who/which stakeholders?*, and *when and where/which setting?* should guide the design of game-based approaches (Aubert et al., 2019).

2.2. Evaluation procedures for game-based interventions

Few studies rigorously evaluate game-based approaches (den Haan and van der Voort, 2018; Aubert et al., 2019; Mayer et al., 2014). However, also existing evaluations are somewhat wanting. Some evaluations lack a control treatment (Soekarjo and van Oostendorp, 2015), and others use small sample sizes (Flood et al., 2018). Sometimes, the results are equivocal (Flood et al., 2018, Dichev and Dicheva, 2017), thus calling for deeper investigation. This can include collecting complementary qualitative and quantitative data to evaluate game-based approaches (den Haan and van der Voort, 2018). Moreover, some studies actually evaluate other aspects of game-based approaches than those they claim to use the game-based approaches for (Aubert et al., 2019). Here, using value-focused thinking (Keeney, 1992) would help to design evaluation (Phillips, 1984). Value-focused thinking proposes to first focus on 'what is important', which would entail thinking about the rationales justifying the game-based approach. Value-focused thinking has also been proposed to evaluate other interventions (Phillips, 1984). Based on this short overview, it is evident that the evaluation of game-based intervention needs to improve.

Reflecting on evaluation studies was also recently done in the field of behavioural operational research (OR) (Franco and Hämäläinen, 2016; Franco et al., 2021). OR interventions include among others problem-structuring workshops to generate decision objectives. Evaluating OR interventions is as challenging as evaluating game-based participatory approaches, and identifying the underlying context and assumptions can help (Midgley et al., 2013). Evaluation can use the lens of human behaviour, which can be seen as either voluntarist or determinist (Franco et al., 2021). It can also use different research methodologies, by either focusing on the variance of the outcome or the process (Franco et al., 2021; Poole and Van De Ven, 2010). This choice between outcome and process also needs to be made when evaluating game-based approaches if we answer the questions *did it work?* or *why/how did it work?* (Seaborn and Fels, 2015). To answer the latter question, we need to rely on theory. Thus, designing an evaluation procedure requires many choices.

In a recent framework (Aubert et al., 2019) (Fig. 2), we suggested that the design of the evaluation procedure should occur in parallel with the design of the game-based approach. Similar to the design of the game-based approach, designing the evaluation procedure requires identifying the context of the intervention (Whetten, 1989), and answering the four basic questions listed in 2.1. Applying this framework should allow context-specific, purpose-oriented evaluation (Keeney, 1992), adjusted to the intervention's purposes (Phillips, 1984). Thus, applying this framework should contribute to investigating the effectiveness of game-based interventions specifically designed to support decision-making processes. This is what we tested in an illustrative case.

3. Methods

We tested this framework (Aubert et al., 2019) with the simultaneous design of a game-based approach and its evaluation in an illustrative case. Our illustrative case is an intervention for generating objectives in the opening-up phase of problem-structuring workshops. It started in November 2017, when the idea of a game-based approach for generating objectives in a workshop for wastewater management was initiated. It continued until November 2019, when the game-based intervention and its evaluation were pre-tested in a pilot study with 10 students from Uppsala University in Sweden. Following the framework, we designed an intervention using a card game and, in parallel, the evaluation of this game-based intervention.

Applying the framework resulted in defining the context (Section 4.1), designing the game-based intervention (Section 4.2), and designing the evaluation procedure (Section 4.3). We pre-tested the game-based intervention and its evaluation procedure in November 2019 in a pilot study, detailed in Section 4.4.

4. Results

4.1. Defining the context

The first step in the framework (Fig. 2) is to define the context, which thereafter guides the design (Aubert et al., 2019; Morschheuser et al., 2017). In this section, we answer each question that defines the context of our chosen illustrative case.

4.1.1. What?

The topic chosen for the intervention was an example of public resource and service management, namely wastewater management. We had collected data from several wastewater management case studies in rural Switzerland (Haag et al., 2019; Beutler and Lienert, 2020), which informed the present work. In Switzerland, over 90% of households benefit from centralized wastewater treatment, which means that wastewater is discharged via sewers to a centralized wastewater treatment plant (Eggimann et al., 2018). This capital-intensive infrastructure is ageing and rural municipalities cannot always cover the rehabilitation and maintenance costs (Beutler and Lienert, 2022). Alternative decentralized technologies exist, but are not yet common in Switzerland. In an earlier research project, we had used facilitated processes based on

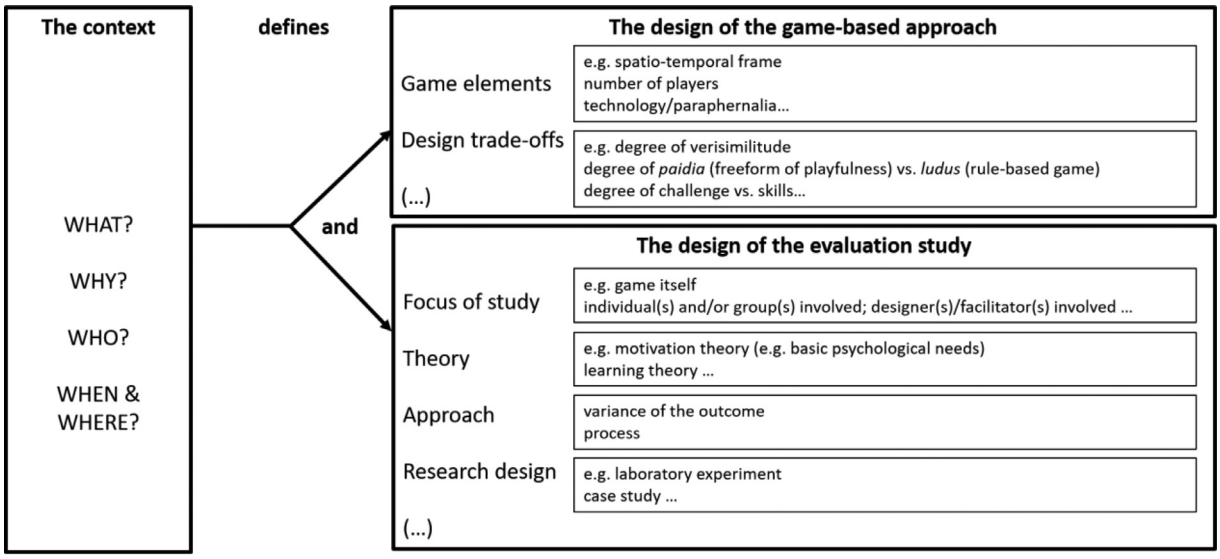

Fig. 2. Framework for simultaneously designing the game-based approach and its evaluation procedure. Adapted from Aubert et al. (2019).

value-focused thinking (Keeney, 1992) and MCDA to identify the most suitable local wastewater management options (the full MCDA process is described in Beutler and Lienert (2022).

4.1.2. Why?

The primary purpose of the game-based intervention was to support decision-makers in generating a comprehensive list of objectives, with state-of-the-art techniques (Haag et al., 2019; Ferretti, 2019; Bond et al., 2010; Keeney, 1996). In this work, we focused on the diverging phase of generating objectives (Box 1, also see Section 4.1.4). Formulating and structuring objectives, also called criteria, are critical steps of multi-criteria decision analysis (MCDA) (Marttunen et al., 2017). Decision-makers often omit objectives that actually are of fundamental importance to them (Bond et al., 2008). Generating a comprehensive list of objectives is demanding for the stakeholders (Haag et al., 2019; Keeney, 1988). A lack of motivation and lack of a (semi-structured) creative process can prevent broad thinking (Haag et al., 2019). Our hypothesis is that using a specifically-designed game-based intervention may better engage and motivate participants, thus increasing the stakeholders' performance when generating objectives.

Box 1. Importance of objectives in multi-criteria decision analysis (MCDA).

In MCDA, specifically multi-attribute value/utility theory (Keeney and Raiffa, 1976), the performance of options on the objectives (predictions) and the stakeholders' elicited preferences are aggregated in a performance score (value) for each option. Thus, the set of objectives is a cornerstone for assessing options in MCDA. The set of objectives should cover all dimensions of the problem, and all stakeholders' concerns. This helps ensuring transparency, minimizing post-decision regret, or suspicions of a biased process. Identifying a comprehensive set of objectives is a two-phase process. First, there is a diverging brainstorming phase to capture all perspectives. Second, there is a converging phase to reduce the number of objectives to a reasonable set, and to specify objectives with measurable attributes. (Franco and Montibeller, 2010; Marttunen et al., 2019)

In addition, the game-based intervention aimed to enhance the stakeholders' factual and social learning about the topic. Factual learning should be enhanced by informing participants about categories of objectives (e.g., environmental, socio-economic) and possible options (for wastewater management in our example). Structuring the problem around objectives and options breaks it into smaller issues and reveals that trade-offs between achieving objectives are necessary. This process helps participants develop a deeper understanding of the system. Social learning should be enhanced by informing about the perspectives of different stakeholders on these objectives, by providing space for participants to express their views, and potentially by creating an environment for open discourse or 'positive conflict' (Chidambaram and Bostrom, 1997). Such activities help avoid groupthink (Eden, 1992). In particular, suppressed or absent conflicts can lead to groupthink (Chidambaram and Bostrom, 1997; Janis, 1982; Esser, 1998). Moreover, low consensus in a group is not a necessary condition for avoiding poor decisions (Kerr and Tindale, 2004). Rather, in the diverging phase of generating objectives, low consensus is desired to capture a broad variety of views. While broadening the perspective on objectives would be the aim of any decision-making process, we postulate that our game-based intervention should enhance factual and social learning.

Finally, the game-based intervention should provide participants with a positive experience for both individuals and the group.

4.1.3. Who?

The participants of the game-based intervention for generating objectives about wastewater management in rural Switzerland would include following stakeholders: the municipal authorities in charge of the infrastructure, regulators, local consultants, representatives of citizen groups such as inhabitants that are potentially affected by new wastewater systems, and environmental associations (Lienert et al., 2013). Our target group had no gender or age limits. Most participants would have some basic knowledge about the topic. In case not all affected stakeholders participate, those engaged in the intervention should represent the interest of the absent ones. Some participants might be experts on the topic. One or more facilitators might be present.

4.1.4. When & where?

The proposed game-based approach should be integrated in a facilitated workshop for problem structuring, which usually would not include game elements (Midgley et al., 2013; Marttunen et al., 2017). The game-based intervention targeted only one step, the diverging phase of generating objectives, of the intervention for problem structuring. These workshops usually last several hours up to two days. In pre-pandemic times, such workshops took place in person, gathering the participants in the same location, and at the same time.

4.2. How? Design of the game-based intervention for generating objectives

Ideation. After identifying the context (answers to the what, why, who, and when & where questions, Section 4.1), we reflected on 'how' to design the game-based intervention. This should be integrated into a facilitated intervention to generate objectives about wastewater management. Experimental studies and real-world interventions have investigated techniques for enhancing the generation of objectives in the diverging phase (Box 2) (Haag et al., 2019; Ferretti, 2019; Bond et al., 2010). Accordingly, we chose five techniques: (1) the wish list, or individual brainstorming, where the participants are asked about what they think is important to consider for the decision at stake; (2) providing generic objectives, or categories, for instance by asking what environmental, social, and economic objectives are important; (3) considering the options' strengths and weaknesses; (4) considering the stakeholders' perspectives by acknowledging which objectives would matter most or least for the various stakeholders; and (5) asking participants to select and match objectives from a master list.

Box 2. Studies and interventions investigating how to enhance the generation of objectives

One guideline suggests using a subset of the following techniques, until the same objectives are identified multiple times (Keeney, 1996). Keeney's (1996) list of techniques includes: (1) a wish list (individual brainstorming), (2) considering the options' strengths and weaknesses, (3) thinking in terms of problems and shortcomings, (4) thinking in terms of consequences, (5) considering goals, constraints, and guidelines, (6) considering perspectives of different stakeholders, (7) identifying the strategic objectives, (8) providing generic objectives, (9) structuring objectives, e.g. in means-ends relationships, and specifying them, and (10) identifying how to measure objectives and why one objective would be more important than another. Clemen and Reilly (2001) make similar recommendations. The techniques can lead to redundancy when one objective is mentioned with different techniques, but identifying redundant objectives is easier than identifying missing ones (Keeney, 1996).

Recent studies have investigated the effect of subsets of these techniques. Haag et al. (2019) experimentally tested four techniques in an online survey for a real case study concerning regional wastewater planning. They included a wish list, providing generic objectives, and considering various stakeholders' perspectives, and they added selecting and matching objectives from a master list. The master list was the most effective intervention, both regarding the number and diversity of objectives. Selecting from a master list of objectives was originally proposed by Bond et al. (2008, 2010) to complement Keeney's list (Keeney, 1996). Bond et al. (2010) also recommended directly challenging the stakeholders to do better, e.g., encouraging them to think of more objectives. In their study, providing some generic objectives with a warning that important objectives are omitted was the most effective technique for generating objectives. Along these lines and on the evidence of two interventions, Ferretti (2019) recommends using thought-provoking questions developed from Keeney's list (Keeney, 1996) to boost the generation of objectives.

Card games are sometimes used in group decision-making, negotiation (Hämäläinen et al., 2020; Yamori, 2012), and brainstorming activities (e.g. Bond et al., 2010). Card games are convenient to bring to a workshop, can be low cost, and require middle to low skills for production, at least for prototyping purposes. Thus, we considered the game mechanics of several card games. The serious card game KlarText (Bundesamt für Statistik, 2022), developed by UCS Ulrich Creative Simulations GmbH (Planspiele für Unternehmerische Nachhaltigkeit) for the Swiss Ministry of Statistics, stood out as particularly suitable. KlarText aims to communicate sustainability issues, particularly to raise awareness about the multiple criteria that are important for sustainability. KlarText includes various types of information on the situation in Switzerland at the time of the game creation: categories or criteria of sustainability, perspective-taking with small narratives about Swiss inhabitants, and factual information in words and statistics. These levels of information corresponded to some of the techniques for generating objectives. They enable communication on facts about the topic and a variety of perspectives. Finally, KlarText is a fully-fledged game, with functional game mechanics, and was used in Swiss schools. We therefore decided to adapt KlarText for our intervention for generating objectives.

Game-based intervention. The intervention to generate objectives is described here. It would start introducing the purpose of the problem-structuring workshop: identifying objectives. It would also introduce value-focused thinking (Keeney, 1992), differentiating objectives from options, and inform participants about the schedule. First, participants would brainstorm individually by formulating an initial wish list of objectives they would find important to consider when deciding about wastewater management (Supprting Information, SI 3). The haptic card game would then be introduced, and participants would receive their cards and thus became players. They would update their initial wish lists after receiving and reading their first hands of cards, and again after each round of the game. At the end of the game, they would compile their final lists of objectives and rank them in order of preference. The decision analyst would collect the forms and would have processed the lists before a follow-up intervention, which could take place after a lunch break. This follow-up intervention would focus on the converging phase of generating objectives: identifying the fundamental objectives, as opposed to means or instrumental objectives, removing overlapping or less important objectives, discussing their exact meaning, determining attributes, and consolidating a final hierarchy of objectives (Marttunen et al., 2019). This converging phase was beyond the scope of our illustrative case.

The embedded card game. For complete details, see SI 1. For information about designing the card game (content development, prototype testing and fine-tuning), see SI 2.3. Each player represented a rural municipality of about 3,000 inhabitants whose centralized wastewater treatment plant was ageing. The goal of the game was to manage the employees of the municipality to best answer the requests from inhabitants, thereby learning about wastewater management to choose the best option for the municipality. Players competed with one another. There were three decks of cards (Fig. 3). Municipal employees working with wastewater were represented by 21 employee cards. The employees were more or less experienced and had skills related to one to three of the six generic objectives: economy, environmental protection, societal well-being, municipal organization, resources, and technical operation. The stakeholders' perspectives were captured with 64 situation cards, which contained stories about inhabitants of the rural municipalities on side of the cards. The other side presented an objective (e.g., high recovery of phosphorus) and its category (e.g., resources), and a short text described how an option fulfilled this objective or not (e.g. agricultural use recycles 95% of phosphorus found in wastewater for fertilizer use). Finally, 20 event cards introduced random events (e.g. Receive 3 points if at least 3 different wastewater treatment alternatives are represented in the situations that you are reporting.) and challenges (e.g. Choose one of the situation cards being reported and ask the other players a question based on the information given on the coloured side of the card. All players who answer correctly receive 3 points) to earn bonus points or receive penalties.

The card game was played in rounds and each round had four steps (SI 1; see Fig. 3 for initial table organisation). Each player first received employee cards. In the first step, the players offered their most suitable employee to address a situation, which was described in an inhabitant's testimonial on a situation card that was shown to all. In the second step, the player whose employee's expertise matched the situation won this situation card. In the third step, the players shared resources by exchanging employee and situation cards. The goal of this step was to gain

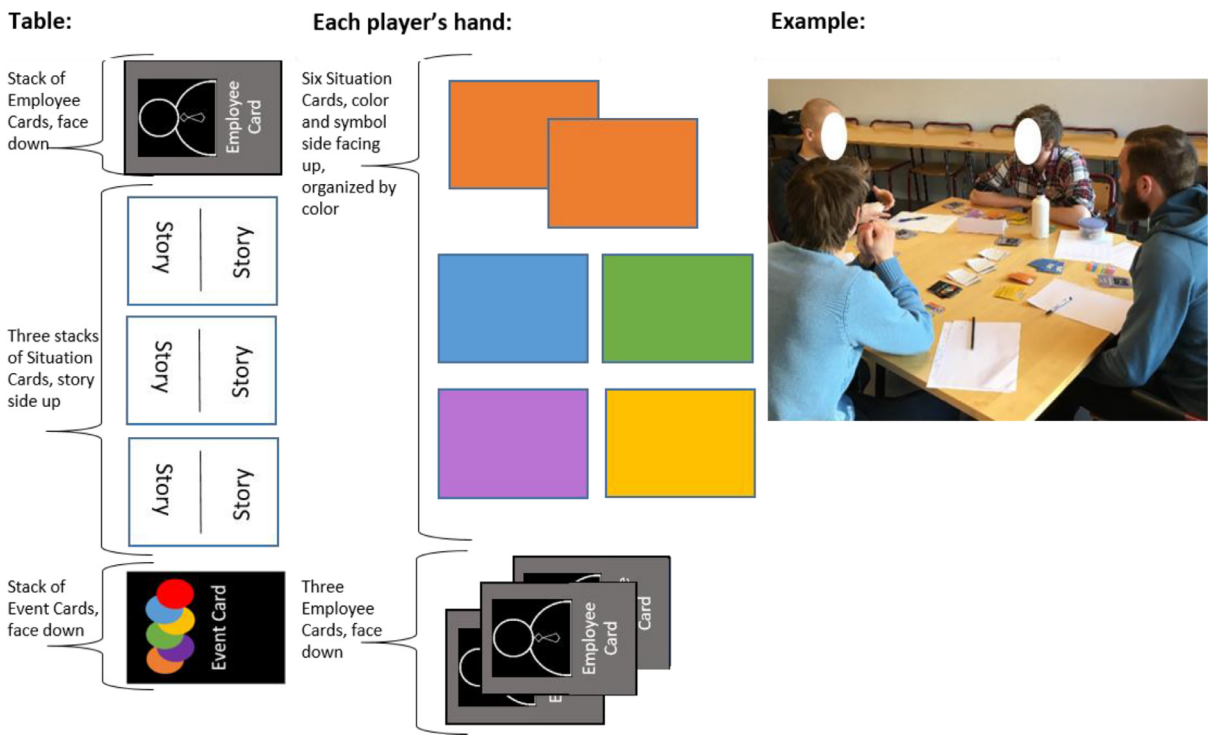

Fig. 3. Card game, at the start of the game, the table should look as presented. There are three decks of cards: employee cards, situation cards, and event cards.

employees skilled in the desired category (e.g. economy, environmental protection, etc.) and to exchange situation cards in order to collect at least three of the same category. In the fourth step, players reported the cases dealt with whenever they had at least three situation cards of the same category. Players won one point per situation card. These four steps were repeated until all situation cards had been distributed, which usually happened in about 5 rounds, or as many times as the length of the game session allowed. The player with the most points won the game. The winner of the game was the player who reported the most situations by having had the most cards. This meant that the winner had read the most information on various objectives, options, and worldviews. The winner had been exposed to the most categories and objectives and thus was expected to be able to produce the most comprehensive list of objectives. However, as all cards were visible to all players, this may not necessarily have been the case, and also other players were exposed to all situations and thus objectives. Competition was also kept in the gameplay because of its motivational affordance: it increases engagement in the activity and in turn should generate more objectives.

4.3. How? Evaluation procedure for our game-based intervention

4.3.1. Purpose-oriented evaluation

Answering our overarching question about the effectiveness of game-based interventions requires developing meaningful evaluation procedures. We designed a procedure to evaluate whether our game-based intervention fulfilled the purposes for which it was developed. We adopted a value-focused thinking approach to design this evaluation (Keeney, 1992; Phillips, 1984). Note that this value-focused thinking approach is generic and can be adapted to the evaluation of any game-based intervention. We applied it to our card game about wastewater management developed for generating objectives (Section 4.2, above). During the game-based intervention, the participants should: (1) generate a comprehensive list of objectives that matter (when deciding about wastewater management) and rank them in order of importance to learn about their preferences; (2) learn about various options (for wastewater management) by remembering basic facts about how options fulfil objectives; (3) learn about the diversity of various stakeholders' perspectives; and (4) have a positive group experience. This led to the following evaluation questions (EQ):

- EQ1: Do individuals in groups with game-based intervention generate lists of important objectives at least as comprehensive in number and diversity as individuals in control groups?
- EQ2: Do individuals in groups with game-based intervention remember facts about options at least as well as individuals in control groups? In particular, do they remember the strengths and weaknesses of options (in the wastewater planning case)?
- EQ3: Are individuals in groups with game-based intervention aware of the diversity of existing worldviews at least as much as individuals in control groups? In particular, do they know what matters most for stereotypical stakeholders involved in and affected by decisions as presented in the game (about wastewater management)?
- EQ4: Do individuals in groups with game-based intervention have more positive experiences than individuals who participate in control workshops without card game?

We added a fifth question about the influence of group dynamics on the process of generating objectives. During the game, as in any group process, a high degree of consensus can develop, termed groupthink (Janis, 1982; Hämäläinen, 2015). Because we wished to promote the divergent phase of generating objectives, strong groupthink and group cohesion is undesired; it is thus important to check the degree of consensus in the outcomes.

- EQ5: Is the degree of consensus in the groups with game-based intervention the same as in control groups without card game?

4.3.2. A mixed experimental design

The current article presents the designed evaluation procedure. We were only able to test it in a pilot study for the game-based intervention, without control (Section 4.4), due to the COVID-19 pandemic which interrupted the planned workshops. Nevertheless, we think that the pro-

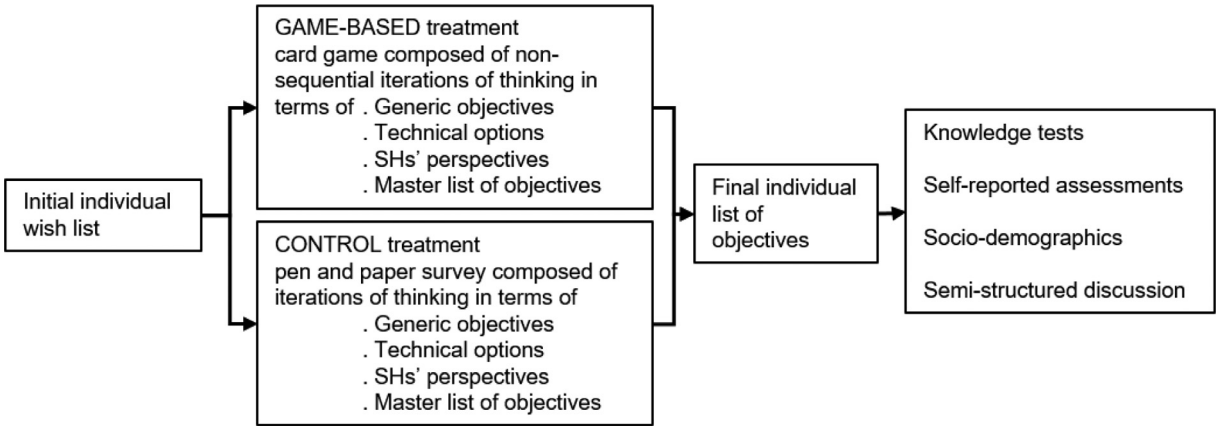

Fig. 4. Experiment flow of the evaluation procedure for game-based interventions supporting the diverging phase of the generation of objectives (between participants experiment). SH: stakeholders.

posed procedure to evaluate game-based interventions is valuable for future research. We therefore present the quantitative and qualitative evaluation (den Haan and van der Voort, 2018), which we pre-tested (Section 4.4).

We designed an experiment to compare the game-based intervention with a control. The control intervention should minimize confounding effects when evaluating the benefits or drawbacks of using the haptic card game. Thus, the control treatment would start with a wish list, receive the same information on objectives and categories, options (for wastewater management), and stakeholders' perspectives, be haptic rather than digital, and allow exchange in groups of three to four participants, as in the game-based intervention. To operationalize this, we created sheets that present the information in table format in batches to simulate the rounds of the game, with instructions on how to read the table (SI 4). At the end of the control intervention, participants would compile a final list of objectives. The facilitator should only provide introduction, instructions, and material. Overall, the participants in the control intervention would complete a pen-and-paper survey, including informative texts in batches, possibilities to interact with other participants in a group, and use the same form as in the game-based intervention to list the objectives.

Our proposed experimental design follows five steps (Fig. 4). First, after a welcome and signing an informed consent form, the participants would brainstorm individually to produce an initial wish list of objectives, before being informed on the topic. Second, the treatment would take place: either the game-based or control intervention. In both treatments, five techniques are used to enhance the generation of objectives (Fig. 4). Third, the participants would produce a final list of objectives and prioritize them. Fourth, participants would complete a questionnaire, including a knowledge test, self-reported assessments, and sociodemographic questions. Finally, a semi-structured facilitated discussion would cover our evaluation questions and would be audio-recorded (SI 5-7).

4.3.3. Measures

For each evaluation question, we developed (1) an *empirical* measure, or performance check, and (2) a *subjective* self-reported assessment by each participant, both based on literature (Table 1; details see SI 8). The qualitative data from the audio-recorded semi-structured discussion at the end would provide complementary material for answering our evaluation questions.

Measures to test the generation of objectives (EQ1). To measure the generation of objectives empirically, we reused the measures from Haag et al. (2019). We calculated the difference between the final and the initial lists in (1) the number of objectives, and (2) the diversity of objectives (number of categories).

The self-reported assessment of the generation of objectives included four questions, adapted from previous work (Anderson and Clemen, 2013; Aubert et al., 2020, 2022): To what extent are you confident that your final list of objectives includes all objectives important to consider (when deciding about wastewater management)?, How much do you think your final list of objective extensively covers the different aspects (of wastewater management)?, How satisfied are you with your final list of objectives?, and How comfortable would you be using the objectives from your list to decide (about wastewater management)?. Answers were given on a 7-point Likert scale from very low / very little to very high level / a great deal (SI 8.1).

We added nine questions to assess the usefulness of the five techniques to generate objectives: the wish list, thinking in terms of generic objectives, technical wastewater management options, stakeholders' perspectives, and a master list of objectives. We asked how much each technique helped the participants to critically re-evaluate the objectives that they initially found important, and how much the techniques helped them uncover new objectives that they had not initially considered (see SI 8.1 for exact wording). Answers were given on the same 7-point Likert scale.

Measures to test factual learning about options (EQ2). To measure factual learning about the options empirically, we adapted a previously developed knowledge test (Aubert and Lienert, 2019). One question addressed each option, making a total of 11 questions (SI 8.2). Participants were asked to tick all the correct statements on the strengths and weaknesses of each option as presented in the card game, and were able to choose from four statements for each option. We calculated a score with a point system: 1 point if responses to all four statements were correct, meaning that all statements for that option were correctly checked or correctly not checked; 0.5 points if three options were correct; and 0 points otherwise. The total score was the sum for all questions: at best 11 and at worst 0. It should be noted that the information delivered in the card game was based on data originating from Swiss case studies (Haag et al., 2019; Beutler and Lienert, 2020), and were proof-read by wastewater engineers (SI 2.3).

The self-reported assessment of factual learning about the options included four questions: How much did the exercise make you critically re-evaluate your initial knowledge about the options (of wastewater management)?, To what degree do you think that the information provided in the descriptions of options on the coloured side of the situation cards was in conflict with your previous knowledge?, How much did the exercise present you with information about options that you did not know before?, and How much did the game uncover new options or

Table 1
Summary of the evaluation questions and measures.

Questions (relating to the purposes of the intervention)	Measure type	Measures	Refs. & SI
1. Do individuals in groups with game-based intervention generate lists of important objectives at least as comprehensive in number and diversity as individuals in control groups?	Empirical	List of objectives - Number of objectives created - Diversity of objectives	(Haag et al., 2019) SI 3
	Self-reported	Self-reported questions (7 Likert scales 1 very low / very little to 7 very high level / a great deal) - Confidence in final list (4 items) - Critical re-evaluation enabled by technique (4 items) - Uncovering of objectives enabled by technique (5 items)	(Anderson and Clemen, 2013; Aubert et al., 2020; Aubert, 2022), SI 8.1, SI 10.1
2. Do individuals in groups with game-based intervention remember facts (about the introduced wastewater management options) at least as much well as individuals in the control group(s)? In particular, do they remember the strengths and weaknesses of options (in the wastewater planning case)?	Empirical	Knowledge test (score from 0 to 11)	(Aubert and Lienert, 2019), SI 8.2
	Self-reported	Self-reported questions (7 Likert scales, same as RQ1) (4 items)	SI 10.2
3. Are individuals in groups with game-based intervention aware of the diversity of existing different worldviews, at least as much as individuals in the control group(s)? In particular, do they know what matters most for stereotypical stakeholders involved in and affected by the decision (as presented in the game)?	Empirical	Knowledge test (score from 0 to 5)	SI 8.3
	Self-reported	Self-reported questions (7 Likert scales, same as RQ1) (5 items)	(Franco, 2018), SI 10.3
4. Do individuals in groups with game-based intervention have more positive experiences than individuals who participate in control workshops without card game?	Empirical	Counts of positive and negative signs	SI 8.4
	Self-reported	Self-reported questions GAMEFULQUEST (7 Likert scales, from 1 I strongly disagree to 7 I strongly agree) Accomplishment (8 items); Challenge (9 items); Competition (7 items); Guided experience (7 items); Immersion (9 items); Playfulness (9 items); Social experience (8 items)	(Högberg et al., 2019), SI 8.5
5. Is the degree of consensus in the groups in game-based intervention the same as in control groups without card game?	Empirical	Consensus score from the list of objectives	SI 9.5
	Self-reported	Self-reported questions (7 Likert scales, same as RQ1)	(Franco, 2018; Amason, 1996; Schweiger et al., 1986), SI 8.6

facts about options that you did not initially consider?. Answers were given on the same 7-point Likert scale.

Measures to test factual learning about stakeholders' perspectives (EQ3). To measure empirical factual learning about the stakeholders' perspectives, we developed a knowledge test, as for RQ2, consisting of three questions (SI 8.3). In one question, the participants were asked to select the stakeholders that were presented in the game among 12 listed. We used a point system for scoring: 3 points if 10 to 12 responses were correct, 1.5 points if seven to nine responses were correct, 0 points otherwise. Two questions concerned the preferences of the stakeholders as presented on the cards of the game. Participants were asked to tick the correct statements out of four. We calculated a score with the same point system as for RQ1.

The self-reported assessment of learning about the stakeholders' perspectives included five questions, partly adapted from Franco (2018): To what degree do you feel that different stakeholders' perspectives (about wastewater management) need to be worked through to make a decision?, How much friction between stakeholders can surface when deciding (about wastewater management)?, How much more aware did you become of clashes of interest when deciding (about wastewater management)?, To what extent do you believe the social information in the game (e.g. story side of situation cards) exposed a fair representation of the different perspectives (about wastewater management)?, and To what extent does the social information in the game (e.g. story side of situation cards) consider each stakeholder's opinion carefully?. Answers were given on the same 7-point Likert scale.

Measures to test positive experience (EQ4). To measure the participants' experience empirically, the facilitator and her assistant observed the participants, and completed an observation sheet (SI 8.4). In particular, the observers counted positive signs such as laughter, positive small talk, and signs of enjoyment, and negative signs such as sighs, grunting, yawning, negative small talk, and signs of boredom, aggression, and anger. Whenever possible, observers specified the moments in the game when these signs occurred. Observers also reported whether the participants required help or needed clarification.

The self-reported assessment of experience was measured with the gameful experience questionnaire, also called GAMEFULQUEST test (Högberg et al., 2019). It is based on the most up-to-date literature about games and gamification. It contains 57 items describing seven constructs: accomplishment, challenge, competition, guided experience, immersion, playfulness, and social experience. Answers to the items are given on 7-point Likert scales from I strongly disagree to I strongly agree. We kept those original items that made sense in our context and slightly adapted other items (SI 8.5). As in GAMEFULQUEST, we randomized the order of the constructs and of the items within each construct.

Measures to test the group effect (EQ5). To measure the groupthink effect empirically, we used the lists of objectives. To make objective lists comparable, three raters categorized the participants' objectives from

the initial and final lists against a master list of objectives (Haag et al., 2019). Three iterations among the three raters were necessary until the independent categorizations converged. In some cases, the objectives listed were very generic, for instance categories rather than objectives, which made it difficult to identify differences between individuals. We searched the literature to find formulas for calculating a consensus score. Those we found did not apply to our context (e.g. Scott et al., 2013; Jabeur and Martel, 2010; Hou, 2015). Thus, we calculated the degree of consensus within the group as follows: both for the initial and the final list of objectives, (1) the number of objectives shared between a participant and their group (shared objectives), (2) the number of objectives in the group (double counts removed; group total objectives), and (3) the ratio of each individuals' shared objectives to group total objectives. If the participants listed all and only the objectives that all other participants of the group listed, this ratio equals 1. Finally, we calculated the difference between each individual's final and initial ratios. Negative values indicate that the consensus of an individual with the group increased during the intervention.

The self-reported assessment of group effect was measured using 12 questions adapted from Franco (2018), based on group negotiation literature (Amason, 1996; Schweiger et al., 1986). It included two items for each of two constructs, influence/impartiality and dissent/psychological safety (SI 8.6), and items to measure the group atmosphere for satisfaction, effectiveness, leadership, harmony, and conflict (SI 8.6). Answers to the items were given on 7-point Likert scales from very low level/very little to very high level/a great deal.

4.3.4. Participants

The evaluation procedure was designed as a between-participants experiment: each participant participating in a single treatment. Published work evaluating video games generally involve around 80 participants (Ryan et al., 2006; Ryan, 2017). Optimally, that would mean having 40 participants in each treatment, with 10 groups in the game-based intervention and 10 groups in the control intervention. In our illustrative case, the participants would ideally be stakeholders in wastewater management in rural Switzerland. Alternatively, the facilitator would prime the participants to behave as if they were such stakeholders.

4.4. Pre-test study

Before going to the real stakeholders in Swiss wastewater management, we tested our game-based intervention and its evaluation procedure with 10 students from Uppsala University in Sweden in a pilot case. Note, the card game itself had already been play-tested multiple times with research assistants and interns at Eawag, and laypersons outside the institution, before it was embedded in a workshop to generate objectives (SI 2.3). The students participated as a compulsory part of their MSc programme, *Environmental and Water Engineering*, in a course titled *Selection of Water and Sanitation Systems*. A workshop titled *Identifying criteria to decide on wastewater management options* was facilitated by their lecturer (one of the authors) and an assistant. The four women and six men were aged between 23 and 28 years (see SI 8.7 for demographic characteristics). The students were knowledgeable about wastewater management systems applied in Sweden. The students played the game in three groups of three to four students. Due to the COVID-19 pandemic it was unfortunately impossible to replicate the workshops and carry out the control evaluation procedure. Given the small sample size and the absence of a control group, this pilot study should solely be considered as illustrative, and as a usability check. As discussed in Section 5.3, validity and reliability analysis would also be needed. Because the detailed results do not provide systematic, experimentally tested evidence, we present these only in the Supporting Information (SI 9-10). However, we draw on some results in the Discussion below because they do provide first interesting insights and informed us on a few issues with our measures and tools.

5. Discussion

Our study was driven by the need to investigate the effectiveness of game-based interventions supporting participatory decision-making processes. Reviewing the state-of-the-art literature and going through an illustrative case (Section 4), we observed that such game-based interventions (1) were challenging to design because they should enhance open discussions and not promote a specific outcome (unlike many serious games), and (2) were difficult to thoroughly evaluate, making it challenging to judge about their effectiveness. We reflect on these challenges in light of our illustrative case. However, we were not able to answer the research question. Instead, we uncovered a number of issues that provide additional insights and avenues for future research.

5.1. Game-based interventions to induce learning and critical thinking

First, we think that game-based interventions supporting participatory decision-making processes should not emphasize a specific option, about wastewater management in our case, contrarily to many (educational) serious games that advertise a specific solution (Aubert et al., 2019). We believe that our design choices for the card game met this requirement: based on state-of-the art facts acquired by engineers in case studies, we introduced 11 technical wastewater management options and presented strengths and weaknesses for each. Similarly, we introduced the objectives an equal number of times to avoid attracting attention to specific ones. Unfortunately, the master list that we used (Haag et al., 2019) presented an unequal distribution of objectives in the different categories: the high environmental protection category contained more objectives. This could have created an undesirable bias, encouraging participants to generate more objectives in this category. However, because the intervention focuses on the diverging phase of generating objectives, we are not too concerned. In the subsequent converging phase, which is beyond the scope of this paper, the most important objectives would be selected, and the final set of objectives organized in a hierarchy according to good practice (Marttunen et al., 2019). Overall, we are confident that our design did not tell the participants what to think but effectively provided inputs to reflect upon.

The card game conveyed up-to-date context-specific information on wastewater management in rural Switzerland, based on real case studies (Beutler and Lienert, 2022). It was designed to be a source of factual, short, simple information. One student participating in the pilot case study found reading the cards longwinded, while another opposed, saying that he found that the text satisfied their curiosity. Detailed reading was not necessary to play the game: the stories about the inhabitants on the situation cards should suffice to stimulate thinking about objectives. The design aimed at being informative and neutral. How this translates into critical thinking and constructing preferences is still to be addressed in future laboratory or field studies [see e.g. (Franco et al., 2021)] investigating how effective game-based interventions are.

General game design aspects (Aubert and Lienert, 2019) such as immersive experience, the degree of seriousness vs. playfulness and the degree of verisimilitude also became relevant. Our experience with the illustrative case and the debriefing after the pilot study highlighted four trade-offs which seem crucial to design effective game-based interventions supporting participatory decision-making processes. These trade-offs are tensions created when anchoring the playfulness in reality and giving it a meaning, as stated in triadic serious game design (Aubert et al., 2018; Harteveld, 2011). We develop the trade-offs below. The game designers and designers of the intervention are responsible for making these trade-offs, which may strongly influence the resulting game-based intervention, potentially with consequences on the decision-making process.

Seriousness vs. play. Some design elements target the purpose of the participatory workshop in the decision-making process, in our case generating a comprehensive list of objectives, while others focus on creating an enjoyable experience. The risk is that participants either find the

game-based intervention engaging without meeting the serious purpose or that participants meet the purpose but criticize the intervention's format, not finding the game part worthwhile if it fails to create a positive experience. In our case, if participants are caught up in the playfulness of the card game, they could forget that it is embedded in a workshop for generating objectives. Consequently, they might forget to complete the list of objectives, or not read the information on the cards carefully. If needed, the facilitator could remind the participants about the list of objectives and the reading. This trade-off was well summarized by one of the students who took part in the pilot study: 'it [the reading] is bad for the game, but good for the purpose of the game'.

Investing in rule learning vs. directly discussing. The question of rules and instructions in gameplay is important. When discovering a new game, learning the rules requires time, and is sometimes reported as difficult. However, once rule-learning is overcome, the games are usually fun. We experienced this in the pilot study. All students agreed that they found it difficult to learn the rules at first. Then, one group particularly appreciated the game mechanics, which are based on these rules. When planning game-based interventions, significant time has to be dedicated to explaining the rules, and perhaps even to a trial round. Are the benefits of gameplay worth the time spent for learning rules? Ideally, the game mechanics and rules should be models of real-world complexity, so elements of social learning can be blended into the experience of rule-learning, as in some simulation and role-playing games (Barreteau, 2003). Alternatively, the rules of the games can be co-designed with the participants, as sometimes done in companion modelling (Barreteau, 2003). Based on the feedback from our pilot participants, we realized that our proposed game-based intervention was rule intensive. After the pilot study, we consider that game elements bringing a more freeform playfulness instead of a structured gameplay might be more suitable for this type of exercise (to generate objectives for decision-making) and audience (stakeholders involved in wastewater management decisions).

Accuracy vs. generality. How much should the information contained in the game be context-specific or general so as to be reusable in other contexts? This trade-off between context accuracy and generality is recurrent when developing game-based approaches (Lankford and Watson, 2007). Accuracy allows high context embedding and is appropriate if participants are knowledgeable and used to dealing with complexity. In our example, this could be the case for experts such as local wastewater authorities. For such participants, accuracy most likely supports higher immersion. Generality allows the engagement of less expert participants and can save preparation time, because a general game can be reused in interventions with somewhat different contexts. This could be the case for instance for local inhabitants in a case study that do not know much about wastewater management. This trade-off also relates to the transference of learning (Wesselow and Stoll-Kleemann, 2018): how much learning in the game is transferable to real-world contexts? The question of whether information accuracy or generality facilitates this transfer has yet to be answered in future research. Our proposed game-based approach was developed with Swiss data and tested in a pilot study in Sweden. Students were disturbed when the cards displayed information that did not match their prior knowledge. In hindsight, we find these cognitive dissonances valuable because they fed the semi-structured debriefing session, when 'learning begins when the game is over' (Garcia et al., 2016). Thus, both context-specific and general game-based approaches have pros and cons.

Individualism vs. collectivism. Some game mechanics activate the competitive and individualistic nature of players. At the same time, a participatory intervention in a decision-making process is meant to create a positive group dynamic or collectivism (Chidambaram and Bostrom, 1997). Often, playing a game can by-pass real-world hierarchies and power disparities among participants. It can thus provide space for participants to express their views and potentially create an environment for open discourse, or 'positive conflict' (Chidambaram and Bostrom, 1997) in a safe trial environment. How much a lasting positive group dynamic can be created by game mechanics is unclear and is a further field for future research. The answer likely depends on pre-existing social and cultural dynamics within the group. High individual variation is also expected (Koivisto and Hamari, 2014). How different stakeholders in different cultures perceive the use of game-based approaches also deserves further investigation (Zhou and Mayer, 2018). Would some groups appreciate collaboration while others would be more engaged by competition? Identifying these issues prior to using game-based interventions and perhaps even framing the 'game' as something other than a 'game' (e.g., a tool) can lead to better acceptance by participants who are a priori hostile to games. Our game-based intervention was appreciated by one student because he won, thus highlighting an individualist view. However, the group dynamic was overall positive (mean group atmosphere of 6.03, seven being the maximum). From our pilot case, it seems that some elements enhancing individualism, such as competition do not necessarily destroy collectivism. Identifying the balance point is an interesting aim for subsequent research.

Overall, our pilot study confirmed that the card game was playable and indicated that it matched the purpose of the intervention. Using the proposed framework (Fig. 2, (Aubert et al., 2019)) to guide the design of the game-based intervention was helpful. Particularly, defining the purposes enabled us to identify the means to achieve them. In our case, the means were techniques found in the literature about generating objectives (Section 4.2). Obviously, we were fortunate that the game KlarText existed and only needed to be adapted to our context (Bundesamt für Statistik, 2022). In hindsight, we identified many crucial questions: future research is needed to answer them. Answers to these crucial questions should make the design of future game-based interventions easier. In our case, we were able to outsource decisions about some design trade-offs that would otherwise be required to design context-specific game-based approaches. However, not all interventions may benefit from already existing games, and investigating the design trade-offs would be useful. Thinking in terms of the purpose the game aims to achieve facilitated the design of a game-based intervention that could effectively support the diverging phase of the generation of objectives. To determine how effective it actually is, a tailored evaluation procedure was developed, and is discussed below.

5.2. The proposed purpose-oriented evaluation procedure

We used a framework for designing concurrently game-based interventions and their evaluation (Aubert et al., 2019) to tailor a purpose-oriented evaluation procedure. We used value-focused thinking (Keeney, 1992) to investigate how the game-based intervention fulfilled each purpose it was developed for. The measures we used were developed from literature (Section 4.3.3) and were both empirical (performance check) and subjective (self-reported assessment). In addition to these quantitative data, we collected qualitative data (den Haan and van der Voort, 2018) in a semi-structured debriefing session. We proposed to measure the generation of objectives (Haag et al., 2019; Bond et al., 2010), factual learning about options and stakeholders' perspectives (Aubert and Lienert, 2019), participants' positive experience and how the card game was perceived (Högberg et al., 2019), and groupthink (Franco, 2018; Amason, 1996; Schweiger et al., 1986) (Tab. 1).

In our pilot study, we obtained convergent results from the empirical and self-reported measures and the qualitative data (SI 9-10). For instance, in our pilot study, students' learning about options (EQ2) was only moderate according to the empirical measure (SI 9.2). Answers to the self-reported questions about learning about options corroborated this result (SI 9.2), indicating that the information presented was moderately in conflict with their previous knowledge. The qualitative data from the audio-recorded debriefing session confirmed this, and cognitive dissonances were discussed at length. Furthermore, we experienced how valuable the different types of collected data are to be able to interpret our observations and evaluate the game-based intervention. We

encourage the use of complementary data types: both empirical and self-reported quantitative and qualitative (Table 1).

The convergent results from the different data make us think that our evaluation procedure was understandable, sound, and solid, and can provide a good basis for future research. We acknowledge that this pilot study with 10 students only constituted a usability check, and not a complete validity and reliability test of our measure instruments. Validity and reliability tests would be needed for the instruments that we adapted or newly created. The pilot study showed us that a few measures need improvement. We commented on how to modify these measures in the SI. For instance, one question for the empirical evaluation of learning about stakeholders' perspectives had a different structure than the other questions. It required an adapted point allocation. The issue was resolved by dividing the original question into three questions (SI 8.3). Overall, the framework (Aubert et al., 2019) helped to structure a rigorous evaluation procedure.

However, we experienced the typical weaknesses observed in evaluation of game-based interventions, including small sample size, no control treatment, no control for the potentially confounding factors (Seaborn and Fels, 2015; Koivisto and Hamari, 2019; Lumsden et al., 2016; Bailey et al., 2015). Some of these weaknesses are hard to overcome. As first reason we observed that it is practically demanding. For instance, our haptic card game is designed for a limited number of participants, up to four. Thus, reaching the sample size for the proposed evaluation procedure of at least 80 participants (Section 4.3.4) may be difficult, or at least very time consuming. Second, we observed that game-based interventions are context-specific and often applied in action research (Lankford and Watson, 2007). This again limits the possibility of repetition. Consequently, evaluations often consist in reporting a single or few field applications and targeting the 'did it work' question (Seaborn and Fels, 2015). Finally, developing experiments that include variations in the confounding factors increases the complexity of the experimental design. Personality traits, socio-demographics (Koivisto and Hamari, 2014), and the experience of the facilitator are only three examples of factors that can moderate the effect under study. Our illustrative case did not enable us to answer the question of effectiveness of game-based interventions to support decision-making processes. However, it helped us identify necessary pre-steps to go in this direction. We propose our vision for overcoming these typical weaknesses in evaluating the effectiveness of game-based interventions in Section 5.3.

5.3. Future research to rigorously evaluate game-based interventions

Here, we sum up the main challenges for future research on game-based interventions supporting participatory decision-making processes. We should note that we are convinced that studying group interventions in general, without game-based approaches, faces many of the same challenges (as discussed in e.g., Phillips, 1984; Franco et al., 2021; Midgley et al., 2013). Our experience clearly confirmed that design frameworks (Aubert et al., 2019; Morschheuser et al., 2017), which allow for simultaneous development of game-based interventions and their evaluations are valuable. This guarantees alignment of the experiment with the purpose of the game-based intervention and supports the design of practically feasible evaluations. In our case, operationalizing the framework was useful and helped design a tailored evaluation procedure to test the game-based intervention. Our illustrative case allowed us to identify several challenges.

First, developing valid and reliable measures for evaluating game-based interventions is an endeavour of its own. In theory, it requires multiple experiments with large sample sizes to test the internal and external validity of the measures (Landers et al., 2018). As discussed above, haptic game-based interventions, requiring in person meetings, have natural limits to experimental requirements. Developing reliable measures, for instance by continuing to develop GAMEFULQUEST (Högberg et al., 2019), is certainly a valuable research avenue. In practice, slight adaptations of the items to the task at hand are acceptable. Doing so requires confirming that the measures are valid, which is possible with internal validity analyses (e.g., Cronbach's alpha coefficient; (Kline, 2000)). Moreover, it is necessary to develop and test measures that are specifically adapted to special characteristics of game-based interventions. For instance, to the best of our knowledge, there are currently no experimentally validated measures that allow gauging participants' experience of group dynamics during a game.

Second, disentangling the intertwined evaluation levels is challenging. Evaluations should clearly state which evaluation level they target. They should specify the focus of the study: Is it the game itself or the intervention? Is it the individual participants or the group? When the focus of study is specified, the *'did it work?'* question and the *'why/how did it work?'* questions can be answered (Seaborn and Fels, 2015). Accordingly, the researcher can choose between an outcome-oriented variance approach or a process approach (Franco et al., 2021). This in turn allows collecting quantitative or qualitative data or both (den Haan and van der Voort, 2018), depending on the focus, the questions, and the researchers' skills. Some evaluation design choices require a control intervention; others may not. It becomes obvious that proper evaluation of game-based interventions requires multiple complementary experiments. These experiments, with different foci and thus different methods, stem from different disciplines, including psychology, behavioural OR, group decision-making, or the disciplines of the application topic. Studying game-based interventions calls for interdisciplinary research.

Finally, to overcome the weaknesses observed in the literature mentioned above and our own experience (Section 5.2), scientists could join efforts and collaborate on a single experiment. For instance, the data collection effort could be distributed among different research groups to increase sample size. This allows including the control treatment and covering the variation span of the confounding factors more broadly. We hope that this article encourages colleagues to continue our effort and follow up on the many identified research questions.

6. Conclusion

We designed a game-based intervention, using a card game to generate objectives for sustainable wastewater management. In parallel, we designed a tailored evaluation procedure based on literature for assessing each purpose of the game-based intervention. It used complementary data types: empirical performance measures, self-reported assessments, and qualitative data. Based on an illustrative case, we were able to gain valuable insights and formulate suggestions for future research, e.g. adding precision to our starting research question. We recommend that the design of game-based approaches and their evaluation procedures should be intertwined and simultaneous. Our preliminary findings, suggest that our evaluation procedure is usable. However, further studies in other contexts, including a control, and possibly with other game-based interventions are now needed to rigorously test and improve the evaluation procedure. Additionally, further studies are needed that evaluate the benefits or drawbacks of our proposed game-based intervention, which is intended to stimulate the generation of objectives in the problem-structuring phase of decision processes about wastewater management.

The game-based intervention developed in this study can be adapted to other themes. We share all material to facilitate the collective, interdisciplinary work that is needed to meet the challenges faced by game-based interventions and their evaluation. We are only at the start of our understanding of the benefits of game-based interventions. Other open research questions include the following. How much game-based facilitated learning translates into critical thinking and constructing preferences? Is transference of game-based facilitated learning best enhanced with accuracy or with generality? Can game-based interventions create a positive group dynamic lasting beyond the gameplay? How do culture or stakeholders' personality traits influence the perception of game-based approaches? For obvious reasons, the decision analysis community, especially researchers focusing on group processes and behavioural OR, is

very well equipped to meet these challenges. We hope that others join efforts in documenting and evaluating game-based interventions in a rigorous way.

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.

CRediT authorship contribution statement

Alice H. Aubert: Conceptualization, Methodology, Validation, Resources, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Jennifer McConville:** Methodology, Validation, Investigation, Writing – original draft, Writing – review & editing. **Sara Schmid:** Formal analysis, Data curation, Writing – review & editing, Visualization. **Judit Lienert:** Methodology, Writing – original draft, Writing – review & editing.

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Supplementary materials

Supporting Information (SI) document presenting the game and its instruction, the questionnaires for the measures, and additional results can be found, in the online version, at doi:10.1016/j.ejdp.2022.100021.

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